Building evidence for conservation globally

Journal of Threatened Taxa

10.11609/jott.2023.15.4.22927-23138
www.threatenedtaxa.org

26 April 2023 (Online & Print)
15(4): 22927–23138
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Mauve Stinger *Pelagia noctiluca* by Swaathi Na. Medium used is soft pastels and gelly roll.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 April 2023 | 15(4): 23016–23028
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8128.15.4.23016-23028
#8128 | Received 02 August 2022 | Final received 31 March 2023 | Finally accepted 12 April 2023
COMMUNICATION

Vertebrate road kills on State Highway 26 in Khandwa Forest Division, central India

Kamran Husain [1] & **Prachi Mehta** [2]

[1,2] Wildlife Research and Conservation Society, 1A Shreeyog, 127/3, Sus Road, Pashan, Pune, Maharashtra 411021, India.
[1] kamran.wild95@gmail.com, [2] prachimehta@wrcsindia.org (corresponding author)

Abstract: The road network is spreading rapidly in human dominated as well as forested areas in India. Roads passing through forested areas are known to negatively impact wildlife populations by contributing to wildlife-road kills besides causing habitat fragmentation, soil erosion, and disruption of gene flow. This paper documents encounters of wildlife road kills on the State Highway 26 (SH 26) passing through the forested area of Khandwa Territorial Forests in central India. Between October 2015 and June 2017 and from November 2021 to June 2022 we collected opportunistic data on wildlife mortalities on SH 26. We recorded 61 wildlife mortalities on a stretch of 34 km of SH 26. Of the road kills encountered, 71% were birds, 21% were mammals, and 8% were herpetofauna. Highest among bird kills were members of nightjars (Caprimulgidae) (26%) and owls (Strigidae) (23%). Among owls, we recorded two road kills of the endangered Forest Owlet *Athene blewitti* and individuals of five other owl species. Among other taxa, road-hits of Jungle Cat, Indian Palm Civet, Golden Jackal, Central Indian Langur, and a few snakes were recorded. Most bird kills on the road were recorded in February while the highest number of mammal and herpetofauna kills were recorded in the month of November. We report that the land use around the road and species trait contribute to vulnerability of a species to road-hit. Based on the frequency of road kills, we have identified seven hotspots of road kills on SH 26. Since road construction is one of the major mandates of the Government in India, it is suggested to carry out systematic environment impact assessment on existing and proposed roads to understand the patterns of spatio-temporal incidents of road kills. Planting of tall trees and installation of speed bumps and signboards to alert drivers should be planned at the initial stage of road construction. If appropriate mitigation measures to prevent wildlife mortalities are incorporated while the road is being constructed, it may be possible to bridge the gap between development and conservation.

Keywords: Animal-vehicle collision, conservation, Forest Owlet, Jungle Cat, Madhya Pradesh, wildlife-friendly road, wildlife mortalities.

Editor: L.A.K. Singh, Bhubaneswar, Odisha, India.

Date of publication: 26 April 2023 (online & print)

Citation: Husain, K. & P. Mehta (2023). Vertebrate road kills on State Highway 26 in Khandwa Forest Division, central India. *Journal of Threatened Taxa* 15(4): 23016–23028. https://doi.org/10.11609/jott.8128.15.4.23016-23028

Funding: Madhya Pradesh Biodiversity Board, Raptor Research and Conservation Foundation, and Department of Science and Technology.

Competing interests: The authors declare no competing interests.

Author details: Kamran Husain is a research biologist with WRCS (Wildlife Research and Conservation Society). Kaman is currently working on radio-telemetry studies of owls in Melghat Tiger Reserve. Prachi Mehta is a senior scientist with WRCS and is working on ecology of owls and human-elephant coexistence mitigation in the country.

Author contributions: PM—funds for the project, concept of the paper, data analysis and writing of the paper. KH—part of field data collection, preparation of maps and compiling initial draft.

Acknowledgements: This paper is a part of ongoing research project on owls in central India. We thank Akshay Anand and Jabbar Singh for their help. We are grateful to the officers of Madhya Pradesh Forest Department for their long-term support for our project. We thank Madhya Pradesh State Biodiversity Board (Bhopal), Raptor Research and Conservation Foundation (Mumbai), and Department of Science and Technology (New Delhi) for financial support for the project.

INTRODUCTION

India has 62.16 lakh kilometres of road network, which is the second largest road network in the world after the USA (GOI 2022). While road network is critical to development, it has severe social, environmental, and ecological impacts on the biodiversity and natural resources. Vast stretches of roads passing through natural habitats are known to cause forest fragmentation (Forman & Alexander 1998), wildlife-vehicle collisions (Andrews 1990; Underhill & Angold 1999; Baskaran & Boominathan 2010; Raman 2011; Gubbi et al. 2012; Jeganathan et al. 2018; Saxena et al. 2020), increased predatory activity (Ortega & Capen 1999), habitat loss, disruption of corridors, loss of population heterogeneity, & genetic variability (Reh & Seitz 1990; Clark et al. 2010), and soil erosion, landslides, degradation of surrounding forests, & water pollution (Rajvanshi et al. 2001; Goosem et al. 2010; Raman 2011; Lyamuya et al. 2021).

While a small animal may get overridden, a large one will collide with the vehicle causing an accident and/or death. For all such instances, we have used the term wildlife-vehicle collision (WVC). Incidents of wildlife mortalities due to collision with speeding vehicles (WVC) in forested landscapes has far-reaching implications compared to poaching, hunting or natural death as WVC can also affect healthy individuals, leading to loss of genetic flow, subsequently resulting in population decline or isolation (Sutherland et al. 2010; Jackson & Fahrig 2011). Roadkill rates are attributed to the type of road, speed of the vehicles, and traffic volume (Forman & Alexander 1998; Underhill & Angold 1999; Clevenger et al. 2003; Saxena et al. 2020). Land use by the roadside has a major impact on accelerated rates of road kills. Presence of agricultural fields, forest patches, ditches, wetlands, canal crossing, shrubby vegetation and uneven height of road have been identified as hotspots of road kills (Main & Allen 2002; Mackinnon et al. 2005; Özcan & Ozkazanc 2017). Species traits such as group living animals, large home ranges, high dispersal rate,s and poikilothermic species are most likely targets of road kills (Saxena et al. 2020). Diet and morphometry of a species contributes to their vulnerability to road kills. Species feeding on rodents, insects, and carcass are vulnerable to road causalities since their life traits make them an easy victims of road kills (Adams & Geis 1983; Main & Allen 2002; Silva et al. 2019; Underhill & Angold 1999; Medrano-Vizcaíno et al. 2022).

The studies on road kills from India and outside India have commonly reported mortalities of mammals (Reed et al. 1979; Lavsund & Sandegren 1991; Behera & Borah 2010; Gubbi et al. 2012; Saxena et al. 2020; Lyamuya et al. 2022), birds (Channing 1958; Dunthorn & Errington 1964; Dhindsa et al. 1988; Sundar 2004; daRosa & Bager 2012; Bishop & Brogan 2013; Siva & Neelnarayanan 2020; Sacramento at al. 2022), and herpetofauna (Vos & Chardron 1998; Aresco 2005; Langen et al. 2007; Glista et al. 2008; Baskaran & Boominathan 2010; Bhupathy et al. 2011; Quintero-Ángel et al. 2012; Samson et al. 2016; Jegannathan et al. 2018; Pallares & Joya 2018; Hastings et al. 2019). In India, the majority of studies on WVC have been carried out on national highways (NH) passing through protected areas of Western Ghats (Kumara et al. 2002; Seshadri et al. 2009; Baskaran & Boominathan 2010; Santhoshkumar et al. 2017), Madhya Pradesh (Pragatheesh 2011; Pragatheesh & Rajvanshi 2013; Saxena et al. 2020), Karnataka (Hatti & Mubeen 2019), Rajasthan (Sharma & Dhakad 2020; Kumawat & Purohit 2020), Himalayan region (Kumar & Srinivasulu 2015; Kichloo et al. 2020), and Assam (Das et al. 2007; Choudhury & Ghosh 2008; Sur et al. 2022).

