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Research Article

Wildlife casualties from the road-stretches adjacent to two national parks of Assam, North-East India

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ABSTRACT

Wildlife road-kill studies in India have mainly focused on herpetofauna and mammals with a very few reports on birds and other invertebrates whereas, the wildlife road-kill studies in Assam are meagre. In this study, we report road -kill individuals of different select taxa from select road-stretches of Dehing-Patkai National Park (DPNP) and Kaziranga National Park (KNP), Assam, which were surveyed, adapting visual encounter method by using bike (speed limit 20±5 km/h) for a duration of 300 hours spread over 30 days (15 days in each national park) during the rainy season (July-September) in the year 2019. A total 187 road-kill individuals, representing 41 species of eight different classes were recorded from DPNP, whereas 33 road-kill individuals representing 20 different species of the six different classes were recorded from KNP. There was also a significant difference in road casualties from both the national parks, Mann-Whitney U test supported the null hypothesis ($p \leq 0.05$) wherein the different types of habitats contributed viz. forest, paddy fields, human settlements, tree plantation and tea gardens to the road kill. This study is an important attempt in terms of conservation to reduce the dearth of road-kill information from the studied protected areas of Assam.

Key words: Dehing-Patkai National Park, highways, Kaziranga National Park, road casualties, road-kill, protected area

INTRODUCTION

Importance of roads for human development, connectivity and transport is undeniable. Ullman (1956), stated that "Few forces have been more influential in modifying the earth than transportation". Roads are commonly considered as the main source of connectivity between two different landscapes, and are known to play a huge impact on wild fauna and flora and their habitats (Spelleberg, 1998). Major roads split the Earth's terrestrial surface into ~6000,000 patches, of which more than half are <1 km^2 in area, and only 7% are larger than 100 km^2 (Ibisch *et al.,* 2016). Roads are recognized as one of the most problematic and common human-caused threats towards wild populations (Forman & Alexander, 1998) causing primary and secondary effects. It is expected that at least 25 million kilometers of new roads will be built globally by 2050, a 60% increase in road lengths since 2010 (Laurance *et al.,* 2014). Ecosystems always get affected in different ways due to the trespassing roads (Van der *et al*., 1980; Forman, 1995). So, wildlife-vehicle collusions are expected to increase with time (Schwartz, Shilling, & Perkins, 2020).

The impacts of roads on wild animal populations and their natural habitats are well documented in several countries (Thos, 1938; Hodson, 1960; Hodson, 1962; Van der Zande *et al.,* 1980; Seibert & Conover, 1991; Coffin, 2007; Taylor & Goldingay, 2010; Filius *et al.,* 2020; Schwartz *et al.,* 2020; Rendall *et al.,* 2021).Vehicular road-traffic are the major cause for wildlife road-kill as the collisions with small mammals, birds, reptiles and amphibians are common, that causes direct mortality of these individuals (Hodson, 1966). Even more, the road-kill always plays a huge impact on other fauna present in the ecosystem (Spelleberg, 1998). According to Hill, Devault, & Belant(2019) globally roads are second largest source of anthropogenic mortality for many vertebrates. In case of invertebrates few studies have been undertaken in spite of their frequent mortality rate on the roads (McKenna *et al.,* 2001; Soluk, Zercher, & Worthington, 2011; Baxter-Gilbert *et al.,* 2015; Muñoz, Torres, & Megías,2015; Skórka, 2016). Roads always act as a barrier for insect communities which require the need for micro level conservation approaches towards these tiny individuals (Muñoz *et al.,* 2015; Andersson *et al.,* 2017).

There are few studies from India that report the mortality of different species due to increasing numbers of vehicles and fragmented habitats (Sundar, 2004). Most of the road-kill studies from India are for amphibia, herpetofauna and mammals (Kumara *et al.,* 2000; Vijaykumar, Vasudevan, & Ishwar, 2001; Sundar, 2004; Das *et al.,* 2007; Bhupathy *et al.,* 2011; Islam & Saikia, 2014; Mahananda & Jelil, 2017). Insect causalities are also not as well defined or reported for their conservation aspects from India (Rao & Girish, 2007; Choudhuri & Ghosh, 2009; Ray *et al.,* 2021). The

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literature on road-kill animals shows a paucity of information from the North East state of Assam, India with few studies undertaken in recent years. These include the impacts of roads on butterfly species by Choudhuri & Ghosh (2009) from lower Assam. The road-kill of reptiles was documented by Das *et al.,* (2007) from Kaziranga National Park, while Islam & Saikia (2014) studied the reptile and amphibian mortality rate from Dehing-Patkai Wildlife Sanctuary (now Dehing-Patkai National Park). There is lack of systematic study on road-kill of mammals from Assam except for a report by Mahananda & Jelil (2017). Recently, Sur *et al*. (2022) published their work on roadkill of various species of amphibia, reptiles, birds, and other small mammals from a 64 km road-stretch that passes through Kaziranga National Park (KNP) followed by another publication from the same work on specifically focusing on road-kill of two civet species (Sur *et al*., 2023). The data was collected in the year of 2016, October to 2017, September for the published work of Sur *et al.,* (2022); whereas, our study provides systematic road-kill information about various taxa for the limited time period of the year 2019.

