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MONITORING ROADKILL IN AMRAVATI, INDIA: A CITIZEN SCIENCE PROJECT

Mandar Pawgi[1*], Yogesh Joshi[1*], Sawan Deshmukh[2], Anoop Purohit[3], Kedar Pawgi[1], Reuven Yosef[4]

[1]*Koola Wild Foundation, Munshi Complex, Ambapeth, Amravati 44601, India.*
[2]*Center for Animal Rescue and Study (CARS), "Abhiruchi", 31 Saurabh Colony, Kathora Naka VMV Road, Amravati 444604, India*
[3]*Independent conservationist, Kranti Colony, Behind Darga, Akoli Road, Amravati 444607, India.*
[4]*Ben Gurion University of the Negev, Eilat Campus, P. O. Box 272, Eilat 8810201, Israel. ORCID 0000-0003-4331-9866*
**Corresponding Authors: Mandar Pawgi (mandarpawgi@gmail.com), Dr. Yogesh Joshi (joshiyogesh26@gmail.com)*

Abstract.
Roadkill is a global conservation problem, and India is no exception. Animal-vehicle accidents on roads are a leading cause of death for a variety of animal species both within and near protected areas. However, documentation of roadkills remains sparse due to field constraints and the absence of dedicated IT platforms. The lack of documentation and unavailability of traffic fatality data pose major limitations for government agencies and conservationists. In 2018, as part of a citizen science program to collect opportunistic data, we launched a free "ArRM" mobile app and website, www.arrm.org.in. In 2022, we conducted a systematic random survey of 10,500 km covering the entire road network in Amravati district, Maharashtra, India. Through citizen science initiatives and our concerted efforts, we documented 364 roadkills, comprising 336 wild species and 28 domestic species, representing a diverse array of 70 species. Our project aims to overcome the non-documentation of roadkills in the Amravati district and provide data on an interactive map that is freely accessible in the public domain. This will help wildlife authorities, conservationists, and policymakers plan or implement effective measures to reduce the number of wildlife killed on roads.

Key words: *Roadkill, wildlife, citizen science, ArRM, Amravati*

1. Introduction

Linear infrastructures (roads, power lines, water canals) are known to impact wildlife in various manners (population degradation, genetic isolation), the most obvious of which is animal-vehicular accidents (Ascensão et al. 2019). In and around protected areas, many endangered species are at risk from vehicular traffic. Roadkills are estimated to have a more pronounced impact on the mortality rates of various species compared to poaching (Ontiveros 2022).

India has a road network of over 600,000 km, making it the second largest in the world. There are also around three million registered vehicles in India. In 2021, the number of traffic accidents increased by an average of 12.6% compared to the previous year, 2020 (MoRTH 2022). However, all critical statistics available relate only to human deaths. Data on animal deaths are sporadic and regionally (Baskaran and Boominathan 2010, Behera and Borah 2010, Behera et al., 2021, Bhupathy et al. 2011, Jeganathan et al., 2018, Sur et al. 2018) or taxonomically limited (amphibians – Seshadri et al., 2009; birds – Siva and Neelnarayanan 2020). Additionally, there is a significant information gap regarding wildlife mortality, further exacerbating the lack of understanding in this area.

We aim to record and map roadkills across the entire road network in Amravati district (area 12,235 km²), Maharashtra state, India. While similar studies have been undertaken in India, this stands out as the first to comprehensively investigate roadkill incidents across various road sections at the district level. We wanted to analyse essential data such as numbers, seasonal variations, species, and to identify roadkill hotspots (Hadad et al. 2023). However, we focus on bringing all this data into an interactive mobile application and associated website and collecting as much data as possible in the long term. The main aim of this application and website is to build a database for collective documentation of roadkills and make it freely accessible for public use (cf. Vercayie and Herremans 2015). Ordinary citizens, political institutions, Forest Department employees, academicians, wildlife researchers, and all concerned people can contribute and benefit from the multi-featured mobile application that captures individual observations, geotags, and photos of roadkilled wildlife. All these and other information are also available on a separate web portal (www.arrm.org.in) for convenience. The data encompassed four vertebrate groups: mammals, birds, reptiles, and amphibians, spanning from July 2018 to December 2022.

