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Status, Characteristics and Factors Affecting Roadkills on NH-64: The Dandi Path, Navsari, Gujarat, India

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Abstract: Roads are among the significant threats to the conservation of wild mammals across the globe. In the present study, we assess roadkill, its characteristics, and factors affecting their presence on a stretch of NH-64 of Navsari district. To evaluate roadkills, we monitored the road weekly; whereas to assess the factors affecting road presence, we followed used-unused sampling. A total of 70 roadkills were encountered from a sampling effort of 336 kilometres from October 2021 to March 2022. Reptiles were the most affected taxonomic groups, followed by amphibians and mammals. Among reptiles, the garden lizard was the most killed species, while the common frog and five stripped squirrel were the most killed among amphibians and mammals. Maximum kills happened during March, while maximum kills happened in the agricultural habitat. Shrub cover, ground cover, distance from the road edge, and distance from human habitation affected roadkill positively, while canopy cover was related negatively. The present study will act as a baseline for the future, and help fill the knowledge gap in roadkill studies in a human-dominated landscape.

Keywords: Roadkill, Linear infrastructure, Development, Reptiles, Amphibians, Mammals, Conservation

The increase in human population has led to increased demands for better facilities, leading to a rapid increase in global developmental activities (Steffan et al 2015). Such developmental activities have proven detrimental to wildlife across the globe since they have led to habitat destruction, fragmentation, and high access to natural resources, leading to a decline in wildlife population and illegal extraction of natural resources, respectively (Bastin et al 2019). Development of the road network is affecting wildlife negatively (Strano et al 2017). Modern civilizations also used to develop across the roads for easy human mobility and move goods among locations, further increasing the negative effects on wildlife (Laurance et al 2009). Roads affect wildlife in direct and indirect ways. Direct effects involve deaths through vehicular traffic. For example, Lalo (1987) estimated vertebrate mortality on roads in the United States at 1 million individuals per day. Road construction and widening lead to habitat destruction and fragmentation and severely impact species that used to avoid the road edge (Lesbarreres and Fahrig 2012). Roads also restrict the movement of the species, known as the barrier effect, and divide areas in the temporary island, especially during high vehicular activity (Shepard et al 2008, Kociolek et al 2011). The barrier effect also reduces the gene flow, which negatively affect the species' population size (Riley et al 2006). Also, road construction changes the environment along the roads by changing the soil properties, hydrological cycles, and increasing noise and light intensity (Laurance et al 2009). The adverse effects of roads are so deep that it has emerged in a new ecological discipline known as "Road Ecology" (Forman 1998).

India has the second largest human population globally, and during the last few years, its economy has grown very fast. A highly growing economy has led to increased infrastructure development, including roads. For example, in India, highway length (national and state highways) increased by 50% between 1980-2000. At the same time, road length increased by nearly 40% between 2001 and 2015 (https://data.gov.in/). Nayak et al (2020) found that 46,700 kilometres of roads exist in India's forest area, which has resulted in forest fragmentation and habitat loss across the country. Most of India's studies on road ecology have been concentrated on the stretches of roads going through the protected area or landscape surrounding protected areas. However, there is a paucity of studies in human-dominated landscapes regarding roadkill, which limit understanding of road impact on wildlife in the human-dominated landscape.

In the present study, we aimed to fill the knowledge gap of road ecology by assessing the status and factors affecting roadkills on a stretch of 14 kilometres on National Highway 64 in the human-dominated landscape of Navsari district, Gujarat, India. Objectives of the present study were a) To assess the status and characteristics of roadkills b) To assess factors affecting the presence of roadkill

MATERIAL AND METHODS

Study area: The study area of the present study includes National Heritage Highway 64 between Eru char Rasta to Dandi Sea Coast (Fig. 1). Dandi is a village in the Jalalpore taluka in Navsari District of Gujarat state of India. Dandi is located on the coast of the Arabian Sea near the city of Navsari between 20.95 0 N -72.93 0 E. This is one of the busiest routes of the area and used commonly by two-wheelers and cars. The Dandi road consisting habitats of mostly rainfed crop lands, barren lands, human habitations, pond and a few coastal forest patches. The entire road passes through villages Ethan, Pethan, Kothmadi, Matvad and Samapor. The vegetation present on either side of the road consists of the plant species namely *Ficus benghalensis* L., *Ficus religiosa* L., *Azadirachta indica* A. Juss., *Eucalyptus globules* Labill., *Albizia lebbeck* (L.) (Personal Observation).