The state of Madhya Pradesh has a vast network of roads measuring up to 70,156 km which includes 8,000 km of national highways, 8,728 km of state highways (SH), 22,129 km of district roads, and 28,623 km of rural and other roads (GOI 2022). Earlier studies on wildlife road kills from Madhya Pradesh have been carried out on NHs passing through Pench Tiger Reserve and Satpura Tiger Reserve (Pragatheesh 2011; Pragatheesh & Rajvanshi 2013; Saxena et al. 2020) but there is no published information on road kills outside the protected areas in the state. In this paper, we describe wildlife mortalities encountered on the State Highway 26 (SH 26) passing through the forested area of Khandwa District. The objectives of our study were (i) to assess which taxa are represented in the road kills and (ii) to identify the locations that record most wildlife mortalities. In the light of a recent notification on SH 26 proposed to be widened from a 2-lane state highway to a 4-lane national highway, the findings and recommendations of this paper would be of considerable importance since we describe the hotspots of the road kills and suggest precautionary measures and mechanisms to reduce wildlife kills on SH 26.

Study Area

We recorded the road kills on the SH 26 that passes through Khandwa Forest Division in Khandwa District (21.8259^{0}N, 76.3678^{0}E) of Madhya Pradesh (Figure 1). Both sides of the road were bordered by dry deciduous teak *Tectona grandis* forests and crop fields. Teak is the dominant species in the forests with

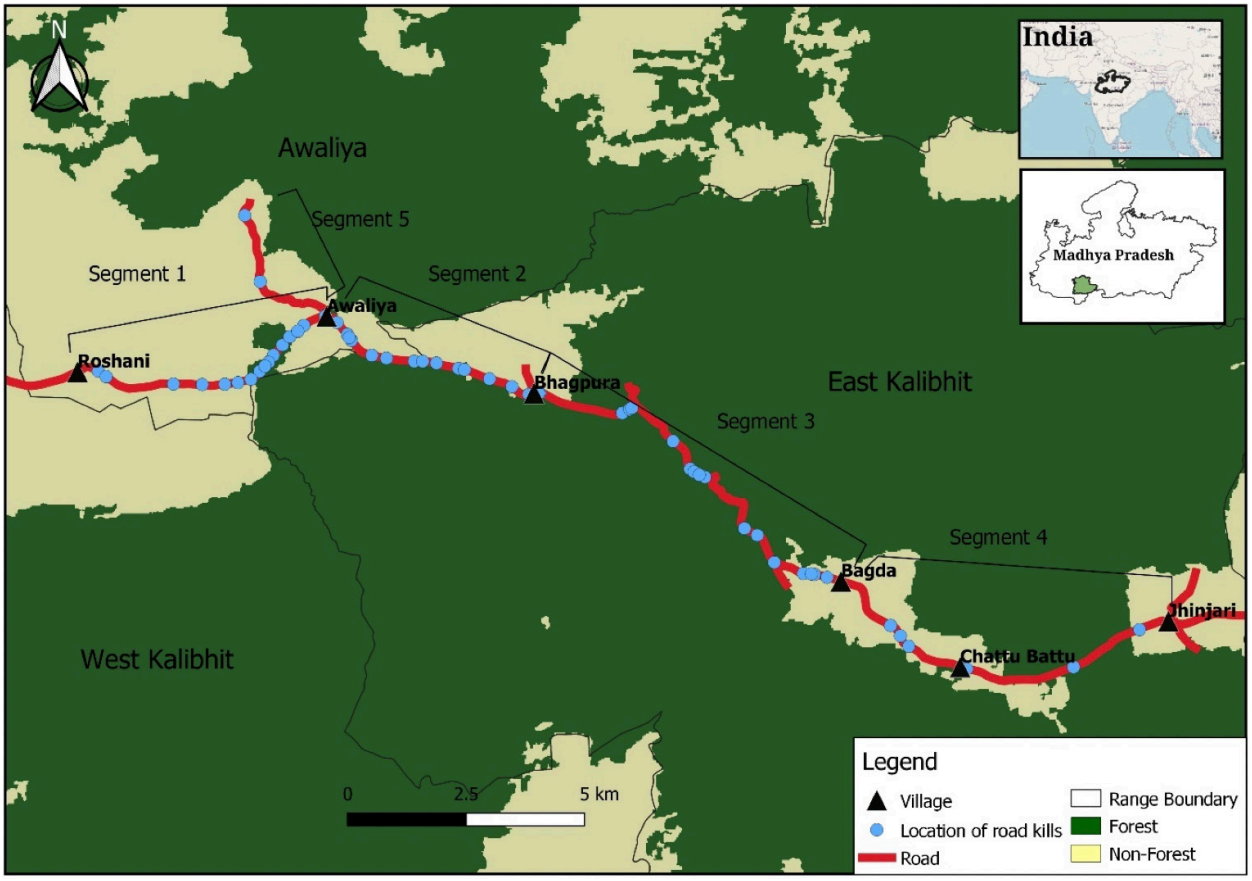

Figure 1. Location of State Highway 26 and incidents of road kills in different segments.

associated species such as *Anogeissus latifolia*, *Lannea coromendelica*, *Terminalia alata*, *Butea monosperma*, *Diospyros melanoxylon*, and *Garuga pinnata*. Bamboo was found mainly in hilly region of the road. Very few houses were close to the highway as villages were settled further away from the road. The topography in the area is hilly with gently sloping terrain interspersed with plain tracts of land. The elevation ranges 300–700 m. Among large mammals, the presence of Bengal Tiger *Panthera tigris,* Leopard *Panthera pardus fusca,* Jungle Cat *Felis chaus,* Chinkara *Gazella benettii*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus,* Four-horned Antelope *Tetracerus quadricornis,* and Wild Boar *Sus scrofa* have been recorded from the area (Shukla 2013). The area supports diverse avifauna and notable among them is the presence of the 'Endangered' and a central India endemic Forest Owlet *Athene blewitti.* Among other owls, the widely distributed Barn Owl *Tyto alba*, Indian Eagle Owl *Bubo bengalensis*, Mottled Wood Owl *Strix ocellata*, Indian Scops Owl *Otus bakkamoena*, Jungle Owlet *Glaucidium radiatum*, and Spotted Owlet *Athene brama* have been recorded from here (Mehta et al. 2018). The region is inhabited by Korku and Gond tribes who practice sustenance agriculture. From June to December, farmers grow Paddy, Wheat, Maize, and pulses. Crop harvesting takes place during January to March, and the fields are fallow in April and May.

The SH 26 connects Khargone District to Amarkantak District in Madhya Pradesh State. This stretch of 45 km passes through Ashapura Village till Jhinjari Village in Khandwa Forest Division traversing the forests of Kalibhit connecting the Khandwa District to Betul District. Heavy vehicles such as multi-axle trucks, passenger buses, other four wheelers and two wheelers drive through the SH from morning to night. Most of the highway passes through teak dominant and teak-mixed forests of East Kalibhit, West Kalibhit, and Awaliya, having several crop fields and very few habitations by the roadside.

Methods

Since 2012, we have been carrying out ecological research on the Forest Owlet and other owls in Khandwa District of Madhya Pradesh. Every day, between 0600 h & 1100 h and 1600 h & 1900 h, we used to drive at the speed of 20 to 40 km/h by a jeep or a motorcycle on the road to monitor locations of owls for a stretch of 34 km

from Roshani to Jhinjari. On the way, we often observed carcasses of dead animals by the roadside. From October 2015 to June 2017 and again between November 2021 to June 2022, we maintained a record of the road kills observed while driving on the road. The data were collected opportunistically, i.e., as, and when we came across a road kill. When we spotted a dead animal on the road, we recorded the following information: date, time of observation, species killed, and GPS location of the kill. To estimate approximate time of the kill, we categorised the road kills in two broad categories, as fresh (killed within last 24 hours) and old (killed over last 24 hours), based on the status of the carcass, skin texture, and blood condition (after Baskaran & Boominathan 2010). To assess the topography at the accident spot, we recorded the gradient of the road as plain, gently sloping, and hilly. For understanding the land use near the accident spot, we classified the habitat as teak forest, teak mix forest, agriculture, human habitation, and a combination of the given categories. After obtaining the data indicated above, we removed the carcass from the road to prevent double counting (Gomes et al. 2009).