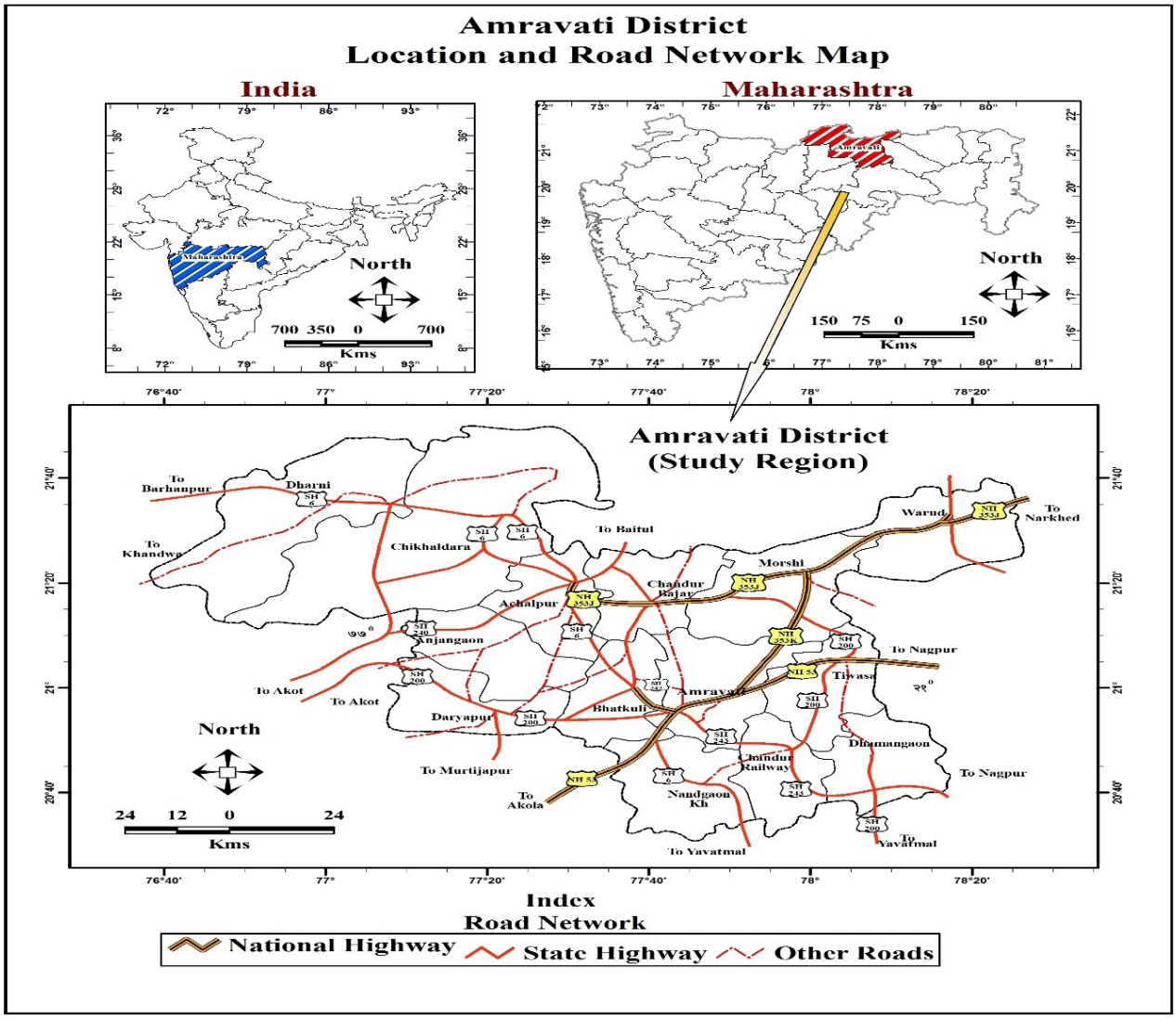

Figure 1. Amravati district and a major portion of the road network map of the study area (map by Dr. Sawan Deshmukh). NH denotes the National highway, and SH denotes the State highway.