High road-kill rate of any taxon directly impacts the food chains of the existing wild-species (Hodson, 1966; Muñoz *et al*., 2015; Andersson *et al*., 2017). Hence, we have attempted to document the road-kill of all lower and higher taxa encountered during our study period in the two national parks. In our study we have also tried to identify the taxons with the highest mortality rate based on their number and species. Our objective also includes assessing, if vehicular traffic is a cause for wildlife road kill. Further, the mortality of different taxa (both species -wise and number) in the habitats encountered is also addressed. Here we provide a glimpse of road-casualties of different taxon during monsoon season from the select road-stretches of these two protected areas based on our primary survey.

MATERIALS AND METHODS

Study area

The study was conducted on the select road-stretches, which are adjacent to two significant protected areas of Upper Assam area i.e., DPNP and KNP (Figure 1).

Dehing-Patkai National Park (DPNP) located in the Dibrugarh and Tinsukia districts of upper Assam has a state highway and a national highway. A total of 21.2 km road-stretch of State Highway 24 (Duliajan-Digboi road, from 27.396463°N, 95.605647°E to 27.317838°N, 95.419596°E) that also passes through Digboi Reserve Forest and another 15.3 km road-stretch of National Highway 38 (Lidu-Margherita road, from 27.396463°N, 95.605647°E to 27.286199°N, 95.661759°E) were surveyed during July–August, 2019 (Figure 1). The select road stretches pass through tea gardens, human habitats, paddy fields and amidst parts of forest habitats of the protected areas. The vegetation of DPNP is characterized by "Assam Valley Tropical Wet Evergreen Forest (Category 1B/C1)" (Champion & Seth, 1968). Due to this specific forest type the park is also known as "Upper Assam *Dipterocarpus- Mesua* forest" (Islam & Saikia, 2014). At the time of our study DPNP was a Sanctuary that was later notified as a National Park.

Kaziranga National Park (KNP) a well-known Tiger Reserve and Important Bird and Biodiversity Area (IBA) of India is located in Golaghat, Karbi Anglong and Nogaon districts of Assam. The National Highway 37 (NH 37) adjacent to KNP covering a total distance of

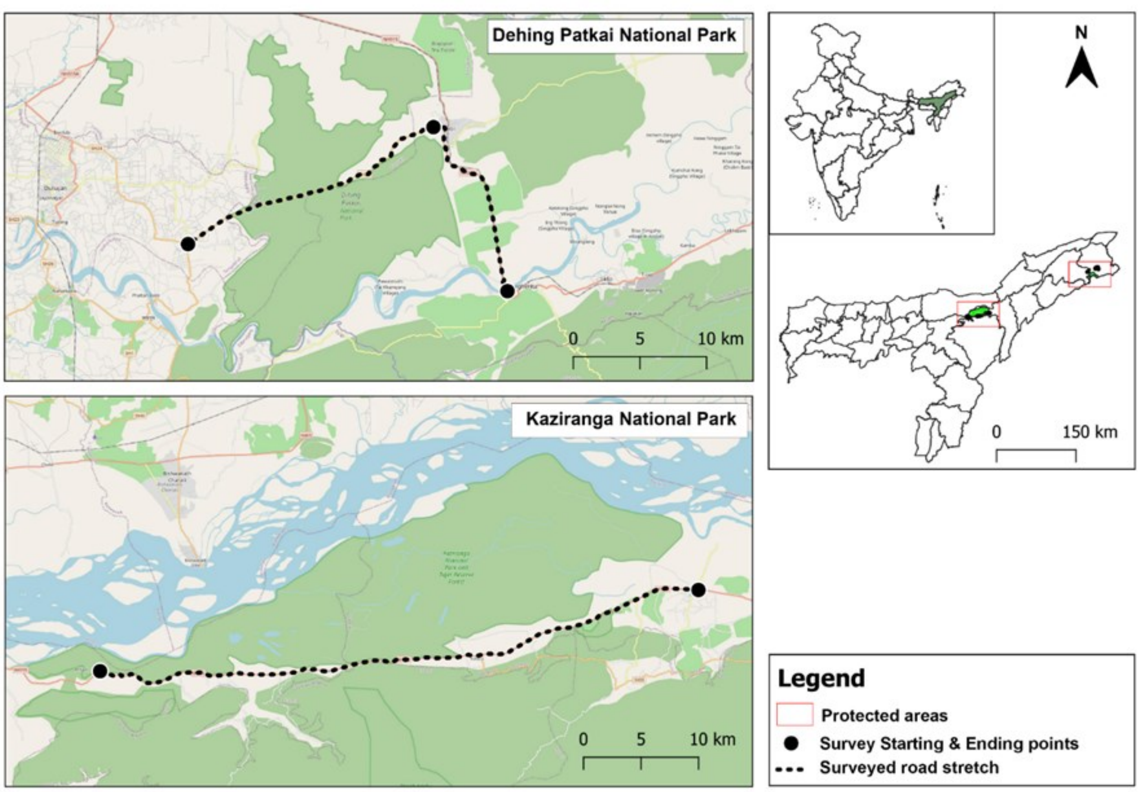

Figure 1. Surveyed road-stretches adjacent to DPNP and KNP.

55 km (From 26.640410°N, 93.603723°E to 26.577222° N, 93.082373°E) was surveyed in the month of September, 2019 (Figure 1). Moreover, the surveyed road stretch i.e., NH 37 also separates the national park from Karbi Anglong Hills on the southern side (Das *et al.,* 2007). The vegetation of KNP is characterized by "Tropical Semi Evergreen Forest" (Champion & Seth, 1968). The select road stretch passes through dominant human habitats, tea gardens, paddy fields, teak plantations besides forest habitats which were well known as animal corridors (Das *et al.,* 2007).