Study segments

In order to have better understanding and interpretation of the WVC patterns we divided the road into five segments according to the location of nearby villages and recorded the landscape features on either side of the segment (Table 1). Study areas 2 and 4 differ in their extent and pattern of cover over agriculture land and teak forests. We used non-parametric Mann-Whitney U test to compare the frequency of road kills among different taxa and the number of mortalities between different road segments. All species encountered in road kills were classified in three broad categories of feeding guilds (Table 1). We used the software PAST 4.0 for the analysis.

Table 1. Description of habitat and land use on different segments of SH 26.

Segment number	Location name	Terrain	Road length (km)	Habitat and land use
1	Roshani to Awaliya	Plain	7.5	Agriculture with some patches of teak forests and a few habitations
2	Awaliya to Kalighodi	Plain	6	Teak forests interspersed with agriculture
3	Kalighodi to Bagda	Hilly	7.5	Teak mix forests
4	Bagda to Jhinjari	Plain	9	Mainly agriculture with very few patches of teak forests
5	Awaliya to Harda	Plain	4	Agriculture with very few patches of open forests

RESULTS

Type of road kills

During the study, we recorded 61 vertebrate road kills belonging to 31 species from 23 families (Table 2). Of these, 43 (71%) mortalities were of birds, 13 (21%) kills of mammals and 5 kills (8%) belonged to herpetofauna (Figure 2). In the study area, birds were more affected taxa in road kills than mammals (Mann Whitney $U = 64$, $P = 0.001$), and herpetofauna ($U = 23$, $P < 0.000$).

Among the birds, family Caprimulgidae (Nightjars) represented the highest (26%) number of kills followed by Strigidae (Owls) (23%), and Cuculidae (Cuckoos) (14%). The most frequently encountered bird kill was that of the nightjars followed by Greater Coucal *Centropus sinensis*, Indian Roller *Coracias benghalensis*, and the Spotted Owlet Athene brama. One species of dove could not be identified because of its decomposed body. Among the mammals, members of the family Sciuridae (Squirrels) were most killed species (31%) followed by Viverridae (Civets) (15%), and Muridae (rats & mice; 15%) (Figure 4; Image 2–9). Of the herpetofauna road kills, we found three species of snakes belonging to two families and one species of toad on the road during the survey. We found an almost equal number of mortalities of diurnal and nocturnal species (Table 2).

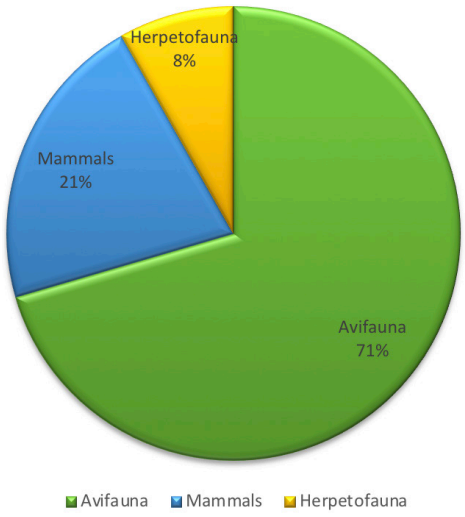

Figure 2. Percentage vertebrate mortalities on SH 26 during 2015–2017 and 2021–2022 in Khandwa District.

Table 2. Percentage frequency, activity pattern, and feeding guilds of mammals, birds, and herpetofauna road kills on SH 26.

	Taxa	Scientific name	Activity pattern	Feeding guild	No. of individuals (% of total)
	MAMMALS				
I	**Family Canidae**				
	1. Golden Jackal	*Canis aureus*	N	C/I	1 (7.69)
II	**Family Cercopithicidae**				
	2. Central Indian Langur	*Semnopithecus entellus*	D	S/G	1 (7.69)
III	**Family Felidae**				
	3. Domestic Cat	*Felis catus*	N	C/I	1 (7.69)
	4. Jungle Cat	*Felis chaus*	N	C/I	1 (7.69)
IV	**Family Viverridae**			C/I	
	5. Small Indian Civet	*Viverricula indica*	N	C/I	2 (15.38)
V	**Family Leporidae**				
	6. Rufous-tailed Hare	*Lepus nigricolis*	N	S/G	1(7.69)
VI	**Family Muridae**				
	Mus spp.	*Mus* spp.	N	S/G	2 (15.38)
VII	**Family Sciuridae**				
	Indian Palm Squirrel	*Funambulus palmarum*	D	S/G	2 (15.38)
	Northern Palm Squirrel	*Funambulus pennantii*	D	S/G	2 (15.38)
	Total				**13**
	BIRDS				
I.	**Family Caprimulgidae**				
	1. Nightjar Species	*Caprimulgus spp.*	N	I	11 (25.58)
II.	**Family Cisticolidae**				
	2. Grey-breasted Prinia	*Prinia hodgsonii*	D	I	1 (2.33)
III	**Family Columbidae**				
	3. Laughing Dove	*Spilopelia senegalensis*	D	S/G	2(4.65)
IV	**Family Coraciidae**				
	4. Indian Roller	*Coracias benghalensis*	D	I	3 (6.98)
V	**Family Cuculidae**				
	5. Greater Coucal	*Centropus sinensis*	D	I	6 (13.95)
VI	**Family Estrildidae**				
	6. Indian Silverbill	*Euodice malabarica*	D	S/G	1(2.33)
VII	**Family Leiothrichidae**				
	7. Jungle Babbler	*Argya striata*	D	I	1(2.33)
VIII	**Family Motacillidae**				1(2.33)
	8. Pipit Species		D	I	
IX	**Family Paridae**				
	9. Great Tit	*Parus major*	D	I	2(4.65)
X	**Family Strigidae**				
	10. Spotted Owlet	*Athene brama*	N	C/I	2 (4.65)
	11. Forest Owlet	*Athene (Heteroglaux) blewitti*	D	C/I	2 (4.65)
	12. Jungle Owlet	*Glaucidium radiatum*	D	C/I	1(2.33)
	13. Mottled Wood-Owl	*Strix ocellata*	N	C/I	1(2.33)
	14. Rock Eagle-Owl	*Bubo bengalensis*	N	C/I	1(2.33)
	15. Indian Scops-Owl	*Otus bakkamoena*	N	C/I	2 (4.65)
XI	**Family Tytonidae**				
	16. Barn Owl	*Tyto alba*	N	C/I	2(4.65)
XII	**Family Sturnidae**				
	17. Common Myna	*Acridotheres tristis*	D	I	3 (6.98)
	18. Unidentified Dove Species			S/G	1(2.33)
	Total				**43**
	HERPETOFAUNA				
I	**Family Bufonidae**				
	1. Common Indian Toad	*Duttaphrynus melanostictus*	N	I	2 (40.00)
II	**Family Elapidae**				
	2. Common Krait	*Bungarus caeruleus*	N	C	1 (20.00)
III	**Family Colubridae**				
	3. Bronzeback Tree Snake	*Dendrelaphis tristi*	N	C	1 (20.00)
	4. Indian Ratsnake	*Ptyas mucosa*	N	C	1 (20.00)
	Total				**5**

Feeding guild: C—Carnivore | G—Fruit/ Granivores I—Insectivore | S—Seed.