Kill monitoring: Sampling was carried out from October 2021 to April 2022 on the road from Eru Char Rasta to Dandi Sea Coast, covering a distance of 14 km (Fig. 1). The road was surveyed weekly from 6 AM to 10 AM using a bicycle. To avoid the problem of duplication of kills, we first monitored five kills of different species, such as amphibians, small mammals, and reptiles. We found that kills decayed entirely in one week. Therefore, we monitored kills every week, assuming that during this time interval, identified kills would be decayed totally, and hence duplication of kills could be avoided. While sampling, going towards Dandi, one side of the road was sampled, and another side was sampled while coming back. Data recorded while encountering roadkill include species names, dates, and broad habitat types. Broad habitat types include agricultural land, human habitation, orchards, wetland, and pond. Field guide and taxonomic keys were used for the species identification (Daniel 2002, Menon 2014).

Factors affecting kill sites: To assess site-specific factors affecting roadkills, we followed a used-unused sampling design where each kill was treated as a used location, and a random location was treated as an unused location (Boyce et al 2002). We considered five variables: canopy cover, shrub cover, ground cover, distance from the road edge, and distance from human habitation. Canopy cover, shrub cover, and ground cover were quantified on a 0- 100 scale by laying down a kill cantered plot of a 20 m radius (Chaudhary et al 2020). The distance of the kill from the road edge was quantified using a measuring tape, while the distance of the kill from human habitation was quantified by measuring the distance of the nearest house using a laser range finder. Further similar variables were collected at a random location on roads and considered as absence points of kills.

Analysis: We segregated roadkills frequency concerning species, taxonomic groups, broad habitat types, and months. Since our data consist of frequency therefore, we used the chi-square test of homogeneity (Zar 2006) to examine a) if the frequency of roadkill is distributed proportionally among different species or taxonomic groups and b) if the frequency of roadkill is distributed proportionally in different habitat types and months.

To assess the factors affecting the presence of kill sites, we used Generalized Linear Models (GLM) (Guisan et al 2002). Since data collection was based on a used-unused sampling design, therefore we used binomial distribution with a logit link (Guisan et al 2002). The presence and absence of kills were used as response variables, while variables defined earlier section were used as predictor variables. A list of all possible models was created using the dredge function of package MuMIn in program R, and a model with $\Delta AIC<2$ was considered the final model (Burnham and Anderson 2002). To assess the relative importance of the model, we used ΔAIC and AIC weight (Burnham and Anderson 2002). Model averaging was done for the models with $\Delta AIC<2$ following Burnham and Anderson (2002). Best model accuracy was assessed through the model validation using sensitivity analysis which is best suited for the binomial outcomes. In validation analysis, 80% of the data was used as a training data set, while 20% was used as testing data set. All analysis was carried out in R statistical software (R Core Team 2018).

RESULTS AND DISCUSSION

A total of 336 kilometres of roads were monitored during the survey, resulting in roadkill of 70 individuals of 15 species, all of which were under the least concern category (Table 1). Out of 70, the maximum number of individuals belongs to reptiles (27), followed by amphibians (23) and mammals (20) (χ 2 = 1.04, df = 2, $p<0.05$). The overall kill rate (Individual killed per kilometre) during the study period was 0.48. The highest kill rate was observed for reptiles, i.e., 0.08, followed by amphibians, i.e., 0.06, and mammals, i.e., 0.05.

The maximum number of kills found during the month of March (24), followed by February (14), April (13), October (9), December (5), November (3), January (2) (χ2 =36, df = 6, $p<0.05$) (Fig. 2). Maximum roadkills were found in the agriculture land (28), followed by human habitation (16), orchard (16), wetland (8) and pond (2) (χ2 = 27.41, df = 4, $p<0.05$) (Fig. 3).

Among reptiles, the highest number of kills were of common Garden lizard (*Calotes versicolor*) (15), followed by checkered keelback snake (*Xenochrophis piscator*) (4), rat snake (*Ptyas mucosa*) (4), common kukri snake (*Oligodon arnensis*) (1), Indian cobra (*Naja naja*) (1), wolf snake-

Lycodon (1) and green vine snake (*Ahaetulla nasuta*), (1) (χ^2 =40.70, df = 6, $p<0.05$) (Table 1).