2. Study Area

Amravati district (21.1162°N, 77.6536°E) is in the northeast part of Maharashtra. The district is characterized by the Gavilgarh hills, a part of the Satpura range situated in the northern region. These hills vary in elevation from 350 m to 1178 m above mean sea level. This district has an excellent network of rural district roads, state highways, and national highways. (Fig. 1).

Notably, Amravati district is home to several well-known protected areas, including the Melghat Tiger Reserve, one of the first eight tiger reserves declared in 1973. Due to its excellent network of protected areas and lakes, the district also serves as a hotspot for migratory birds. Numerous rare and important species of mammals, birds, reptiles, bats, spiders, and amphibians have been recorded in Amravati district, further highlighting its' ecological importance (e.g., Shelekar and Jadhao 2020, Mahadik et al. 2020) and making it one of the most biodiverse districts in the State.

3. Methods

Through popular and social media, citizens were encouraged to install the ArRM (Application for rescue and Roadkill Mapping) on their smartphones and to register roadkills. The opportunistic survey was conducted by 50 citizen science volunteers who systematically recorded roadkills while driving their regular routes throughout the study period.

In addition, we conducted 264 random surveys between December 2021 and July 2022 and collected 116 roadkilled wildlife species from the entire road network of Amravati district, spanning approximately 10,500 km (Table 1).

We rode the motorcycle at a constant, slow speed (> 20 km/h), followed by fixed times (in winter from 5 to 8 in the morning and evening and 6 to 9 a.m. in summer). We recorded all roadkills within 15 meters of the major roads and highways throughout the study area. We identified each encountered roadkill at the species level. Vital

