Assessment of Impacts of National Highway 715 (Earlier NH 37) on Wildlife Passing through Kaziranga Tiger Reserve, Assam

2020

ECOLOGICAL IMPACT ASSESSMENT OF EXISTING AND PROPOSED ROAD INFRASTRUCTURE ON IMPORTANT WILDLIFE CORRIDORS IN INDIA FOR STRATEGIC PLANNING OF SMART GREEN INFRASTRUCTURE

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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Contents

Executive Summary

As part of the project funded by the National Tiger Conservation Authority, New Delhi, three sites were chosen for study- the Central Indian tiger landscape including major roads cutting across the animal corridors in the landscape, the National Highway 37 (now 715) cutting through the Kaziranga-Karbi Anglong landscape in Assam, and the State Highway 33 passing through the Nagarhole Tiger Reserve, Karnataka.

At Kaziranga National Park, we intended to quantify the characteristics of mortality of animals due to wildlife-vehicle collisions, and to assess the responses of wild ungulates to road-related disturbances in terms of changes in group size and composition, and habitat use patterns. Result shows that highways have adverse effects on the population of wildlife including endangered species of mammals and reptiles. Seasonal or monthly changes are the factors that influenced probability of roadkill numbers as it increased with the onset of summer and decreased towards winter.

Annual monsoon floods in Kaziranga National Park from adjacent Brahmaputra River was found to be the main factor influencing large mammal mortality in wildlife-vehicle collisions. Apart from the direct impacts of roads on wildlife the indirect impacts like noise and disturbances associated with them impact significantly on the species that require an undisturbed or interior habitat. Similarly, present study exhibits variation in the group size composition of ungulates relative to distance from road. Group-size increased with respect to distance which indicates that anthropogenic effects of roads can lead to the habitat fragmentation of such species affecting population distribution. However, numbers and factors of wildlife-vehicle collisions may vary with site and condition.

1. Introduction

Linear infrastructure particularly roads form the basis for the development of any region or country as it is the primary way of connecting people. Roads are the means of commerce between places. But roads or linear infrastructure has emerged as one of the main factors that contribute to the fragmentation, degradation and habitat loss of natural landscapes. Increase in road network is associated with any developmental activity. Thus, Biodiversity conservation has emerged as a challenging role in India as extensive roads cut across many of India's precious natural landscape units comprising of protected areas, tiger reserves and vital habitats outside PAs and lead to fragmentation of the wild habitats, endangering many of the species. Wildlife road mortality caused by the collisions with vehicles on the roads that traverses through their habitats is the most obvious effect on the wildlife populations. Although road mortality usually has minimal effects on population viability (Forman 1998, Forman and Alexander 1998), particularly for abundant species with high reproductive rates (Glista et al. 2007), it can be detrimental for wide-ranging species with low population densities and reproductive rates (reviewed by Fahrig and Rytwinski 2009).

Roads have dramatically increased during the past few years both in natural and urban areas for better transportation. Wherever roads and wildlife habitats overlap roadkill seems inevitable. Mammal populations are now mostly fragmented and isolated. Individuals need to cross wide open road segments between habitats getting exposed to risks (Nilton et,al.). Road mortality can be especially limiting for large carnivores, with demonstrated detrimental effects on tigers (*Panthera tigris*), and leopards (*Panthera pardus*; Baskaran and Boominathan 2010, Joshi 2010), African hunting dogs (*Lycaon pictus*; Drews 1995), Florida panthers (*Felis concolor coryi*; Foster and Humphrey 1995), and grizzly bears (*Ursus arctos*; Waller and Servheen 2005). The areas linking protected areas are also important from the point-of-view of maintaining connectivity between them for maintaining viable populations of endangered species of flora and fauna.