Among amphibians' the highest number of kills was of the Common frog (*Rana temporaria*) (11), followed by the Common Indian toad (*Duttaphrynus melanostictus*) (7), Unidentified species, and Indian skittering frog (*Euphlycti scyanophlyctis*) (1) (χ^2 = 9.48, df = 3, $p<0.05$) (Table 1). Among mammals' the highest number of roadkill was of five striped squirrel (*Funambulus pennantii*) (8), followed by common tree shrew (*Tupaia glis*) (6), Indian Gerbil (*Tatera indiaca*) (4) and house rat (*Rattus rattus*) (2) (χ^2 =4, df = 3, $p<0.05$) (Table 1).

A total of eight models performed best (ΔAIC<2) and consisted of all habitat variables, i.e., canopy cover, shrub cover, ground cover, distance from the road edge, and distance from human habitat (Table 2). Model averaging found that shrub cover (b=0.14± 0.95), ground cover (b= 0.58±0.86), distance from road edge (b=1.62±1.11), distance from human habitation (b= 0.51±0.42) were positively associated with kill sites, while canopy cover (b= -1.23±1.16) was negatively associated with the kill sites (Table 2). Model validation analysis found an accuracy of 88 % and sensitivity of 89 %, which depicts the high accuracy of the best model used to evaluate the factor affecting kill sites.

Roadkill is among the most threatening human activities that could severely affect wildlife. Present study results show

Table 1. Road kill incidents of reptile, amphibian and mammal species reported and their IUCN status

Class	Comman name	Scientific name	IUCN status	Number of Individuals killed
Reptiles	Common garden lizard	*Calotes versicolor*	Least concern	15
	Checkered keelback snake	*Xenochrophis piscator*	Least concern	4
	Green vine snake	*Ahaetulla nasuta*	Least concern	1
	Indian cobra	*Naja naja*	Least concern	1
	Common kukri snake	*Oligodon arnensis*	Least concern	1
	Rat snake	*Ptyas mucosa*	Least concern	4
	Wolf snake	*Lycodon aulicus*	Least concern	1
Amphibians	Common frog	*Rana temporaria*	Least concern	11
	Common Indian toad	*Duttaphrynus melanostictus*	Least concern	7
	Unidentified	Unidentified	Unidentified	4
	Indian skittering frog	*Euphlyctis cyanophlyctis*	Least concern	1
Mammals	Five striped squirrel	*Funambulus pennantii*	Least concern	8
	Common tree shrew	*Tupaia glis*	Least concern	6
	Indian gerbil	*Tatera indica*	Least concern	4
	House rat	*Rattus rattus*	Least concern	2

Table 2. Factors affecting kill sites during the present study. (Only parameters for the best set of models with ΔAICc < 2 are reported)

Int	DFRE±S.E.	DFHH±S.E.	CC±S.E.	SC±S.E.	GC±S.E.	*df*	ΔAICc	MW
0.65	1.62±1.11	-	-	-	-	2	0.00	0.17
0.95	-	0.51±0.42	-	-		2	0.99	0.10
-0.04	1.62±1.11	0.51±0.42	-	-	-	3	1.16	0.09
2.14	-	0.51±0.42	-1.23±1.16	-	-	3	1.49	0.08
2.35	-	-	-1.23±1.16	-	-	2	1.74	0.07
1.90	1.62±1.11	0.51±0.42	-1.23±1.16	-	-	4	1.80	0.07
-0.07	-	0.51±0.42	-	0.14± 0.95	-	3	1.81	0.07
-0.13	1.62±1.11	-	-	-	0.58±0.86	3	1.66	0.07
MAE	1.62±1.11	0.51±0.42	-1.23±1.16	0.14± 0.95	0.58±0.86			

Int. = intersection; DFRE= Distance from road edge, DFHH-Distance from human habitation, CC=Canopy Cover, SC=Shrub Cover, GC=Ground Cover, df = degrees of freedom; ΔAICc = difference in value of Akaike's information criterion between the focal model and the top-ranked model. MW=Model Weight, MA=Model Average Estimates that reptiles and amphibians are among the most skilled taxonomic group, while mammals are the least. Some earlier studies also found that amphibians and reptiles were among the most affected groups from the roadkill (Baskaran and Boominathan 2010, Selvan et al 2012, Sur et al 2022).