Type of habitat

Total number of road kills were significantly higher on segment 2 compared to segment 4 (Mann-Whitney $U = 484$, $P = 0.049$) and segment 5 ($U = 463$, $P = 0.039$). Segment 1 recorded more road kills than segment 4 (U = 453, P = 0.03, Figure 3). Bird, mammal and herpetofauna road kills were found on segment 1, 2, 3, & 4 while on segment 5 we found road kills of two Three-striped Palm Squirrels *Funambulus palmarum*. However, we did not find significant differences in number of road kills of

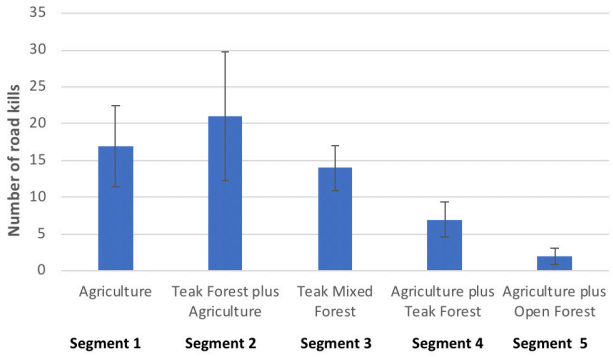

Figure 3. Total number of road kills on different segments of SH 26 in Khandwa district. Study areas 2 and 4 differ in their extent and pattern of cover by agriculture land and teak forests, as mentioned in Table 1.

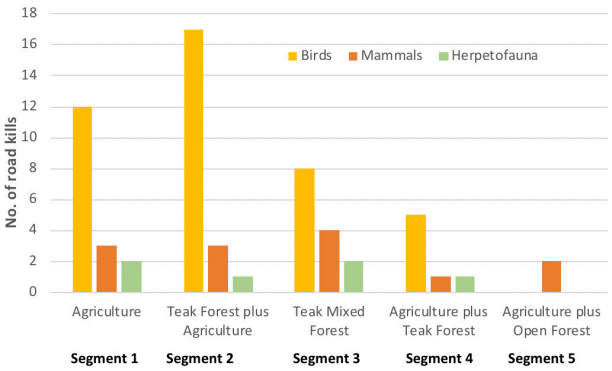

Figure 4. Number of road kills of different taxa on different study segments of during 2015–2017 and 2021–2022 on SH 26 in Khandwa District.

different taxa between different segments (Figure 4).

Monthly patterns of road kills

Most bird road kills were recorded in February, while the highest number of mammal and herpetofauna kills were recorded in the month of November (Figure 5). The number of bird road kills per month was significantly higher than that of mammal kills (U = 16.5, P = 0.033) and herpetofauna kills (U = 8, P < 0.00) per month.

A comparison of percentage of foraging guilds encountered as road kills revealed that the members of insectivore and carnivore-insectivore guilds were getting killed throughout the year while seed/fruit/grain feeders were killed mainly between January to May (Figure 6). Carnivore-insectivore road kills were seen mainly in July and December. We do not have road kill data of August and September as we did not monitor the road during those two months.

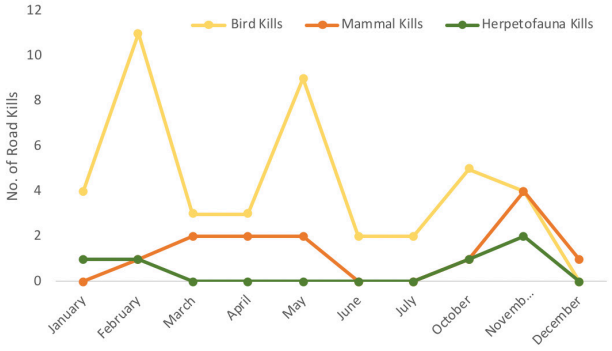

Figure 5. Monthly number road kills of different taxa on SH 26 in Khandwa District.

DISCUSSION

Herpetofauna Road Kills

In India, most studies on road kills have commonly reported high mortality of amphibians, reptiles, and mammals (Kumara 2000; Das et al. 2007; Baskaran & Boominathan 2010; Gubbi et al. 2012; Jeganathan et al. 2018; Kumawat & Purohit 2020; Saxena et al. 2020; Sur et al. 2022). Among herpetofauna, snakes are commonly reported taxa of WVC. Ectothermic animals like snakes utilise roadways to regulate their body temperature during the winter season by resting on them, which makes them easy victims of road fatalities (Rosen & Lowe 1994). Snakes visit agricultural fields hunting for rodents (Pragatheesh & Rajvanshi 2013) and are at the greatest risk of death because their movement is slower on a smooth road than on other surfaces (Row et al. 2007). The higher road mortality of amphibians and reptiles could be attributed to their slow mobility, not reacting quickly to vehicles and the fact that drivers are less likely to notice these animals because of personal disregard for the species (Pragatheesh & Rajvanshi 2013). In our study, we found only four road kills of herpetofauna, including three species of snakes and one species of Common Indian Toad. We report road kills of Common Krait, Rat Snake, and Bronze-back Tree Snake, which appear to be victims of road kills commonly (Das et al. 2007; Baskaran & Boominathan 2010; Pragatheesh & Rajvanshi 2013; Jeganathan et al. 2018). Bronze-back Tree Snake is an arboreal species and its presence on the road is indicative of loss of canopy connectivity induced by road construction (Pragatheesh & Rajvanshi 2013). The above studies have reported the maximum mortalities of amphibians and reptiles during the monsoon months. The lower number of herpetofauna kills in our study may be explained by the fact that we

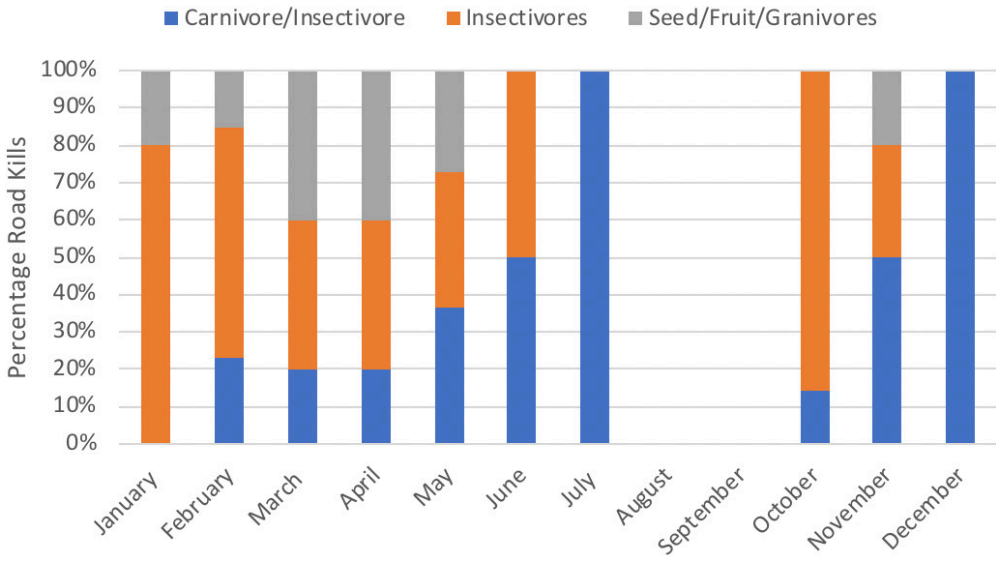

Figure 6. Feeding guilds of monthly road kills encountered on SH 26.

could not monitor SH 26 during the rainy months of August and September.

Mammal road kills

Among mammals, we found carcasses of Jungle Cat, Jackal, Domestic Cat, Rufous-tailed Hare, Palm Civet, and Palm Squirrels which have also been reported as road kills by other studies (Kumara 2000; Sundar 2004; Behera & Borah 2010; Baskaran & Boominathan 2010; Borah 2010; Jeganathan et al. 2018; Saxena et al. 2020; Sur et al. 2022). Nocturnal mammals (carnivores) often forage near the open areas by the road side hunting for small mammals and insects, and get temporarily blinded by powerful headlights thus making them victims of speeding vehicles (Orlowski & Nowak 2006). However, there was also a kill of a Central Indian Langur, which is a diurnal species. Langurs and Macaques often sit on the road to pick fallen fruits and grab food that is thrown out to them from passing vehicles. Langurs are group living animals and many of them run across the roads, thus increasing their chances of collisions with vehicles (Baskaran & Boominathan 2010).