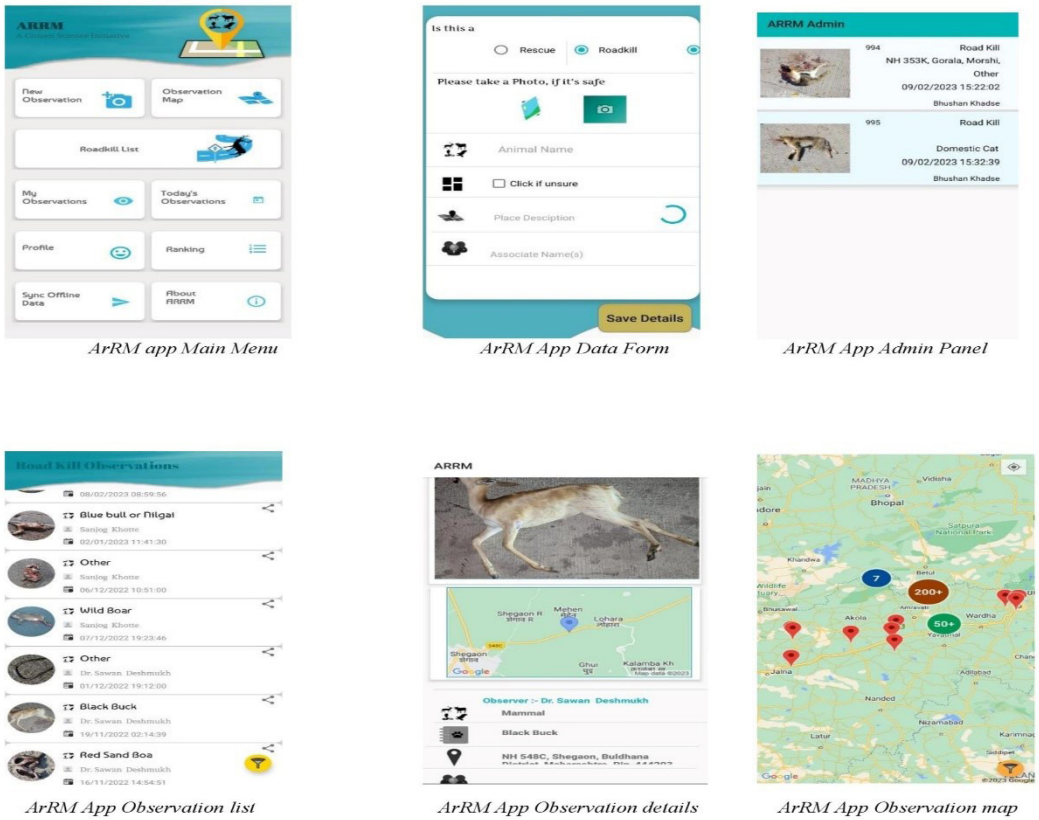

Figure 2. Screenshots of menus and features of the mobile application ArRM and www.arrm.org.in website.

information including photographs and geo-locations were captured using the mobile application, which was then updated in the application database and made accessible on the website www.arrm.org.in (Fig. 2). This interactive website is also freely accessible to the general-public or individuals interested in utilizing the data.

We have created an admin version of the ArRM mobile app to avoid duplicate records or double counting. In this version, observations are either approved or rejected. The data set is subsequently uploaded to the mobile application and website. Moreover, any misidentified species are rectified and crosschecked against database entries to ensure accuracy.

We emphasized and encouraged participants to record only fresh carcasses. We labelled roadkills that were difficult to identify or were in poor condition as "Other/Unidentified." After recording, all carcasses were carefully removed from the site to avoid double counting and mitigate the risk of scavengers being harmed at the location. Carcasses were identified with the help of field guides such as Menon (2014) for mammals, Grimmet and Inskipp (2011) for birds, Whitaker, and Captain (2004) for reptiles, and Das (2002) for amphibians, as well as various websites.

4. Results

We only focussed on wild species collected during our study. With 210 contributions from citizen scientists (2018-2022) and 116 through our efforts (Dec 2021-Jul 2022), while ten samples could not be identified due to their poor condition, a total of 336 individual roadkills were registered (Table 1).

Table 1. Monthly roadkill data of surveys by the Koola Wild Foundation, December 2021-July 2022.

Month	Distance sampled	Roadkills				Monthly Total	No. Roadkills found
	(Km)	Mammal	Reptile	Bird	Amphibian		
Dec-21	1,293.59	5	3	12	0	20	18
Jan-22	1,887.37	5	3	4	0	12	38
Feb-22	1,637.00	3	1	7	0	11	35
Mar-22	1,284.99	2	2	1	0	5	33
Apr-22	755.66	2	1	0	0	3	16
May-22	917.66	5	4	1	1	11	13
Jun-22	1,267.42	5	9	4	0	18	17
Jul-22	1,427.44	4	28	4	0	36	21
		31	**51**	**33**	**1**		
	10,471.13	**116**				**116**	**191**

Table 2. List of roadkilled species on roads in Amravati District.
KWF denotes data collected by the Koola Wild Foundation and CS by Citizen Science.