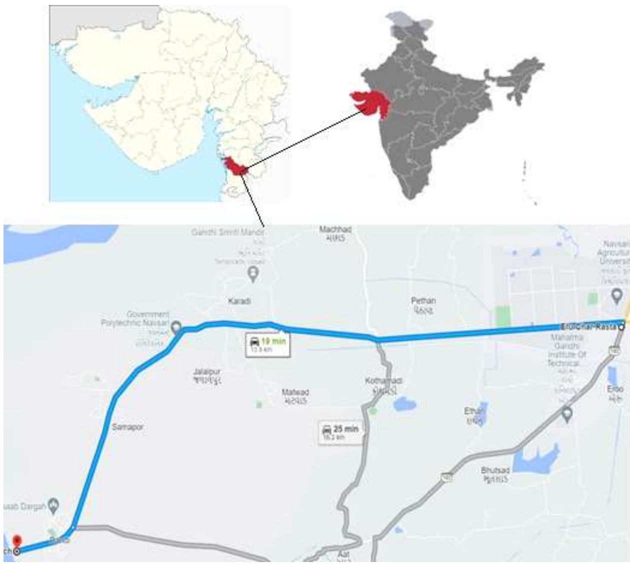

Fig. 1. Map of the study (road in blue)

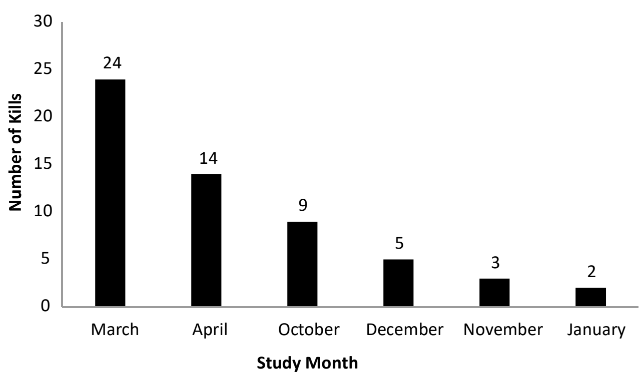

Fig. 2. Distribution of road kill in relation to study month

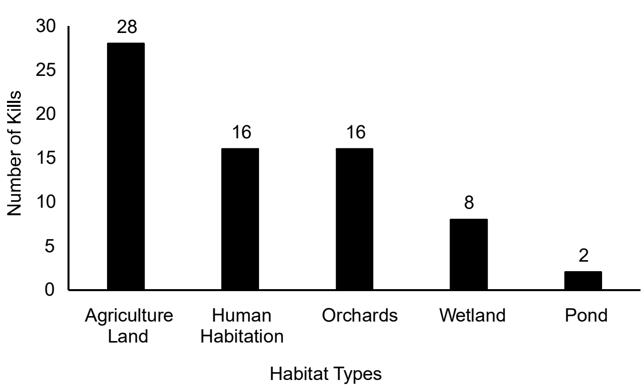

Fig. 3. Distribution of road kills in relation to habitat types

Amphibians and reptiles move slower than mammals and cannot react very quickly to vehicles, leading them to take more time while crossing the roads and increasing the probability of their kills (Row et al 2007, Baskaran and Boominathan 2010, Hatti and Mubeen 2019). The common garden lizard was among the most affected species by roadkill amongst reptiles, while among the amphibians and mammals were a common frog and five stripped squirrels, respectively. The abundance of the species around roads is among the key factors affecting roadkill status (Dutta 2016). Sur et al (2022), while assessing roadkill on the road passing through Kaziranga tiger reserve, found that the most frequently killed species were the generalist and abundant, like common Indian toad and squirrel species. Our study road has ravines and large trees which act as suitable habitats for common species such as frogs and squirrels, respectively. The ravine and large trees provide habitat for the amphibians and squirrels, respectively consequence is their high abundance around the rods, which might lead to their high roadkill. Also, the foraging nature of frogs and toads, which are very fond of gathering near street lamps and vehicle headlights to feast on insects (Daniels 2005) could be one of the possible reasons for their higher susceptibility to becoming roadkill victims. High roadkill of garden lizards could be due to canopy gap, which forces them to cross the