Field Methods

Sampling permits

The survey was carried out after obtaining permission from Assam State Biodiversity Board (Ref. no: ABB/ Permission/2012/82) and Office of the Principal Chief Conservator of Forests, Assam Forest Department (Ref. no. WL/FG.31/Pt/Technical Committee/2018) and Office order (No. 258, date: 11/01/2019).

Data Collection

We adopted the Visual Encounter Survey (VES) method described by Islam & Saikia (2014) for the survey on the select adjacent road-stretches passing by these two protected areas in Assam. Ten hours each day (morning and evening) from 4.00 to 11.00 hours and 15.00 to 18.00 hours were invested on road-kill surveys for both of the protected areas by using motorbike at a controlled speed of 20±5 km/h. We sampled for a total of 300 hours in the two protected areas during "rainy season" (July–September) when Assam also faces critical flood situations due to heavy rainfall (Das *et al.,* 2007). The road-stretches adjacent to DPNP were surveyed for 15 days in the month of July-August 2019 whereas the road-stretch of KNP was surveyed for 15 days in the month of September, 2019. The road-kill encountered were photographed using Canon 80D DSLR camera for identification and documentation while 'Compas' mobile app was used to geotag the locations. The habitat around the road-kill encountered were also documented by following Das *et al.,* (2007) and the vegetation maps given on Bhuvan portal were taken as a reference. After taking the photographs, the carrions were removed from the road using a stick and gloves and placed on the road side to avoid duplication of count.

Analytical Methods

Identification and statistical analysis

Taxonomic identification of documented road-kill animals was done by using different available field guides, books such as Grimmett, Inskipp, & Inskipp(2016) was used for avifauna identification; Ahmed, Das, & Dutta (2009) was used for reptiles' identification; Kehimkar (2016) and Shubhalaxmi (2018) were used for identification of Lepidoptera species. Authentic online species identification sites such as "Birds of India (Satos *et al.,* 2021), Reptiles of India (Khandekar *et al.,* 2021), Amphibians of India (Gosavi *et al.,* 2021), Butterflies of India (Kunte, Sondhi, & Roy, 2021), Moths of India (Sodhi *et al.,* 2021)" were also visited for confirmation of identified species. A few species (especially for reptiles and amphibians) were not identified due to highly damaged condition of the carrions, as only scraps were remaining or most of them were already flattened along with the road, hence these samples were identified up to the class level only. Checklist of road-kill taxon were prepared by incorporating their recent status in IUCN and Wildlife Protection Act (2022), carrion status (fresh/ dry) and individual numbers. The traffics volume during our study period were collected personally from the officials at the local bus counters and the forest check post. The traffic movements of the study period were represented in percentage for its influence on the documented road kill.

We used publicly available Past 4.05 and R 3.6.3 software to analyze the sampled data. Alpha diversity indices for eight different taxons from each of the national parks were calculated by using Past 4.05 software. The alpha diversity (α-diversity) indices that were measured from the road-kill individual numbers are Simpson 1-D, Shannon-H, Menhinick and Evenness_e^H/S. Sorenson's Similarity index was calculated using Excel to measure the percentage of similarities of road casualties of similar species among the two protected areas. Independent t-test was performed using Past 4.05 to compare the mean differences of road-kill taxons. To compare differences in taxa wise and habitat wise mortality from the two protected areas Mann-Whitney U test was performed using R 3.6.3 software. For Mann-Whitney U-test analysis we have compared among the number of road-kill individuals per taxa along with their class and also in the habitats i.e., forest, paddy field, tree plantation, tea gardens and human settlements where the road kill was recorded.

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The geo-tagged road-kills were plotted on the map and based on the landscape and the number of killings recorded from a particular location, the road-kill intensity heat map was prepared (Bansal, 2020). Based on the record of number of individual road-kills at a particular location the intensity ranging from 0–3, 3–5, 5 –7, 7–9, 10 and above were classified.

RESULTS

Road-kill of 220 individuals representing eight different classes, comprising of 52 different species (i.e., four mammalia, five aves, 13 reptilia, five amphibia, 21 insecta, one malacostraca, two diplopoda and one gastropoda) were recorded from the study area (Table 1).