Bird road kills

In India, a handful of studies have discussed the frequency of bird road kills (Dhindsa et al. 1988; Sundar 2004; Siva & Neelanarayanan 2020). Outside India, several studies have highlighted the frequency of bird road kills (Hodson 1962; Erritzoe et al. 2003; Gomes et al. 2009; Cook & Blumstein 2013; Husby 2016). Every year several millions of birds are estimated to die due to road hits in USA, UK, and Europe (Erickson et al. 2005; Bishop & Brogan 2013; Bíl et al. 2020), indicating the vulnerability of birds to speeding vehicles.

Our study also reports that avifauna were the major (71%) victims of the WVC. We recorded 33.33% mortalities of nocturnal birds, which included 11 individuals of nightjars and 11 individuals of owls belonging to seven owl species (Table 2). Nocturnal birds of prey move along the road side to hunt for insects collected near street lamps. Pools of water ditches, and wells by the road side make ideal feeding grounds for predatory birds feeding on amphibians and reptiles, and therefore get into collision with vehicles (Hernandez 1988). Studies reporting road kills of nightjars have surmised that nightjars often sit on the roads to feed on the insects near light posts. Also, during the breeding season nightjars sit by the road side to incubate their eggs because roads become warmer at night. The sudden flash of headlights temporarily blinds the nightjar, and they are unable to fly off (Erritoze et al. 2003).

Among owls, we recorded two road kills of the Forest Owlet. In 2015, one breeding male Forest Owlet was found dead on the road. After the incident, we could not locate the juvenile and the female in the area. It is likely that the female may have abandoned the area because the provisioning male had died. In 2022, one more breeding male Forest Owlet was found dead on the road. Although the Forest Owlet is a diurnal owl, they hunt during low-light hours during dusk and dawn (Prachi Mehta pers. obs. 2013). Losing an endangered species to road kill is a matter of grave concern as it has a direct implication on its in-situ conservation. We also report road kills of large owl species such as the Barn

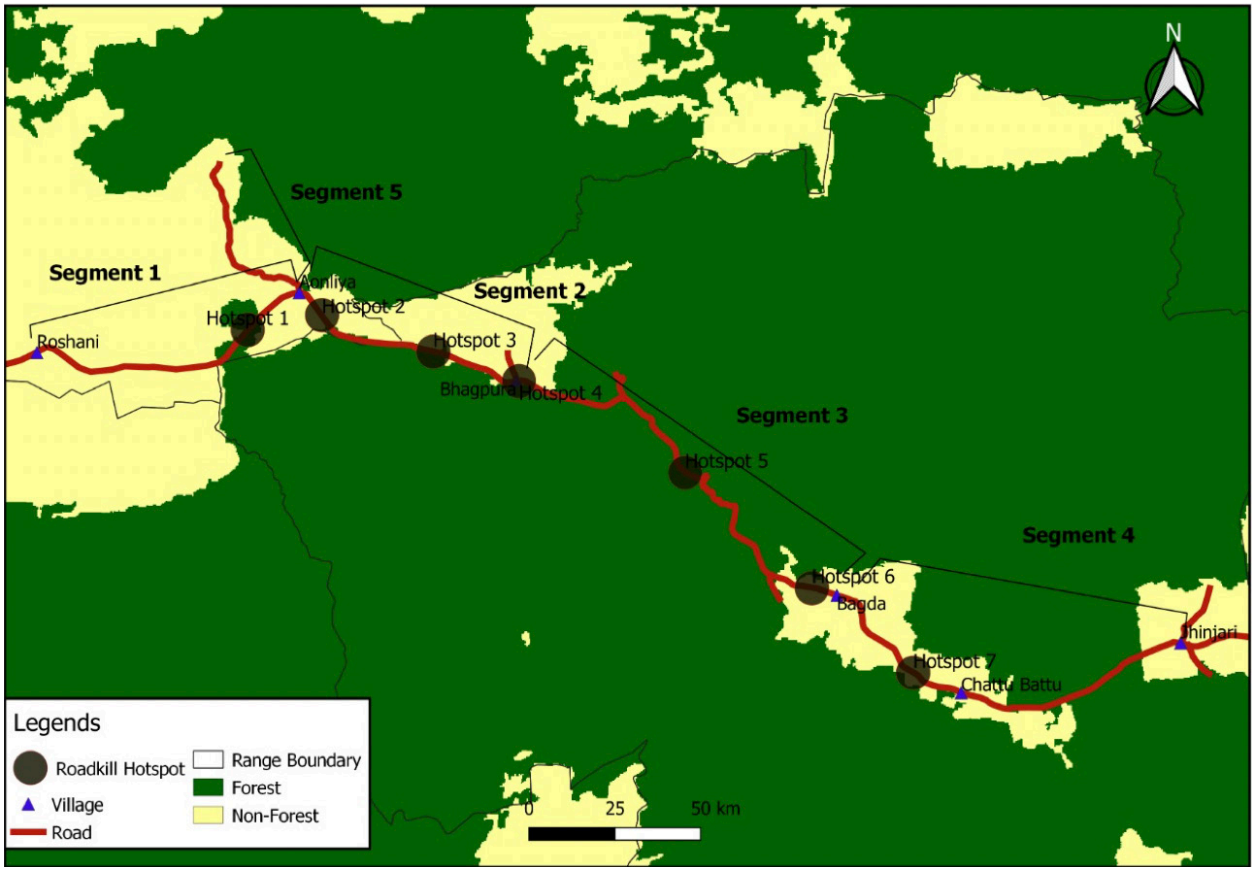

Figure 7. Locations of roadkill hotspots on SH 26 in Khandwa District.

Owl, Mottled Wood Owl, Indian Eagle Owl, and smaller owl species such as the Jungle Owlet, Indian Scops Owl, and the Spotted Owlet.

Several studies have documented Strigiformes to be common victim of WVC (Hernandez 1988; Gomes et al. 2009; Baskaran & Boominathan 2011; Le Gouar et al. 2011; Guinard et al. 2012; Siva & Neelanarayanan 2020; Sur et al. 2022). Authors have attributed greater road kills of Strigiformes to the hunting techniques of owls. Owls, unlike diurnal birds of prey, do not use hot wind currents to soar in the air but use perch and pounce technique (Mikkola 1983). Many owl species use trees, posts, fences, and cables as perches to scan the ground for prey (Mehta et al. 2018). Barn Owl and Eagle Owl often sit on the light pole near agricultural fields to prey on rodents. Smaller owls such as the Spotted Owlet often perch on low bushes, near a light source or on the edge of the road to catch insects (Mehta et al. 2018) and may be getting overrun by a speeding vehicle. Also, illuminated roads attract invertebrates, which in turn, attract the owls (Hernandez 1988). Abundance of prey attract owls to roads and flying from one bush to another can get them killed (Nero & Copland 1981). A combination of hunting technique and availability of open areas make owls an easy victim of road kills. Large numbers of mortalities of Strigiformes due to WVC is an issue of serious conservation concern as it can affect their population structure (Forman & Alexander 1998; Le Gouar et al. 2011; this study).

Among the diurnal bird kills, we observed the carcass of doves, pipits, and coucal, who often feed by the roadside on the grains (Dhindsa et al. 1988). Most bird-vehicle collisions occur because of the bird's quick flight ability and their tendency to fly across the road (Rilley et al. 2014). Also, roads that have agricultural land by the side is preferred by birds for feeding on spilled grains from the agricultural land or feeding on rodents from the crop field (Dhindsa et al. 1988; Erritoze et al. 2003).

Monthly patterns of road kills

From January to May, crops are harvested and bagged. During this process, there is a spill over of grains on the road and an influx of insects and rodents in the crop fields, which in turn attracts the movement of insectivores, carnivore-insectivores and seed/fruit/grain feeders near the road. Further monitoring and data will

be required to understand the influence of diet on the taxa encountered in road kills.