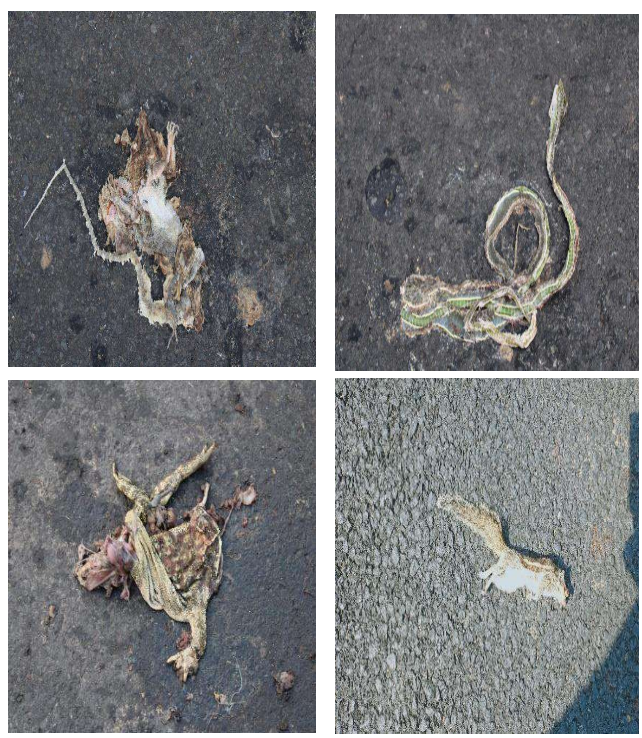

Fig. 4. Some of the roadkill encounter during the survey [clockwise a) Common garden lizard b) Green wine snake c) Five stripped squirrel d) Common Frog]

roads and hence the high number of kills (Sur et al 2022). Among reptiles, apart from one species, i.e., the common garden lizard all other kills were of snake species. Rosen and Lowe (1994) estimated 2383 per 35.5 km $year^{-1}$ of snakes killed by automobiles in the United States. The Later study also stated that resting or coiling snakes on the road surface, especially during the spring season for warmth, contributes to snakes' high road mortality. Snakes use the road surface for thermoregulation, which seems to be the reason for the high death rate of snakes by roadkill (Rosen and Lowe 1994, Vijayakumar et al 2001). Among mammals, Indian gerbils and House rats were among the most killed after five stripped squirrel. Both the Indian gerbil and House rats are nocturnal in their activity pattern. Many more nocturnal mammal species are present in this landscape, like leopards and wild pigs, but gerbils and rats were roadkill victims because they were smaller in size and less noticed on the road by the drivers.

Maximum roadkills happen during March, which is the onset of the summer, which could be due to increased vehicle intensity in March owing to festivals like Holi when people visit Dandi. Otherwise, one could expect more kills during April if the summer season is the reason. However, further research is needed in this direction. The highest roadkill happened when agricultural habitat was in the surroundings. The presence of agricultural habitat possibly led to the high abundance of some species, like Five stripped squirrels that used to feed on crops (Hill 1997). A high abundance of some species might result in increased roadkills around the agricultural habitat.

The generalized linear model suggested that roadkill probability increase with an increase in ground cover, shrub cover, distance from the road edge, and distance from human habitation. In contrast, with an increase in canopy cover, roadkill probability increased, which is in accordance with some earlier studies (Habib et al 2020). Both high ground cover and shrub cover may create a visibility hindrance for both animals crossing the roads and vehicle drivers, which might lead to high kill around high ground and shrub cover areas. Furthermore, studies have found that wildlife across the globe avoids human disturbances (Steffan et al 2015). Possibly areas further to human habitation have a high abundance and richness of species, leading to high crossing by them, and hence high roadkills. Inverse relations of roadkill with canopy cover could be due to high usage by the species like lizards and five-stripped squirrels, which make a maximum of all the kills. With the decrease in canopy cover, the canopy gap increased, leading to high road usage by certain species like squirrels and lizards consequence of which is high roadkills (Sur et al 2021).

CONCLUSION

The present study provides basic information about roadkill. Road widening could increase the magnitude of roadkill, threatening species' survival. The present study will also provide a baseline for future surveys and hence could be helpful to assess the impact of road widening on the roadkill if it happens.

REFERENCES

Baskaran N and Boominathan D 2010. Roadkill of animals by highway traffic in the tropical forests of Mudumalai Tiger Reserve, southern India. *Journal of Threatened Taxa* **2**(3): 753-759.

Bastin JF, Finegold Y, Garcia C, Mollicone D, Rezende M, Routh D, Zohner CM and Crowther TW 2019. The global tree restoration potential**.** *Science* **365**(6448): 76-79.

Boyce MS, Vernier PR, Nielsen SE and Schmiegelow FKA 2002. Evaluating resource selection functions. *Ecological Modelling* **157**: 281-300.