Family	Common Name	Scientific Name	IUCN status	Roadkilled	
Mammals				KWF	CS
Hyaenidae	Striped Hyena	*Hyaena hyaena*	NT	00	01
Carnivora	Indian Fox	*Vulpes bengalensis*	LC	00	01
Carnivora	Indian Golden Jackal	*Canis aureus*	LC	00	12
Felidae	Jungle Cat	*Felis chaus*	LC	04	04
Hystricidae	Indian-Crested Porcupine	*Hystrix indica*	LC	01	00
Bovidae	Blackbuck	*Antilope cervicapra*	LC	01	07
Bovidae	Nilgai	*Boselaphus tragocamelus*	LC	01	03
Viverridae	Small Indian Civet	*Viverricula indica*	LC	03	02
Suidae	Wild Pig	*Sus scrofa*	LC	01	05
Herpestidae	Indian Grey Mongoose	*Urva edwardsii*	LC	03	03
Sciuridae	Common-Palm Squirrel	*Funambulus palmarum*	LC	09	26
Chiroptera	Bat spp			01	00
Muridae	Indian Gerbil	*Tatera indica*	LC	05	01
Lagomorpha	Indian Hare	*Lepus nigricollis*	LC	01	01
Cercopithecidae	Indian Gray Langur	*Semnopithecus entellus*	LC	00	05
				30	**71**
			Total	**101**	
Reptiles					
Trionychidae	Indian softshell turtle	*Nilssonia gangetica*	EN	00	01
Varanidae	Bengal Monitor Lizard	*Varanus bengalensis*	NT	00	06
Pythoniade	Indian Rock Python	*Python molurus*	NT	00	02
Boidae	Red sand Boa	*Eryx johnii*	NT	00	01
Boidae	Common Sand Boa	*Eryx conicus*	NT	00	01
Elapidae	Indian Spectacled Cobra	*Naja naja*	LC	02	04
Elapidae	Common Krait	*Bungarus caeruleus*	LC	03	04
Uropeltidae	Elliot's shieldtail	*Uropeltis ellioti*	LC	00	01
Viperidae	Russel's Viper	*Daboia russelii*	LC	05	07
Viperidae	Saw-scaled Viper	*Echis carinatus*	LC	03	02
Colubride	Indian Egg Eater	*Elachistodon westermanni*	LC	01	06
Colubride	Indian Smooth Snake	*Wallophis brachyura*	LC	00	01
Colubridae	Banded Kukri	*Oligodon arnensis*	LC	08	03
Colubridae	Banded Racer	*Argyrogena fasciolata*	LC	01	03
Colubridae	Green Keelback	*Macropisthodon plumbicolor*	LC	07	03
Colubridae	Checkered Keelback	*Xenochrophis piscator*	LC	04	07
Colubridae	Striped Keelback	*Amphiesma stolatum*	LC	01	03
Colubridae	Common Trinket	*Coelognathus helena*	LC	06	16
Colubridae	Common Cat Snake	*Boiga trigonata*	LC	01	00
Colubridae	Common Wolf Snake	*Lycodon aulicus*	LC	04	03
Colubridae	Barred wolf Snake	*Lycodon striatus*	LC	03	01
Colubridae	Indian Rat Snake	*Ptyas mucosa*	LC	01	02

Psammophiidae	Stout sand Snake	*Psammophis longifrons*	LC	00	02
Agamidae	Indian Garden Lizard	*Calotes versicolor*	LC	04	01
Typhlopidae	Beaked-worm Snake	*Grypotyphlops acutus*	LC	00	01
Other/Unidentified				02	01
				56	**82**
			Total	**138**	
Birds					
Accipitridae	Shikra	*Accipiter badius*	LC	01	00
Burhinidae	Indian Stone Curlew	*Burhinus indicus*	LC	00	01
Picidae	Black-rumped Flameback	*Dinopium benghalense*	LC	00	01
Rallidae	White Breasted Waterhen	*Amaurornis phoenicurus*	LC	00	01
Phasianidae	Jungle Bush Quail	*Perdicula asiatica*	LC	01	00
Dicruridae	Black Drongo	*Dicrurus macrocercus*	LC	01	00
Paradoxornithidae	Yellow-eyed Babbler	*Chrysomma sinense*	LC	03	03
Leiothrichidae	Common Babbler	*Argya caudata*	LC	00	01
Leiothrichidae	Jungle Babbler	*Turdoides striata*	LC	01	01
Caprimulgidae	Indian Nightjar	*Caprimulgus asiaticus*	LC	04	03
Tytonidae	Barn Owl	*Tyto alba*	LC	01	03
Strigidae	Spotted Owlet	*Athene brama*	LC	00	01
Psittaculidae	Rose-ringed Parakeet	*Psittacula krameri*	LC	00	01
Cuculidae	Greater Coucal	*Centropus sinensis*	LC	08	13
Cuculidae	Common Hawk Cuckoo	*Hierococcyx varius*	LC	00	01
Cuculidae	Asian Koel	*Eudynamys scolopaceus*	LC	02	00
Cuculidae	Jacobin/Pied Cuckoo	*Clamator jacobinus*	LC	01	00
Alcedinidae	White-throated kingfisher	*Halcyon smyrnensis*	LC	00	03
Ardeidae	Great Egret	*Ardea alba*	LC	01	00
Coraciidae	Indian Roller	*Coracias benghalensis*	LC	00	05
Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	LC	06	11
Columbidae	Rock pigeon	*Columba livia*	LC	00	01
Columbidae	Spotted Dove	*Spilopelia chinensis*	LC	00	02
Sturnidae	Common Myna	*Acridotheres tristis*	LC	00	01
Sturnidae	Brahminy starling	*Sturnia pagodarum*	LC	00	01
Muscicapidae	Oriental-Magpie Robin	*Copsychus saularis*	LC	01	00
Passeridae	House Sparrow	*Passer domesticus*	LC	00	01
Corvidae	House Crow	*Corvus splendens*	LC	00	01
Other/Unidentified				02	05
				33	**61**
			Total	**94**	
Amphibians					
Bufonidae	Common Indian Toad	*Duttaphrynus melanostictus*	LC	00	02
Dicroglossidae	Indian Bullfrog	*Hoplobatrachus Tigerinus*	LC	01	00
				01	**02**
			Total	**03**	
		Grand Total		**336**	