Habitat surrounding the road

On SH 26, road segments 1, 2, & 3 passed through plain terrain and the road side habitat was mainly teak forests interspersed with agriculture. Segment 4 passed through hilly terrain and had teak mixed forests all along the road. Segment 5 passed through plain terrain with agriculture fields and open forests by the road side. We found maximum wildlife mortalities of doves, munias, rollers, babblers, nightjars, coucals, owls and mammals such as Jungle Cats, civets, Jackal on segments 1, 2 and 3. Most of the above species feature in other studies as road kills (Dhindsa et al. 1988; Sundar 2004). Agriculture fields have plentiful spilled over grains for granivores, insects for insectivores, and rodents for birds of prey. Additionally, interspersion of agriculture and forests forms 'edge' habitat which offers foraging opportunities for a variety of bird (Dhindsa et al. 1988) and mammal species (Baskaran & Boominathan 2010). The speed of the vehicle also contributes to the frequency of road kills (Erritzoe et al. 2003; Saxena et al. 2020). Segments 1, 2, & 3 had plain terrain therefore vehicles move faster on this stretch of the road. Segment 4 passed through hilly portion, so the vehicles must slow down while driving through this segment. This could be the reason for relatively lower numbers of road kills on segment 4. Studies have reported lower frequencies of animal collision on roads passing through farm lands but much higher frequencies of causalities on roads passing through a mix of crop fields and forests (see review in Erritzoe et al. 2003). This may be a possible explanation of lowest number of road kills on Segment 5, which had mainly crop fields and patches of open forests.

CONCLUSION AND RECOMMENDATIONS

The road kills encountered in the present study shows that diverse wildlife exist outside the protected areas, and they move between different habitats such as agriculture fields, forests, and forest edge for foraging, and other ecological requirements. Our study reports that the vehicular traffic on SH 26 is taking a toll on the wildlife in the area. Numerous kills of Nightjars and different species of owls, including two individuals of the endangered Forest Owlet, is alarming as it indicates that these species use the road frequently and are at high risk of getting into collisions with vehicles. Through this paper we have provided information on type of species killed, the locations of road kills and monthly patterns of WVC. Our findings could be used as a baseline information to prevent further wildlife mortalities on SH 26.

Based on the frequency of road kills, we have identified seven hot spots for the accidents on SH 26 (Figure 7). Installation of speed bumps and rumblers are effective in controlling speeding vehicles. We suggest installation of speed rumblers at each hotspot.

For preventing mortalities of nocturnal animals, we suggest removing shrubs from the roadside and planting tall native trees on either side of the hotspots and all along the roadside on SH 26. On hotspots 1, 2, & 3, the road level is uneven, which allows accumulation of water in ditches. This can attract owls and other mammalian predators for hunting of small prey. The height of the road should be made even to prevent water accumulation.

Generalist species like Domestic Cat, Jungle Cat, Jackals, Langurs, babblers, robins, rollers, and mynas have got exposure to a variety of habitats and therefore are not wary of crossing the roads. Such species often come on to the road to scavenge and become a victim of road hits (Medrano-Vizcaíno et al. 2022). The habitat around hotspots 1, 2, 3, 6, & 7, is mainly agricultural fields interspersed with patches of forests. The owners of the crop fields should be requested to keep the road side free of grains, and fruits that may be attracting animals for foraging. The highways should be kept free of carcasses too as it attracts bird and mammalian scavengers.

Animal crossing signages and reflectors are helpful in alerting the driver to watch out for wildlife crossing the roads. We have recently put up a few such signboards on SH 26 urging the drivers to maintain slow driving speed (Figure 8). The signboards should be shifted to new locations every few months, because if the signboards are at the same place, it will not invite the attention of regular drivers as they get used to seeing it (Sullivan et al. 2004).

The proposed widening of SH 26 for making into a four-lane road will lead to an increase in traffic intensity, vehicle speed and is expected to increase the wildlife death toll. This calls for attention of such studies to be carried out on a wider scale across the country to understand the impact of roads passing through forested areas.

Considering the rapid rate at which roads are being constructed in the country, it is imperative and urgent to carry out systematic and rigorous impact assessment on existing and proposed roads. Further, it is important to institutionalise a mechanism through which effective

Image 1. Awareness poster urging the drivers to go slow on SH 26 installed by WRCS.

Image 2. Langur road kill

Image 3. Jungle Cat road kill

mitigation measures could be implemented which will enable biodiversity conservation and infrastructure development in a compatible manner.

REFERENCES

Adams, L.W. & A.D. Geis (1983). Effects of roads on small mammals. *Journal of Applied Ecology* 20: 403–415. https://doi.org/10.2307/2403516

Andrews, A. (1990). Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoologist* 26(3–4): 130–141. https://doi.org/10.7882/AZ.1990.005

Aresco, M.J. (2005). Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. *Journal of Wildlife Management* 69: 549–560. https://doi.org/10.2193/0022-541X(2005)069[0549:MMTRHM]2.0.CO;2

Baskaran, N. & D. Boominathan (2010). Road kill of animals by highway traffic in the tropical forests of Mudumalai Tiger Reserve, southern India. *Journal of Threatened Taxa* 2(3): 53–759. https://doi.org/10.11609/JoTT.o2101.753-9

Behera, S. & J. Borah (2010). Mammal mortality due to road vehicles in Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India. *Mammalia* 74: 427–430. https://doi.org/10.1515/MAMM.2010.059

Bhupathy, S., G. Srinivas, N.S. Kumar, T. Karthik & A. Madhivanan (2011). Herpetofaunal mortality due to vehicular traffic in the Western Ghats, India: a case study. *Herpetotropicos* 5(2): 119–126.

Bíl, M., F. Heigl, Z. Janoška, D. Vercayie & S.E. Perkins (2020). Benefits and challenges of collaborating with volunteers: Examples from National Wildlife Roadkill Reporting Systems in Europe. *Journal for Nature Conservation* 54: 125798. https://doi.org/10.1016/j.jnc.2020.125798

Bishop, C. & J. Brogan (2013). Estimates of avian mortality attributed to vehicle collisions in Canada. *Avian Conservation and Ecology* 8(2): 2 https://doi.org/10.5751/ACE-00604-080202

Channing, C.H. (1958). Highway casualties of birds and animals for one year period. *The Murrelet* 39: 41–41.

Choudhury, K. & S. Ghosh (2009). Mortality of butterfly fauna due to vehicular traffic and their conservation in Ripu-Chirang Reserve Forests of western Assam, India. 2nd Asian Lepidoptera Conservation Symposium 2008 at Penang, Malaysia, Conference paper, 16 pp. https://www.researchgate.net/publication/330345758

Clark, R.W., W.S. Brown, R. Stechert & K.R. Zamudio (2010). Roads, interrupted dispersal, and genetic diversity in timber rattlesnakes.

Image 4. Scops Owl road kill

Image 5. Jungle Owlet road kill

Image 6. Nightjar road kill

Image 7. Indian Roller road kill

Image 8. Snake road kill

Image 9. Barn Owl road kill

Conservation Biology 24(4): 1059–1069.

Clevenger, A.P., B. Chruszcz & K.E. Gunson (2003). Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. *Biological Conservation* 109(1): 15–26. https://doi.org/10.1016/S0006-3207(02)00127-1

Cook, T.C. & D.T. Blumstein (2013). The omnivore's dilemma: Diet explains variation in vulnerability to vehicle collision mortality. *Biological Conservation* 167: 310–315. https://doi.org/10.1016/j.biocon.2013.08.016

da Rosa, C.A. & A. Bager (2012). Seasonality and habitat types affect roadkill of neotropical birds. *Journal of Environmental Management* 97: 1–5. https://doi.org/10.1016/j.jenvman.2011.11.004

Das, A., M.F. Ahmed, B.P. Lahkar & P. Sharma (2007). A preliminary report of reptilian mortality on road due to vehicular movement near Kaziranga National Park, Assam, India. *Zoos' Print Journal* 22(7): 2742–2744. https://doi.org/10.11609/JoTT.ZPJ.1541.2742-4

Dhindsa, M.S., J.S. Sandhu, P.S. Sandhu & H.S. Toor (1988). Roadside birds in Punjab (India): relation to mortality from vehicles. *Environmental Conservation* 15(4): 303–310.