Table 1. List of road-kill individuals from DPNP and KNP

Sl. No	Family	Species Name	Scientific Name	IUCN Status	WPA Status	Carrion Status	Encounter Frequency of Species	
							DPNP	KNP
Mammalia								
1	Bovidae	Domestic Goat	*Capra aegagrus hircus*	-	-	Fresh	1	0
2		Rodent sp.	Rodent *sp.*	-	-	Fresh	1	0
3	Falidae	Domestic Cat	*Felis catus*	-	-	Dry	0	1
4	Canidae	Domestic Dog	*Canis lupus familiaris*	-	-	Dry	0	1
Aves								
1	Accipitridae	Hawk sp.	Hawk *sp.*	-	-	Fresh, Dry	2	0
2	Corvidae	Crow sp.	Crow *sp.*	-	-	Dry	1	0
3	Sturnidae	Common Myna	*Acridotheres tristis*	LC	Schedule-II	Fresh, Dry	1	7
4	Pycnonotidae	Red-Vented Bulbul	*Pycnonotus cafer*	LC	Schedule-II	Dry	0	1
5	Columbidae	Spotted Dove	*Stigmatopelia chinensis tigrina*	LC	Schedule-II	Fresh	0	1
Reptilia								
1	Varanidae	Bengal Monitor Lizard	*Varanus bengalensis*	NT	Schedule-I	Dry	0	1
2	Typhlopidae	Blind Snake	*Argyrophis cf diardii*	-	-	Fresh	1	0
3	Colubridae	Chequered Keelback	*Fowlea piscator*	LC	Schedule-I	Fresh, Dry	3	1
4	Colubridae	Red-necked Keelback	*Rhabdophis subminiatus*	LC	Schedule-II	Fresh	1	0
5	Colubridae	Kukri	*Oligodn Sp.*	-	-	Fresh	1	0
6	Colubridae	Copper-head Trinket Snake	*Coelognathus radiatus*	LC	Schedule-II	Fresh	0	2
7	Colubridae	Bar-necked Keelback	*Fowlea schnurrenbergeri*	LC	Schedule-II	Dry	0	1
8	Pareidae	Common Slug-eating Snake	*Pareas monticola*	LC	Schedule-IV	Fresh, Dry	3	0
9	Elapidae	Lesser Black Krait	*Bungarus lividus*	LC	Schedule-II	Fresh, Dry	4	0
10	Viperidae	Viper	*Prothobatrus Sp.*	-	-	Fresh	1	0
11	Pseudaspididae	Common Mock Viper	*Psammodynastes pulverulentus*	LC	Schedule-II	Dry	1	0
12	Pythonidae	Burmese Rock Python	*Python bivittatus*	VU	Schedule-I	Fresh, Dry	0	2
13	-	Unidentified sp.	Unidentified *sp.*	-	-	Dry	4	0
Amphibia								
1	Bufonidae	Asian common toad	*Duttaphrynus melanostictus*	LC	-	Fresh	2	2
2	Dicroglossidae	Indian Bullfrog	*Hoplobatrachus tigerinus*	LC	Schedule-II	Fresh, Dry	4	1
3	Ranidae	Cope's Assam Frog	*Hydrophylax leptoglossa*	LC	Schedule-II	Dry	2	0
4	Rhacophoridae	Polypedates sp.	*Polypedates sp.*	-	-	Fresh	1	0
5	-	Unidentified sp.	Unidentified *sp.*	-	-	Fresh, Dry	11	2
Insecta								
1	Papilionidae	Red Helen	*Papilio helenus*	-	-	Dry	1	0
2	Papilionidae	Yellow Helen	*Papilio nephelus*	-	-	Dry	1	0
3	Papilionidae	Spangle	*Papilio protenor*	-	-	Dry	2	0
4	Papilionidae	Common Mormon	*Papilio polytes*	-	-	Dry	0	2
5	Pieridae	Common Grass Yellow	*Eurema hecabe*	LC	-	Fresh	0	1

6	Nymphalidae	Tawny Rajah	*Charaxes bernardus*	-	Schedule-II	Fresh	1	0
7	Nymphalidae	Dark Archduke	*Lexias dirtea*	-	Schedule-II	Dry	1	0
8	Nymphalidae	Large Yeoman	*Cirrochroa aoris*	-	-	Dry	1	0
9	Nymphalidae	Powdered Baron	*Euthalia monina*	-	-	Dry	1	0
10	Nymphalidae	Crow sp.	*Euploea sp.*	-	-	Fresh	1	0
11	Nymphalidae	Grey Pency	*Junonia atlites*	-	-	Fresh	0	1
12	Geometridae	Hill Blue Tiger Moth	*Dysphania militaris*	-	-	Fresh, Dry	68	0
13	Erebidae	Artena sp.	*Artena sp.*	-	-	Dry	1	1
14	Erebidae	Asota sp.	*Asota sp.*	-	-	Dry	2	0
15	Erebidae	Unidentified sp.	*Unidentified sp.*	-	-	Dry	2	0
16	Gomphidae	Indian Common Clubtail	*Ictinogomphus rapax*	LC	-	Dry	1	0
17	Libellulidae	Green Marsh Hawk	*Orthetrum sabina*	LC	-	Dry	2	1
18	Libellulidae	Fulvous Forest Skimmer	*Neurothemis fulvia*	LC	-	Dry	1	2
19	Acrididae	Oxya sp. 1	*Oxya sp. 1*	-	-	Dry	1	0
20	Acrididae	Oxya sp. 2	*Oxya sp. 2*	-	-	Dry	1	0
21		Unidentified sp.	Unidentified *sp.*	-	-	Dry	1	0
Malacostraca								
1	-	Crab sp.	Crab *sp.*	-	-	Fresh, Dry	3	0
Diplopoda								
1	-	Milipade sp. 1	*Milipade sp. 1*	-	-	Fresh, Dry	15	0
2	-	Milipade sp. 2	*Milipade sp. 2*	-	-	Fresh, Dry	33	2
Gastropoda								
1	-	Snail sp.	*Snail sp.*	-	-	Fresh	2	0