The samples represent 70 wild species, including 15 mammals, 25 reptiles, 28 birds, and two amphibians (Table 2). Reptiles were the most affected group at 138 (40.8%), followed by mammals at 101 (30.1%), birds at 94 (28.0%), and amphibians were the least affected (0.9%). (Table 2) In addition, comparing the total number of observations reported by citizen science compared to our surveys shows that the former contributed considerably to the data set. During the study period, citizens reported 216 (64.3%) of the roadkill as compared to 120 (35.7%) we found on our surveys (Table 2).

The highest number of roadkills was observed in July 2022, whereas no roadkills were recorded during multiple months spanning from 2018 and 2022 (ESM 2). We also evaluated the seasonal variations for 2018-22 and found that the highest roadkill rate occurred from June to September during the peak monsoon season (ESM 2). The fewest casualties were recorded in the late winter and early summer months, specifically from December to March (ESM 2). During this study, we identified the roadkill hotspots in Amravati district and found that NH353K (14.88%), NH353J (6.84%), and SH243 (15.47%) recorded the highest number of roadkills. (Fig 3).

5. Discussion

This study shows a high mortality rate in mammals, unlike other studies conducted in India (Seshadri et al., 2009; Baskaran, 2010; Somotiya et al., 2022). One possible explanation is that previous studies were conducted in regions characterized by high average rainfall, such as northeast India or the Western Ghats. The central Indian landscape is predominantly a dry habitat with fewer water bodies near roads. The roadkill of listed species (Striped Hyena, Small Indian Civet, Indian Fox, Indian Golden Jackal; Table 2, ESM 1) is of conservation concern.

In recent years, there has been a sharp increase in the population of herbivores such as nilgai (*Boselaphus tragocamelus*), blackbuck (*Antilope cervicapra*), and wild pigs (*Sus scorfa*) in rural areas (Narasimmarajan et al. 2014). On both sides of the roads, particularly in agricultural fields, herds of ungulates are frequently observed crossing the roads, thereby heightening the risk of

roadkill incidents. This is similar to the results in Lithuania, where an increase in roe deer (*Capreolus capreolus*) led to an increase in the number involved in animal-vehicular accidents, especially during the anthropopause due to the COVID-19 pandemic (Balciauskas et al. 2023).

Herpetofauna often appears on roads on cold days because tar roads are much warmer than surrounding areas. In winter, they must sunbathe early in the morning and seek a warmer place, which leads to them often choosing roads. During the monsoon season, particularly during the pre-monsoon and the onset of the first rains, snakes emerge from their burrows and disperse in various directions. This dispersal increases their vulnerability to vehicular traffic. Our records include the endangered Indian softshell turtle, Bengal monitor lizard, red sand Boa, common sand boa, and the rare Elliot's shield-tail (Table 2, ESM 1).