Dunthorn, A.A. & F.P. Errington (1964). Casualties among birds along a selected road in Wiltshire. *Bird Study* 11(3): 168–182. https://doi.org/10.1080/00063656409476067

Erickson, W.P., G.D. Johnson & P. David (2005). A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. In: Ralph, C.J., R.D. Terrell (eds.). Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24. Asilomar, California, Volume 2, Gen. Tech. Rep. PSW-GTR-191. Albany, CA: US Dept. of Agriculture, Forest Service, Pacific Southwest Research Station, 191: 1029–1042. https://www.fs.usda.gov/treesearch/pubs/32103

Erritzoe, J., T.D. Mazgajski & Ł. Rejt (2003). Bird casualties on European roads—a review. *Acta Ornithologica* 38(2): 77–93. https://doi.org/10.3161/068.038.0204

Forman, R.T.T. & L.E. Alexander (1998). Roads and their major ecological effects. *Annual review of ecology and systematics* 29: 207–31. https://doi.org/10.1146/annurev.ecolsys.29.1.207

Glista, D.J., T.L. DeVault & J.A. DeWoody (2008). Vertebrate road mortality predominantly impacts amphibians. *Herpetological Conservation and Biology* 3(1): 77–87.

Gomes, L., C. Grilo, C. Silva & A. Mira (2009). Identification methods and deterministic factors of owl roadkill hotspot locations in Mediterranean landscapes. *Ecological Research* 24(2): 355–370. https://doi.org/10.1007/s11284-008-0515-z

Government of India Report (2022). Bharatmala: Road to Prosperity. Annual Report 2021-22. Ministry of Road Transport & Highways, New Delhi, 116 pp. https://morth.nic.in/bharatmalaphase

Goosem, M., E.K. Harding, G. Chester, N. Tucker, C. Harriss & K. Oakley (2010). Roads in rainforest: Best practice guidelines for planning, design and management, 61pp

Gubbi, S., H.C. Poornesha & M.D. Madhusudan (2012). Impact of vehicular traffic on the use of highway edges by large mammals in a South Indian wildlife reserve. *Current Science* 102(7): 1047–1051.

Guinard, É., R. Julliard & C. Barbraud (2012). Motorways and bird traffic casualties: carcasses surveys and scavenging bias. *Biological Conservation* 147(1): 40–51. https://doi.org/10.1016/j.biocon.2012.01.019

Hastings, H., J. Barr & P.W. Bateman (2019). Spatial and temporal patterns of reptile roadkill in the north-west Australian tropics. *Conservation Biology* 25(4): 370–376. https://doi.org/10.1071/PC18082

Hatti, S.S. & H. Mubeen (2019). Roadkill of animals on the road passing from Kalaburagi to Chincholi, Karnataka, India. *Journal of Threatened Taxa* 11(7): 13868–13874. https://doi.org/10.11609/jott.4292.11.7.13868-13874

Hernandez, M. (1988). Owl (*Athene noctua*) in Spain. *Journal of Raptor Research* 22(3): 81–84.

Hodson, N.L. (1962). Some notes on the causes of bird road casualties. *Bird Study* 9(3): 168–173. https://doi.org/10.1080/00063656209476024

Husby, M. (2016). Factors affecting road mortalities in birds. *Ornis Fennica* 93: 212–224.

Jackson, N.D. & L. Fahrig (2011). Relative effects of road mortality and decreased connectivity on population genetic diversity. *Biological Conservation* 144(12): 3143–3148.

Jeganathan, P., D. Mudappa, M.A. Kumar & T.S. Raman (2018). Seasonal variation in wildlife roadkills in plantations and tropical rainforest in the Anamalai Hills, Western Ghats, India. *Current Science* 619–626. https://www.jstor.org/stable/26495115

Kichloo, M.A., A. Sohil & N. Sharma (2022). Wildlife at the crossroads: wild animal road kills due to vehicular collision on a mountainous highway in northwestern Himalayan region. *Journal of Threatened Taxa* 14(1): 20517–20522. https://doi.org/10.11609/jott.7713.14.1.20517-20522

Kumar, G.C. & C. Srinivasulu (2015). Impact of vehicular traffic on Kashmir Rock Agama *Laudakia tuberculata* (Gary, 1827) near Kalatop-Khajjiar Wildlife Sanctuary, Chamba, Himachal Pradesh, India. *Zoo's Print* 17: 44–47.

Kumara, H.N., A.K. Sharma, A. Kumar & M. Singh (2000). Roadkills of wild fauna in Indira Gandhi wildlife sanctuary, Western Ghats, India: implications for management. *Biosphere Conservation* 3(1): 41–47. https://doi.org/10.20798/biospherecons.3.1_41

Kumawat, R. & A. Purohit (2020). Impact and assessment of wildlife mortalities on road due to vehicular movements in Desert National Park, Rajasthan, India. *Asian Journal of Conservation Biology* 9(1): 173–177.

Langen, T.A., A. Machniak, E.K. Crowe, C. Mangan, D.F. Marker, N. Liddle & B. Roden (2007). Methodologies for surveying amphibian and herpetofauna mortality on rural highways. *Journal of Wildlife Management* 71: 1361–1368. https://doi.org/10.2193/2006-385

Lavsund, S. & F. Sandegren (1991). Moose-vehicle relations in Sweden: a review. *Alces* 27: 118–126.

Le Gouar, P.J., H. Schekkerman, H.P. van der Jeugd, A. Boele, R. van Harxen, P. Fuchs, P. Stroeken & A.J. van Noordwijk (2011). Long-term trends in survival of a declining population: the case of the little owl (Athene noctua) in the Netherlands. *Oecologia* 166(2): 369–379. https://doi.org/10.1007/s00442-010-1868-x

Lyamuya, R.D., K.M. Hariohay, E.H. Masenga, J.K. Bukombe, G.G. Mwakalebe, M.L. Mdaki, A.K. Nkwabi, R.D. Fyumagwa & E. Røskaft (2021). Magnitude, patterns and composition of wildlife roadkill in the Serengeti ecosystem, northern Tanzania. *African Zoology* 56(3): 173–80. https://doi.org/10.1080/15627020.2021.1952896

MacKinnon, C.A., L.A. Moore, R.J. Brooks, G. Nelson, T. Nudds, M. Beveridge & B. Dempster (2005). Why did the reptile cross the road? Landscape factors associated with road mortality of snakes and turtles in the South Eastern Georgian Bay area. In: Proceedings of the Parks Research Forum of Ontario (PRFO) and Carolinian Canada Coalition (CCC) Annual General Meeting 153: 156–166.

Main, M.B. & G.M. Allen (2002). Landscape and seasonal influences on roadkill of wildlife in southwest Florida. *Florida Scientist* 65(3): 149–158.

Medrano-Vizcaíno, P., C. Grilo, F.A.S. Pinto, W.D. Carvalho, R.D. Melinski, E.D. Schultz & M. González-Suárez (2022). Roadkill patterns in Latin American birds and mammals. *Global Ecology and Biogeography* 31(9): 1756–1783. https://doi.org/10.1111/geb.13557

Mehta, P., J. Kulkarni, S. Talmale & R. Chandarana (2018). Diets of sympatric forest owlets, spotted owlets, and jungle owlets in east Kalibhit forests, Madhya Pradesh, India. *Journal of Raptor Research* 52(3): 338–348. https://doi.org/10.3356/JRR-17-00002.1

Mikkola, H. (1983). *Owls of Europe.* Buteo Books, Vermillion, South Dakota, 397 pp.

Nero, R.W. & H.W.R. Copland (1981). High Mortality of Great Gray Owls in Manitoba–Winter 1980–81. *Blue Jay* 39(3): 158–164.

Orlowski, G. & L. Nowak (2006). Factors influencing mammal roadkills in the agricultural landscape of south-western Poland. *Polish Journal of Ecology* 54(2): 283–294.