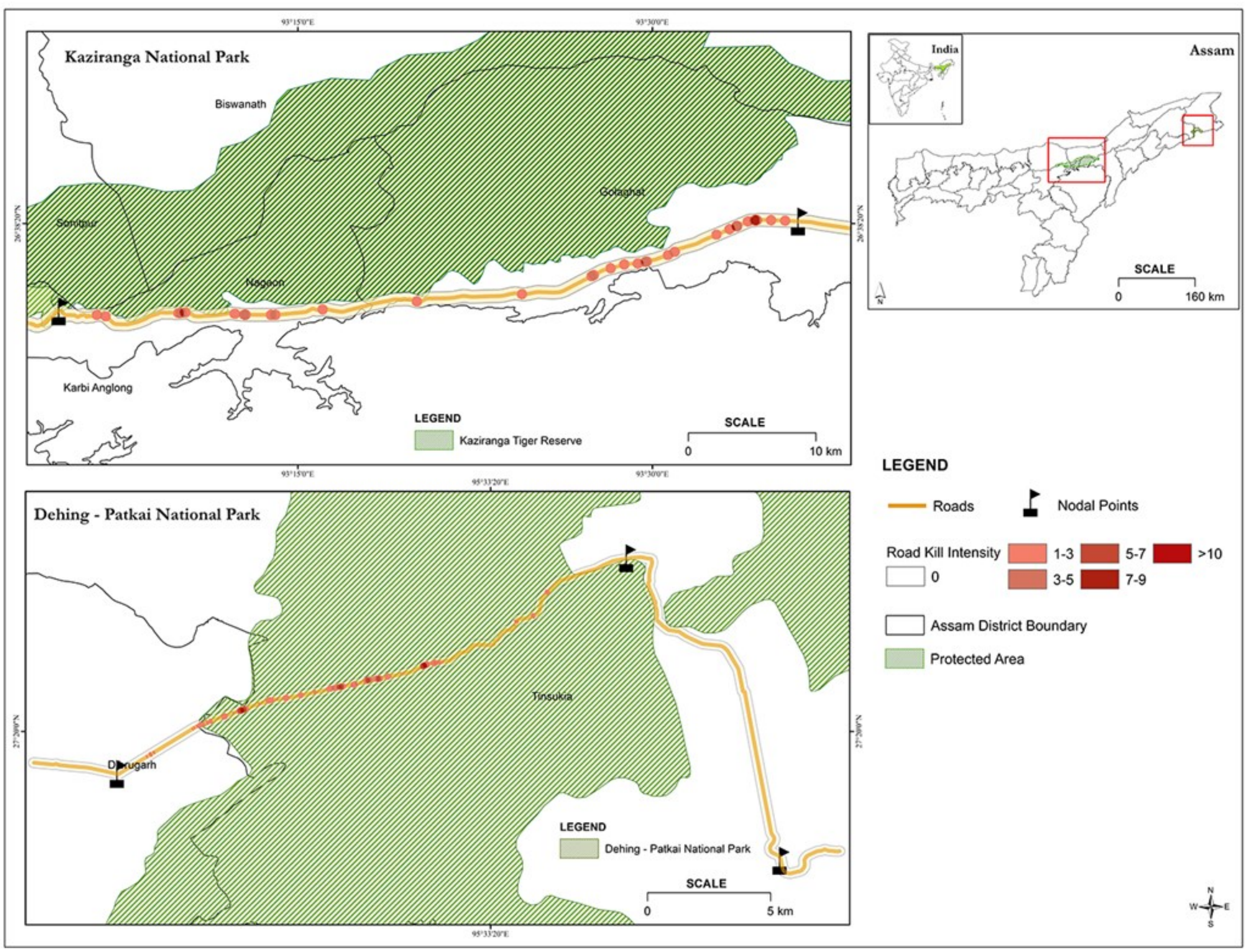

Figure 2. Total intensity of road-kill taxon in surveyed road stretches

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Among the 220 road-killed encounters, 187 individuals comprising 41 species were observed from DPNP (Table 1, Figure 2), while only 33 road-killed individuals of 20 different species were recorded from KNP (Table 1, Figure 2). Among all taxa, in DPNP, Hill Blue Tiger moth (*Dysphania militaris*) (N=68) was encountered daily in high numbers, being killed while puddling on different available food resources along the road-stretches. A high number of Common myna (*Acridotheres tristis*) (N=7) individuals were killed in KNP. Based on our observations, we plotted the intensity of road-kill on the GIS platform for both the national parks (Figure 2). Although the entire road stretch of DPNP has several road-kills, we obtained 18 hotspots along 36.5 km stretch which had high density of road-kill including all taxa. Among the hotspots, 13 were recorded in the road stretch that bifurcate the forest area, while five hotspots were in areas that were adjacent to both the forest and agriculture lands. The road-kill in DPNP was majorly contributed by moth, reptiles and amphibia followed by other taxa. We obtained only six hotspots in KNP along its 55 km road stretch with dominance of avifauna and reptile road-kill.

At DPNP, 187 road-killed individuals were dominated by class insecta (47.59%) followed by diplopoda (25.67%), amphibia (10.7%), reptilia (10.16%), aves (2.14%), malacostraca (1.6%), gastropoda (1.07%) and mammalia (1.07%) (Figure 3). These 187 individuals representing 41 species had the dominance of class insecta (43.9%) followed by reptilia (21.95%), amphibia

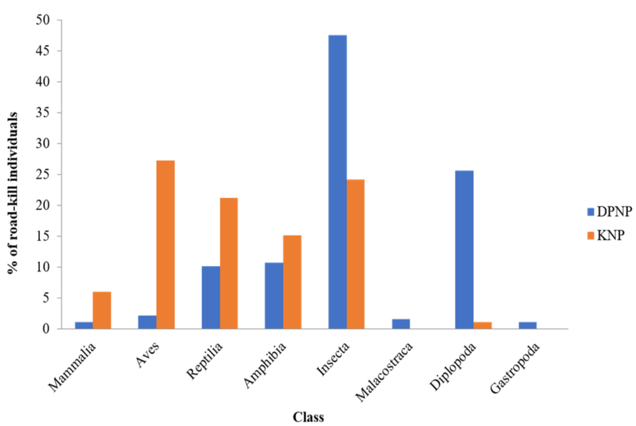

Figure 3. Abundance of road-killed individuals from the select road stretches of DPNP and KNP.