Our study area has water pipes running parallel to at least three major roads. During hot, dry summers, birds cross the road to drink water from leaks in these pipelines (MP, pers. obs.). On early winter mornings, birds caught flies, insects, and other invertebrates after the fresh sunlight hit the surface. The seasonal blooming of flowers and fruits on trees also causes many species to fly across roads at increased frequencies, resulting in increased roadkills. During the breeding season and after the eggs hatch, their foraging in all directions increases significantly (MP, pers. obs.), resulting in a higher risk of vehicle collisions. We have recorded Indian Stone Curlew (*Burhinus indicus*), Indian Nightjar (*Caprimulgus asiaticus*), Jungle Bush Quail (*Perdicula asiatica*), Barn Owl (*Tyto alba*) amongst others (ESM 1).

Most studies of roadkills in India show the highest mortality rate in amphibians (Ganesh et al., 2007, Seshadri et al., 2009, Baskaran and Boominathan 2010, Bhupathy et al., 2011, Santhoshkumar et al., 2017, Jeganathan et al., 2018, Sur et al., 2022) because they move slowly. Additionally, amphibians tend to live and breed near wet areas such as ponds, streams, and water bodies, making roads near these places more prone to roadkills. Surprisingly, there were only three records of amphibians during our study. Citizen scientists may have missed amphibian carcasses due to their small size. Also, these carcasses disintegrate after an accident, making them difficult to identify. More careful sampling is required to improve amphibian records, particularly during the monsoon season. We are also considering conducting walking or bicycle surveys to improve amphibian data.

During this study, we identified the roadkill hotspots (Fig 3) in Amravati district and found that NH353K (14.88%), NH353J (6.84%), and SH243 (15.47%) recorded the highest number of roadkills. All these sections pass close to forest reserves, a dam, and grassland areas, as also reported by Ontiveros (2022). Linear structures near nature reserves or resources required by wildlife (food, water) are especially prone to wildlife-vehicle accidents and require mitigation and education of drivers in these sections (da Rosa and Bager 2012). Mitigation can be in the form of speed-breakers or other structural barriers that prevent speeding and signs depicting the dangers to and from wildlife along specific highways. This is especially relevant to sections identified as roadkill hotspots.

In our study, citizen science provided significantly more data than our surveys and highlighted the importance of involving as many laypeople as possible in similar studies (Yosef and Tryjanowski 2022). Vercayie and Herremans (2015) state that citizen-provided roadkill data is critical to identifying methods for safer transportation and mitigating traffic fatality hotspots. Hadad et al. (2023) show how species-specific studies, on striped hyenas in their case, can contribute to a large-scale, nationwide assessment of roadkill hotspots.

6. Conclusion

Several parts of India have faced significant challenges in providing basic infrastructure facilities. The government's recent unprecedented push to address these challenges has created a major opportunity for linear infrastructure development. While a society's economic progress can be both a blessing and a curse for nature and wildlife, the expanded highway network and massive increase in vehicle purchases will pose a more significant threat in the future. Policymakers and implementers must plan future projects, considering a sustainable ecological framework. As infrastructure development projects progress, it is imperative that factors such as avoidance, prevention, and mitigation measures are accorded greater significance than ever before in the design and planning of linear projects. It is also crucial to regularly update and maintain roadkill data in and around various protected areas. Web-based reporting of wildlife observations, including wildlife-vehicle collisions, is a rapidly growing data source that helps understand the impacts of roads on wildlife and the effectiveness of mitigation measures (Fraser Shilling et al., 2015). Long-term collection of roadkill data can reliably answer broader ecological questions such as demographics, sex ratios, species-level population, and area occupancy. Collaborating with scientists from allied fields like climate change and environment impact assessment in roadkill studies could offer a comprehensive understanding of the challenges and solutions in roadkill prevention. Systematic documentation through rigorous sampling and citizen science, as well as the continuous availability of free roadkill data in public areas via dedicated IT platforms, will be crucial elements in all road ecology and wildlife protection activities.