Ortega, Y.K. & D.E. Capen (1999). Effects of forest roads on habitat quality for ovenbirds in a forested landscape. *Auk* 116: 937–946

Özcan, A.U. & N.K. Ozkazanc (2017). Identifying the hotspots of wildlife-vehicle collision on the Çankırı-Kırıkkale highway during summer. *Turkish Journal of Zoology* 41(4): 722–730. https://doi.org/10.3906/zoo-1601-64

Pallares, E.R. & F.L.M. Joya (2018). Reptile road mortality in a fragmented landscape of the middle Magdalena Valley, Colombia. *Herpetology Notes* 11: 81–91.

Pragatheesh, A. (2011). Effect of human feeding on the road mortality of Rhesus Macaques on National Highway-7 routed along Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa* 3(4): 1656–1662. https://doi.org/10.11609/JoTT.o2669.1656-62

Pragatheesh, A. & A. Rajvanshi (2013). Spatial patterns and factors influencing the mortality of snakes on the national highway-7 along Pench Tiger reserve, Madhya Pradesh, India. *Oecologia Australis* 17(1): 20–35. https://doi.org/10.4257/oeco.2013.1701.03

Quintero-Ángel A., D. Osorio-Dominguez, F. Vargas-Salinas & C.A. Saavedra-Rodríguez (2012). Roadkill rate of snakes in a disturbed landscape of Central Andes of Colombia. *Herpetology Notes* 5: 99–105.

Rajvanshi, A., V.B. Mathur, G.C. Teleki & S.K. Mukherjee (2001). Roads, sensitive habitats and wildlife: Environmental guidelines for India and South Asia, Wildlife Institute of India, Dehradun, 215 pp.

Raman, T.S. (2011). Framing ecologically sound policy on linear intrusions affecting wildlife habitats. Nature Conservation Foundation, Mysuru, India. https://www.conservationindia.org/resources/framing-ecologically-sound-policy-on-linear-intrusions-affecting-wildlife-habitats

Ramsden, D. (2003). Barn owls and major roads: results and recommendations from a 15-year research project. Barn Owl Trust. https://www.barnowltrust.org.uk/product/barn-owls-and-major-roads-results-and-recommendations-from-a-15-year-research-project/

Reed, D.F., T.N. Woodard & T.D.I. Beck (1979). Regional deer-vehicle accident research (Report No. FHWA-CO-RD-79-11). Colorado Division of Highways, Denver, Colorado, 61 pp.

Reh, W. & A. Seitz (1990). The influence of land use on the genetic structure of population of the common frog *Rana temporaria. Biological Conservation* 54: 239–249. https://doi.org/10.1016/0006-3207(90)90054-S

Riley, S.P., J.L. Brown, J.A. Sikich, C.A. Schoonmaker & E.E. Boydston (2014). Wildlife friendly roads: the impacts of roads on wildlife in urban areas and potential remedies, pp. 323–360. In: McCleery, R.A., C.E. Moorman & M.N. Peterson (eds.). *Urban Wildlife Conservation.* Springer, Boston, MA, xi + 406 pp. https://doi.org/10.1007/978-1-4899-7500-3_15

Rosen, P.C. & C.H. Lowe (1994). Highway mortality of snakes in the Sonoran Desert of southern Arizona. *Biological Conservation* 68(2): 143–148. https://doi.org/10.1016/0006-3207(94)90345-X

Row, J.R., G. Blouin-Demers & P.J. Weatherhead (2007). Demographic effects of road mortality in black ratsnakes (*Elaphe obsoleta*). *Biological Conservation* 137(1): 117–124. https://doi.org/10.1016/j.biocon.2007.01.020

Sacramento, E., B. Rodríguez & A. Rodríguez (2022). Roadkill mortality decreases after road inauguration. *European Journal of Wildlife Research* 68(3): 1–8. https://doi.org/10.1007/s10344-022-01574-x

Samson, A., B. Ramakrishnan, A. Veeramani, P. Santhoshkumar, S. Karthick, G. Sivasubramanian, M. Ilakkia, A. Chitheena, J.L. Princy & P. Ravi (2016). Effect of vehicular traffic on wild animals in Sigur Plateau, Tamil Nadu, India. *Journal of Threatened Taxa* 8(9): 9182–9189. https://doi.org/10.11609/jott.1962.8.9.9182-9189

Santhoshkumar, S., P. Kannan, A. Veeramani, A. Samson, S. Karthick & J. Leonaprincy (2017). A preliminary report on the impact of road kills on the herpetofauna species in Nilgiris, Tamil Nadu, India. *Journal of Threatened Taxa* 9(3): 10004–10010. https://doi.org/10.11609/jott.3001.9.3.10004-10010

Saxena, A., N. Chatterjee, A. Rajvanshi & B. Habib (2020). Integrating large mammal behaviour and traffic flow to determine traversability of roads with heterogeneous traffic on a Central Indian Highway. *Scientific Reports* 10(1): 1–12. https://doi.org/10.1038/s41598-020-75810-2

Seshadri, K.S., A. Yadav & K.V. Gururaja (2009). Road kills of amphibians in different land use areas from Sharavathi river basin, central Western Ghats, India. *Journal of Threatened Taxa* 1(11): 549–552. https://doi.org/10.11609/JoTT.o2148.549-52

Sharma, S.K. & M. Dhakad (2020). The Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hillaire, 1831) (Mammalia: Carnivora: Felidae) in Rajasthan, India-a compilation of two decades. *Journal of Threatened Taxa* 12(16): 17213–17221. https://doi.org/10.11609/jot.6064.12.16.17213-17221

Shukla, S. (2013). Working Plan of Khandwa Division (2013–2023). Madhya Pradesh Forest Department, India .

Silva, C., M.P. Simões, A. Mira & S.M. Santos (2019). Factors influencing predator roadkills: The availability of prey in road verges. *Journal of Environmental Management* 247: 644–650. https://doi.org/10.1016/j.jenvman.2019.06.083

Siva, T. & P. Neelanarayanan (2020). Impact of vehicular traffic on birds in Tiruchirappalli District, Tamil Nadu, India. *Journal of Threatened Taxa* 12(10): 16352–16356. https://doi.org/10.11609/jott.5532.12.10.16352-16356

Sullivan, T.L., A.F. Williams, T.A. Messmer, L.A. Hellinga & S.Y. Kyrychenko (2004). Effectiveness of temporary warning signs in reducing deer-vehicle collisions during mule deer migrations. *Wildlife Society Bulletin* 32(3): 907–915. https://doi.org/10.2193/0091-7648(2004)032[0907:EOTWSI]2.0.CO;2

Sundar, G. (2004). Mortality of Herpetofauna, birds and mammals due to vehicular traffic in Etawah District, Uttar Pradesh, India. *Journal of the Bombay Natural History Society* 101(3): 392–398.

Sur, S., P.K. Saikia & M.K. Saikia (2022). Speed thrills but kills: A case study on seasonal variation in roadkill mortality on National Highway 715 (new) in Kaziranga-Karbi Anglong Landscape, Assam, India. *Nature Conservation* 47: 87–104. https://doi.org/10.3897/natureconservation.47.73036

Sutherland, R.W., P.R. Dunning & W.M. Baker (2010). Amphibian encounter rates on roads with different amounts of traffic and urbanization. *Conservation Biology* 24(6): 1626–1635. https://doi.org/10.1111/j.1523-1739.2010.01570.x

Underhill, J.E. & P.G. Angold (1999). Effects of roads on wildlife in an intensively modified landscape. *Environmental Reviews* 8(1): 21–39. https://doi.org/10.1139/ER-8-1-2

Vos, C.C. & J.P. Chardon (1998). Effects of habitat fragmentation and road density on the distribution pattern of the Moor Frog *Rana arvalis*. *Journal of Applied Ecology* 35(1): 44–56. https://doi.org/10.1046/j.1365-2664.1998.00284.x

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

April 2023 | Vol. 15 | No. 4 | Pages: 22927–23138
Date of Publication: 26 April 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.4.22927-23138

Publisher & Host

WILD ZOOREACH
Threatened Taxa