(12.2%), aves (7.32%), mammalia (4.88%), with malacostraca (2.44%) and gastropoda (2.44%) (Figure 4). At KNP, 33 road-killed individuals were dominated by class aves (27.27%) followed by insecta (24.24%), reptilia (21.21%), amphibia (15.15%), mammalia (6.06%) and diplopoda (1.07%) (Figure 3). Whereas the mortality of the 20 species was high for class insecta (30%) followed by reptilia (25%), aves (15%), amphibia (15%), mammalia (10%) and diplopoda (2.44%) (Figure 4).

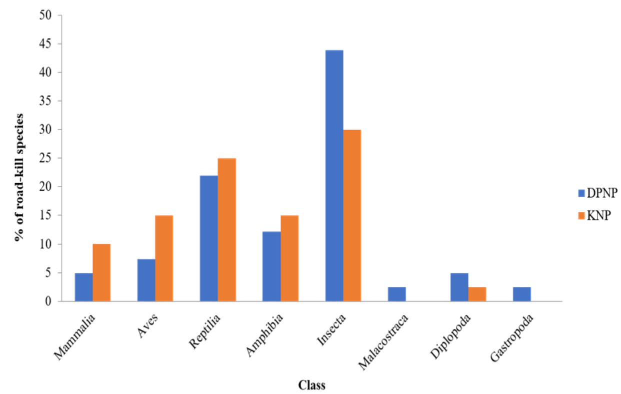

Figure 4. Percentage of road-killed species from the select road stretches of DPNP and KNP.

The alpha diversity (α-diversity) for the different road-kill taxa from two different national parks is given in Table 2. Overall, the dominance value was highest in DPNP (D= 0.177) as compared to KNP (D= 0.081) whereas, the total species diversity, species richness and evenness was highest in KNP (Shannon-H 2.79; Menhinick index 3.482; Evenness 0.814) as compared to DPNP (Shannon-H 2.52; Menhinick index 2.998; Evenness 0.303) (Figure 5). The class-wise indices reveal the species diversity index as high for class reptilia (Simpson_1-D 0.848; Shannon-H 2.014) as compared to DPNP whereas at KNP it is high for class insecta (Simpson_1-D 0.813; Shannon-H1.733). The class reptilia showed high species richness (Menhinick index 2.065) at DPNP whereas class insecta (Menhinick index 2.121) was species rich at KNP. The low evenness index of class insecta (Evenness_e^H/S= 0.185) indicates the dominance of few species at DPNP. Similarly, at KNP, the evenness was low for class aves (Evenness_e^H/S= 0.66).

Table 2. Different Alpha diversity (α-diversity) parameters estimated for road-kill individuals from DPNP and KNP

Taxon	Dominance-D		Simpson_1-D		Shannon-H		Menhinick		Evenness_e^H/S	
	DPNP	KNP	DPNP	KNP	DPNP	KNP	DPNP	KNP	DPNP	KNP
Mammalia	0.500	0.500	0.500	0.500	0.693	0.693	1.414	1.414	1.000	1.000
Aves	0.375	0.630	0.625	0.370	1.040	0.684	1.500	1.000	0.943	0.660
Reptilia	0.152	0.225	0.848	0.776	2.014	1.550	2.065	1.890	0.832	0.942
Amphibia	0.365	0.360	0.635	0.640	1.261	1.055	1.118	1.342	0.706	0.957
Insecta	0.587	0.188	0.413	0.813	1.202	1.733	1.908	2.121	0.185	0.943
Malacostraca	1.000	0.000	0.000	0.000	0.000	0.000	0.577	0.000	1.000	0.000
Diplopoda	0.570	1.000	0.430	0.000	0.621	0.000	0.289	0.707	0.931	1.000
Gastropoda	1.000	0.000	0.000	0.000	0.000	0.000	0.707	0.000	1.000	0.000

We observed a significant difference between the numbers of road casualties in the two protected areas. Further the Sorenson's Similarity Index showed only 30% similarity among road-killed taxa of the two national parks corroborating with the independent t-test (p=0.044). Mann-Whitney U-test showed that class-wise significant differences were present in class reptilia (U=166, p= 0.019) and insecta (U=160, p=0.024) which was not the case among the other taxa (Table 3) of both the national parks.

Mann Whitney U test also showed that only the mortality of class amphibia is influenced by different habitat types (U=22.5, p=0.045) as they were encountered more in habitats closer to the forest and paddy fields. But in case of other road-kill taxa there was no significant influence of habitat types in road-casualties in both the protected areas (Table 3).

Table 3. Man-Whitney U-test prepared for faunal class and habitat wise

Class	Class-wise		Habitat-wise	
	U	p-Value	U	p-Value
Mammalia	112.5	0.972	14	0.796
Aves	106.5	0.769	12.5	0.906
Reptilia	166	0.019	13.5	0.915
Amphibia	144.5	0.119	22.5	0.045
Insecta	160	0.024	14.5	0.724
Malacostraca	127.5	0.164	15	0.424
Diplopoda	129	0.262	13	1
Gastropoda	127.5	0.164	15	0.424

The vehicular movements were almost double in KNP (approx. total 540±85 per day) as compared to DPNP (approx. total 265±60 per day) which underlines on the speed of the vehicles impacting road kill (Table 4), since KNP has a speed limit for the vehicles which is not the case at DPNP.