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Declarations

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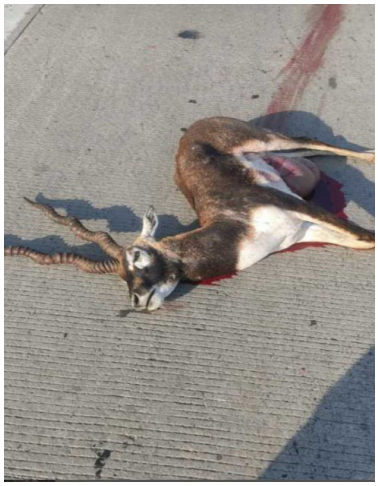
Electronic Supplemental Material

ESM 1. Examples of wildlife Roadkills during 2018-2022.

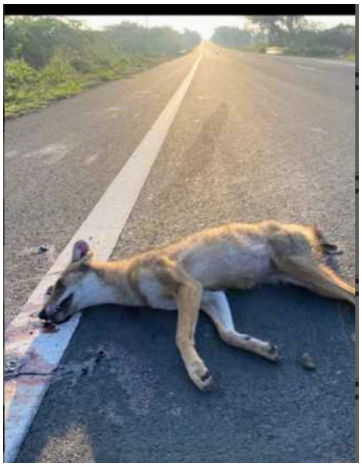
Mammals

Striped Hyena *Hyaena hyaena*

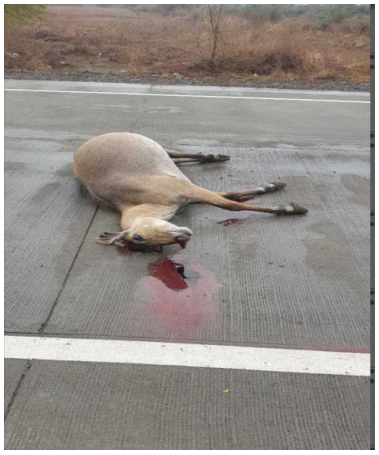
Indian Fox *Vulpes bengalensis*



Blackbuck *Antilope cervicapra*



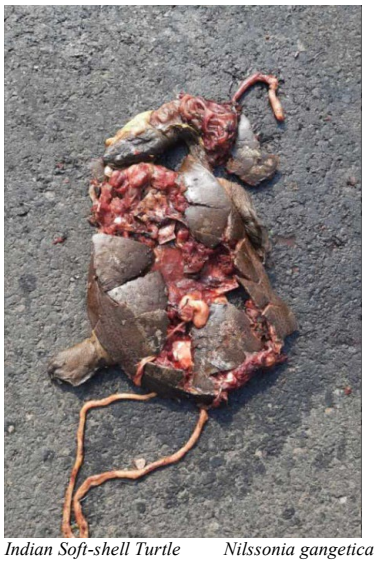
Indian Golden Jackal *Canis aureus*



Nilgai *Boselaphus tragocamelus*

Small Indian Civet *Viverricula indica*

Reptiles

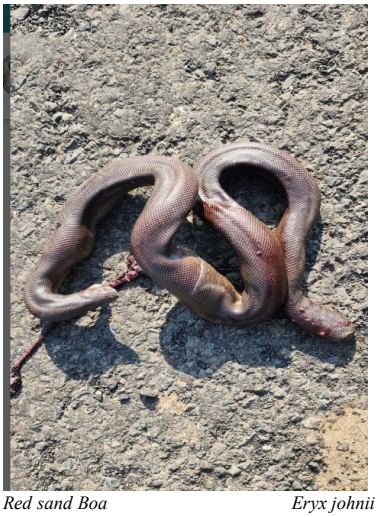


Indian Soft-shell Turtle *Nilssonia gangetica*

Elliot's shieldtail *Uropeltis ellioti*

Indian Egg-eater *Elachistodon westermanni*

Stout sand Snake *Psammophis longifrons*



Red sand Boa *Eryx johnii*

Birds

Indian Stone Curlew *Burhinus indicus*

Indian Nightjar *Caprimulgus asiaticus*

Jungle Bush Quail *Perdicula asiatica*

Barn Owl *Tyto alba*

ESM 2. Monthly roadkill data in Amravati District, July 2018- Dec 2022

Figure 3: Highways registering highest roadkills during 2018-2022. NH denotes National Highway, SH State Highway.