India being one of the mega diverse countries with about 4.88% of its geographical area demarcated as protected for wildlife preservation (WII Envis 2015) harbours many endangered species in higher densities within the Protected Areas (PAs), where the roads are the most pervasive forms of linear features that traverse through the entire length and breadth of the country. India has a network of over 5,603,293 kilometres (3,481,725 mi) of roads as of 31 March 2016. This is the second-largest road network in the world, after the United States with 6,702,178 kilometres (4,164,540 mi). At 1.70 kilometres (1.06 mi) of roads per square kilometre of land, the quantitative density of India's road network is higher than that of Japan (0.91 km, 0.57 mi) and the United States (0.99 km, 0.62 mi), and substantially higher than that of China (0.46 km, 0.29 mi), Brazil (0.18 km, 0.11 mi) and Russia (0.08 km, 0.050 mi).

It can be predicted that many wildlife populations would be threatened in the near future and one of the factors causing it would be the establishment of linear infrastructure. Thus, there is a need of studying the ways roads are affecting wildlife for powerful mitigation of such. Observing and recording the carcasses resulting from wildlife-vehicle collisions can provide critical data for strategic planning of infrastructures based on the type of wildlife being affected.

2. STUDY AREA

Kaziranga National Park being a World heritage Site and Tiger Reserve is the breeding ground of elephants, wild water buffalo, and swamp deer along with the iconic Greater one-horned rhinoceros. Also, the park is recognized as an Important Bird Area by BirdLife International for the conservation of avifaunal species. The sanctuary is blessed with the four different kinds of vegetation. The Tropical moist mixed deciduous forests and tropical semi-evergreen forests is marked by the 41% of the tall grasses, 29% open jungle, 11% short grasses and rest is covered with the rivers and the water bodies.

The Brahmaputra River circumscribes the park and is responsible for the annual flooding and submergence of three-fourths of the western region of the park. This causes the animals to migrate to elevated and forested regions outside the southern border of the park, such as the Karbi Anglong Hills. In the past, the forests of these hills and the grasslands of Kaziranga national park formed one single connected ecological unit, with very few human habitations. In recent years, the national highway 715 (earlier NH 37) that runs parallel to the southern boundary of the park (Figure 1), has opened up the area on the southern side to tea planters and settlers, and due to this the forest cover has diminished and caused fragmentation of the habitats connecting the park and the Karbi Anglong hills. The traffic on the 54 km stretch of highway acts as a barrier to animals moving from the park to the Karbi Anglong hills during the monsoon, and have also resulted in accidents with vehicles. This has affected the natural movement of animal communities between grasslands and woodlands in the landscape to avoid floods as well as to forage and for other life processes.

The area of focus for the proposed study would represent the following wildlife corridors through which NH 715 (Earlier NH 37) passes:

i. Panbari Corridor
ii. Haldhibari Corridor
iii. Bagori Corridor
iv. Harmoti Corridor
v. Hatidandi Corridor
vi. Kanchanjuri Corridor
vii. Deosur Corridor
viii. Chirang Corridor
ix. Amguri Corridor