Burnham KP and Anderson DR 2002. *Model selection and multimodel inference: a practical information–theoretic approach,* Springer, USA, 488p.

Chaudhary R, Zehra N, Musavi A and Khan JA 2020. Evaluating the effect of ecological and anthropogenic variables on site use by sympatric large carnivores in Gir protected area, Gujarat, India. *Wildlife Biology*: wlb.00696.

Daniel JC 2002. *The Book of Indian Reptiles and Amphibians*, Oxford University Press, India, 238p.

Daniels RJR 2005. *Amphibians of Peninsular India*. University Press, Hyderabad, India, 268p.

Dutta S, Janab HP, Sahac S and Mukhopadhyayd S 2016. The cause and consequences of road mortality of herpetofauna in Durgapur, West Bengal, India. *Russian Journal of Ecology* **47**: 88-95.

Forman RTT 1998. *Road ecology: A solution for the giant embracing us.* Landscape Ecology 13, III–V.

Guisan A, Edwards TC and Hastie T 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling* **157**: 89-100.

Habib B, Saxena A, Bhanupriya R, Jhala YV and Rajvanshi A 2020. *Assessment of impacts of National Highway 715 (Earlier NH 37) on wildlife passing through Kaziranga Tiger Reserve, Assam.* Technical Report, wildlife Institute of India, Dehradun, India, 36p.

Hatti SS and Mubeen H 2019. Roadkill of animals on the road passing from Kalaburagi to Chincholi, Karnataka, India. *Journal of Threatened Taxa* **11**(7): 13868-13874.

Hill CM 1997. Crop-raiding by wild vertebrates: The farmer's perspective in an agricultural community in western Uganda. *International Journal of Pest Management* **43**: 1-9.

Kociolek AV, Clevenger AP, Clair CC and Proppe DS 2011. Effects of road networks on bird populations. *Conservation Biology* **25**(2): 241-249.

Lalo J 1987. The problem of roadkill. *American Forests* **50**: 50-52.

Laurance WF, Goosem M and Laurance SGW 2009. Impacts of roads and linear clearings on tropical forests. *Trends Ecology Evolution* **24**(12): 659-669.

Lesbarrères D and Fahrig L 2012. Measures to reduce population fragmentation by roads: what has worked and how do we know? *Trends Ecology Evolution* **27**(7): 374-380.

Menon V 2014. *Indian Mammals: A Field Guide*, Hachette Book Publishing, Delhi, India, 201p.

Nayak R, Karanth KK, Dutta T, Defries R, Karanth KU and Vaidyanathan S 2019. Bits and pieces: Forest fragmentation by linear intrusions in India. *Land Use Policy* **99**: 1-12.

R Core Team 2018. R: A Language and Environment for Statistical Computing. URL. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Riley SPD, Pollinger JP, Sauvajot RM, York EC, Bromley C, Fuller TK and Wayne RK 2006. A southern California freeway is a physical and social barrier to gene flow in carnivores. *Molecular Ecology* **15(7)**: 1733-1741.

Rosen C and Lowe CH 1994. Highway mortality of snakes in the Sonoran Desert of Southern Arizona. *Biological Conservation* **68**: 143-148.

Row JR, Blouin D and Wheatherhead PJ 2007. Demographic effect of road mortality in black Rat Snakes (*Elaphe obsolete*). *Biological Conservation* **137**: 117-124.

Selvan KM, Sridharan N and John S 2012. Roadkill animals on national highways of Karnataka, India. *Journal of Ecology and the Nature Environment* **4**(14): 363-365.

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Shepard DB, Kuhns AR, Dreslik MJ and Phillips CA 2008. Roads as barriers to animal movement in fragmented landscapes. *Animal Conservation* **11**(4): 288-296.

Steffen W, Broadgate W, Deutsch L, Gaffney O and Ludwig C 2015. The trajectory of the Anthropocene: The great acceleration. *The Anthropocene Review* **2**(1): 81-98.

Strano E, Giometto A, Shai S, Bertuzzo E, Mucha PJ and Rinaldo A 2017. The scaling structure of the global road network. *Royal Society Open Science* **4**(10): 1-11.

Sur S, Saikia PS and Saikia MK 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.

Vijayakumar SP, Vasudevan K and Ishwar N M 2001. Hepetofaunal mortality on the roads in the Anamalai Hills, southern Western Ghats. *Hamadryad* **26**(2): 265-272.