Table 4. Approximate number of vehicles passing through the select studied roads of DPNP and KNP on a daily basis

Protected area	Bus & Truck	Four-Wheeler	Local Transports	Two-Wheeler	Total vehicles per day (Approx)
DPNP	115±15	25±15	35±10	80±20	265±60
KNP	210±10	95±30	80±15	115±30	540±85

DISCUSSION

The study brings to light the huge difference in the number of road-killed individuals and species from the

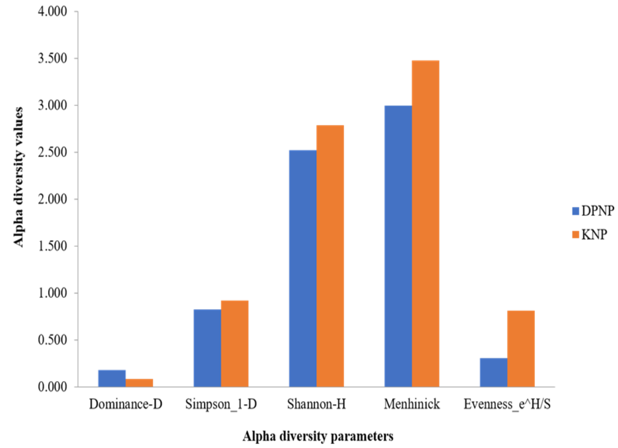

Figure 5. Comparison of Alpha diversity indices for DPNP and KNP

two protected areas of Assam, North-Eastern State of India. Filius *et al.,* (2020) who state that 'Roadkill is not randomly distributed along roads, but tend to be most frequent at certain hotspots where environmental and road conditions increase the frequency of affected organisms, or where nearby source habitat creates a steady supply of potential road-kill victims. In DPNP, road casualties were more in terms of number of individuals but less in species richness despite the highly diverse taxa in contrast to KNP. Species abundance as well as their presence in natural habitats which are closest to roads always plays an important role in road-casualties (Sundar, 2004; Rao & Girish, 2007; Andersson *et al.,* 2017). Sundar (2004), while studying the mortality of herpetofauna, birds and mammals due to vehicular traffic in Etawah District, Uttar Pradesh mentioned that the number of road-kill always depends on the species present on the roads and the number of vehicles moving through it. He also cautioned that the speed of passing vehicles is one of the important factors for which species always tend to get killed in their natural habitats. During our study we observed that apart from the number of vehicles, the speed of the vehicles played a significant role in the wildlife mortality. The roads surveyed in DPNP had very few speed breakers adding to the numbers of road-kill individuals (Figure 6). Whereas in KNP, appropriate placements of speed breakers and surveillance cameras alongside the animal corridor helped monitor the speed of passing vehicles on the national highway indirectly influencing the low rate of road-kill incidents despite the higher number of vehicles passing through it (Figure 7). Further the road-kill intensity maps also emphasize the higher number of road kill in the smaller road stretch of DPNP as compared to the longer road length of KNP.

The road-kill intensity map reflects that numbers of wildlife casualties does not depends on the length of the roads but indeed on the habitats which the road is passing by. In DPNP, surveyed road-stretch was shorter then KNP, but yet, high numbers of road-kill hotspots are present due to the presence of natural habitats on the both sides of road and abundance of taxon into the road for daily activities (Fulton *et al.,* 2008).

Figure 6. Road-kills on select road-stretches of State Highway 24 and National Highway 38 in Dehing-Patkai National Park. a. *Hawk sp*.; b. *Acridotheres tristis*; c. *Argyrophis cf diardii*; d. *Bungarus lividus*; e. *Rhabdophis subminiatus*; f. *Fowlea piscator*; g. *Pareas monticola*; h. *Duttaphrynus melanostictus*; i. *Hydrophylax leptoglossa*; j. *Hoplobatrachus tigerinus*; k. *Polypedates sp*.; l. *Euploea sp*.; m. *Charaxes bernardus*; n. *Lexias dirtea*; o. *Artena sp*.; p. *Dysphania militaris*; q. *Ictinogomphus rapax*; r. *Oxya sp.* 1.

Figure 7. Road-kills on National Highway 37 in Kaziranga National Park. a. *Stigmatopelia chinensis tigrina*; b. *Pycnonotus cafer*; C. *Acridotheres tristis*; d. *Acridotheres tristis*; e. *Python bivittatus*; f. *Python bivittatus*; g. *Coelognathus radiates*; h. *Fowlea piscator*; i. *Varanus bengalensis*; j. *Unidentified sp.*; k. *Unidentified sp.*; l. *Papilio polytes*.

Studies of insect movements show that species behaviour and abundance on roads leads to road casualties by acting as barrier for their natural movements and activities (Muñoz *et al.,* 2014; Andersson *et al.,* 2017). During our study we observed high mortality of Lepidoptera (i.e., butterflies and moths) in DPNP as compared to KNP. Occurrence of Lepidoptera species in the road-kill along the road-stretch of DPNP is associated with the availability of natural food resources (Ray *et al.,* 2021). Coffin (2007) stated the reason that the animals are killed by vehicles are driven mostly by the spatial arrangement of resources and die when they are struck trying to reach the resource (food, water, den sites, etc.). The State Highway no 24 passes through the protected area is also an "Elephant Corridor", which had excess elephant dung for Lepidoptera species to puddle in groups that resulted in their mortality. Other than the elephant dung, in DPNP, moths were encountered feeding on a variety of resources present on the roads such as dead reptiles, crushed crabs and snails, corroborating with the observations for the same by Choudhury & Ghosh (2009).

Other than food availability the temperature plays an important role in the occurrence and mortality of reptiles along the man-made roads. Observed 13 species from the different habitat types of the two protected areas, nine species were recorded from DPNP while KNP has the road kill of five species. The prominent species killed in DPNP were Lesser Black Krait (*Bungarus lividus*), Checkered Keelback (*Fowlea piscator)* and Assam Snail-eater (*Pareas monticola*) (Table 1). In addition to snakes, a Bengal Monitor Lizard (*Varanus bengalensis*) was also recorded from KNP. Reptiles encountered were mostly found killed on roads closer to their natural habitats i.e., forest or paddy fields in both the protected areas. Reptiles being cold blooded animals use roads for thermoregulation (Kumara *et al.,* 2000; Das *et al.,* 2007), further slow movements in front of high-speed vehicles result in the road causalities (Hodson, 1966; Kumara *et al.,* 2000; Das *et al.,* 2007; Islam & Saikia, 2017). In our study also we observed high temperature and rainfall to have a positive impact in increasing number of road-kill taxa (Table 4).

The relatively slow movement of amphibian species in regards to the vehicles speed becomes the main reason for their mortality on the road while crossing (Sundar, 2004; Islam & Saikia, 2017). Amphibians are known to be more active during the monsoon which also increases the rate of their mortality (Islam & Saikia, 2017; Khandekar *et al.,* 2020). Indian Bullfrog (*Hoplobatrachus tigerinus)* was the most commonly killed amphibian in both the protected areas. Although, the identification of amphibians killed on road was most difficult as the carrions would be mostly in flattened condition. The numbers directly relate to the presence of supportive natural habitats for the amphibian species. Road-killed amphibian species were encountered more closely to paddy fields and forest habitats than human settlements. In our study, the DPNP has roads that are closer to the paddy fields and forest area resulting in higher amphibian mortality as compared to KNP.

Avian species come down to the road to feed on insects, seeds or some carrion which as a consequence result in road-kill (Hodson, 1962; Sundar, 2004; Rytwinski & Fahrig, 2012). The road-kill avian species were recorded as the insectivores, granivores, predators and scavengers. Among the five road-kill avian species, Common Myna (*Acridotheres tristis)* was found in both protected areas. Numerically, KNP had highest avian road-kills as compared to DPNP, which we attribute to higher traffic on NH 37. The road-kill of Common Myna (*Acridotheres tristis)*, which is an insectivore species, were recorded after rains or on a clear sky during the early morning. The road-kill of Hawk species found in highways of DPNP was associated with the presence of live amphibians/reptiles or small birds present on the road. While the scavenging species like common crow would get hit by vehicles as it feeds on available carrions on roads.

During the study we observed the presence of elephants and spotted deers from the protected areas. However, it was mostly domestic/stray mammals that were encountered occasionally on the roads as carrions. This can be attributed to the high incidence of these species in the study area is indicative of their local abundance and their ability to use the road side habitat. Road-kills of class malacostraca, class diplopoda and class gastropoda were dependent on their abundance in the surrounding areas which we can directly observe in DPNP with significantly low numbers in KNP. Although, road-kill numbers of any lower taxa are also significant as it highlights the impact of roads on the changing microhabitats (Muñoz *et al.,* 2014; Andersson *et al.,* 2017).

Significant numbers of road-kill individuals from various taxa in both of the national parks remained "unidentified" (N=20) due to their poor carcass conditions, a few of them identified only up to their genus level (N=69). It also holds a specific scope for conducting future research work for the identification of road-kill species by using different available molecular tools.

CONCLUSION

The direct mortality of animals due to vehicle collisions is a primary and obvious effect that reduces animal populations. Forman & Alexander (1998) refer to the consequences of roads affecting the biotic and abiotic components of landscapes by changing the dynamics of populations as "sleeping giant of Conservation Ecology". This study provides an overall scenario of wildlife road-kill from the two highly significant national parks of Assam. Vehicles with control speed can always be very helpful for preventing the wildlife casualties which also been reported to be effective by our study. Moreover, controlling the vehicular speed by increasing numbers of present speed breakers as well as proper monitoring of the road-kill casualties with surveillance camera in the both of the national parks are recommended for the future prevention of these incidents. The study also brings to light the impacts of changing habitat effects on the wildlife. The impacts of population loss of the encountered road-kill taxa from the surrounding habitat remains unknown, Spellerberge (1998), opined that however small the impact is; species specific effects of road-kills on small groups of population are always undeniable. Hence more systematic and rigorous studies are needed to fill up the dearth of knowledge in context to road-kill species from Assam.

AUTHOR'S CONTRIBUTION

Field works were done by Swapna Devi Ray. Permissions were coordinated by Ram Pratap Singh, P. Pramod, Swapna Devi Ray and manuscript was prepared by Swapna Devi Ray, Goldin Quadros, Ram Pratap Singh. The logistics and funding were arranged by Ram Pratap Singh. The manuscript was reviewed by all the authors.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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