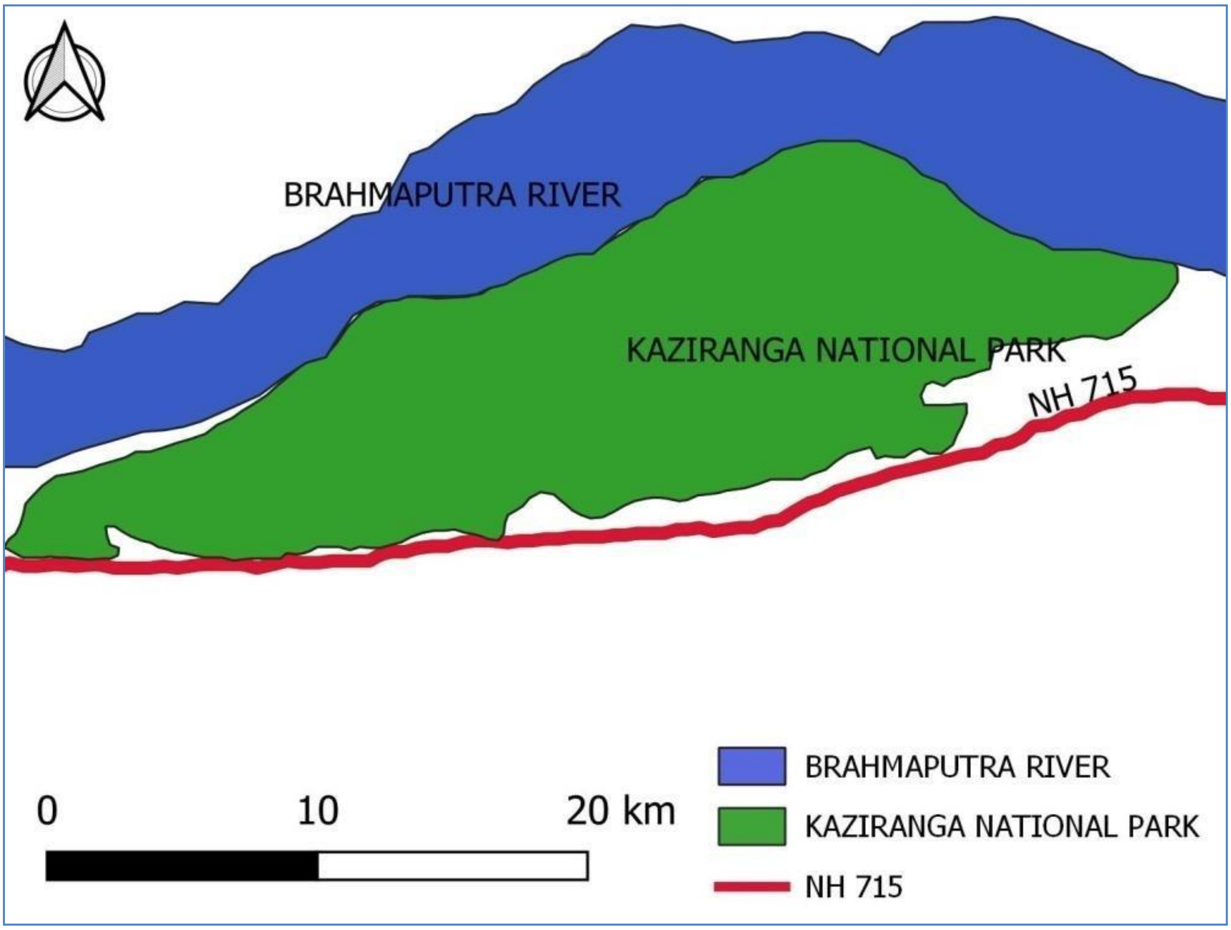

Figure 1: Map showing NH 715 (earlier NH 37) traversing through Kaziranga-Karbi-Anglong Landscape.

3. OBJECTIVES

This study aims to identify the ecological impacts of NH 715(earlier NH 37) on the animal movement corridors for the strategic planning of smart-green infrastructures in the Kaziranga- Karbi Anglong landscape in Assam.

Following are the broad objectives of the proposed study:

i. Quantify wildlife-vehicle collision occurrences on NH 715 (earlier NH 37) that passes through the Kaziranga-Karbi Anglong landscape and evaluate temporal variation in wildlife- vehicle collisions.

ii. Identify wildlife –vehicle collision hotspots in NH 715.

iii. Assess the persistence and detectability of roadkill on NH 715.

iv. Assess the response of wild ungulates to NH 715 by assessing variation in ungulates group size and composition along NH 715.

v. Determine the habitat use pattern of wildlife with respect to vegetation availability type and other disturbance factors in the nine corridors through which NH 715 passes

4. METHODS

Field methods:

To quantify the direct impacts of road on wildlife the number of animal mortality (roadkill) that occurred due to wildlife-vehicle collision on the 54 km Stretch of Highway (NH 715) that passes through the Kaziranga-Karbi Anglong Landscape were recorded. Surveys were done at dawn and dusk over a two-wheeler vehicle at 30-40 kmph for 5 days a week from January-October, 2019. In addition, data were also collected during incidental visits and based on information received from other researchers, or Forest Staff and local people. At every sighting of a roadkill information such as GPS location, topography, habitat and taxonomic classification of the carcass up to species level along with the condition were recorded. Photographs of the carcasses from every possible angle were taken for future identification of the said.

Several factors affect availability of wildlife roadkill, including carcass decomposing rate, the time interval between occurrence and monitoring of roadkill, weather and other environmental factors etc. To get an insight of the roadkill persistence time, every roadkill encountered were not removed from the road. The duration of survival or availability of the carcass on the roads were recorded every 12 hour while surveying for road-kills. Carcass persistence varies with taxonomic class. Some gets removed by the number of vehicles passing through roads, some gets removed by scavengers and some persists for days in an identifiable condition.

Observer experience might also affect carcass detectability i.e. the probability of a carcass being detected. In order to evaluate biasness in carcass detectability the selected study routes were surveyed by two different observer teams. The surveys were done by two different observer teams independently over a two-wheeler motor-bike (one observer, one driver), with one team starting survey 20 minutes later than the other to avoid visual contact between both the teams surveying at 40 kmph. Surveys were conducted along the 54 km stretch at dawn and dusk for a period of 3 months within the study period and data such as GPS location, species, and zone were recorded to avoid double counts and for further analysis of detectability of the two teams.

For assessing the effects of NH715 on the grouping pattern of wildlife, the group size composition and distance of groups to the road of frequently detected ungulates were recorded. If noticed any, data such as number of individuals of the species along with the sex, and distance of the group from the Highway and from cover are also recorded with a handheld Range finder along with the vegetation type. Location is recorded with a Garmin GPS. As data were recorded for a group, sampling was done in a direction approximately parallel to their original course. Information was recorded for the following ungulate species: Hog Deer, Sambar Deer, and Barking Deer.

Distribution of wildlife near roads might depend on the disturbance from road related factors such as noise and also on preferred habitat availability types. To understand the probabilities, randomly selected 10 m^2 plots adjacent to highway in the nine corridors were studied. Within the selected plots presence of vegetation (Herbs, Shrubs, Trees cover), Ungulate pellet (or other animal sign) and noise were recorded.

Analytical methods:

Quantification of wildlife-vehicle collision (roadkill) numbers were analyzed including classification of collisions based on taxonomic classes for mean, median and the frequency of occurrences. Other analyses were done using GraphPad Prism 8 Software and QGIS 3.4.

a. Quantification of wildlife-vehicle collisions:

Abundance of wildlife-vehicle collision numbers varied with months. Chi square goodness of fit test was used to calculate temporal (monthly) differences in frequency of total wildlife road mortality and also differences in frequency of each taxonomic category between months.

Chi-Square goodness of Fit: Chi-Square goodness of fit test is a non-parametric test that was used to find out how the number of wildlife vehicle collisions occurring each month is significantly differed from the expected value between months

$$\chi^2 = \left[\frac{(O-E)^2}{E}\right]$$

Where, χ^2 = Chi-Square goodness of fit test O= observed number, E= expected number.

b. Identification of wildlife-vehicle collision hotspots

The frequency of occurrence of collisions varied with locations. Kernel Density estimation method was used to identify Wildlife Vehicle collision hotspot along the 54 km stretch of Highway using QGIS 3.4. The width of the kernel function used (i.e. the area of influence of each kernel function, or bandwidth) choosen for the present work was 500 m.

c. Assessment of persistence and detectability of roadkill on NH 715

The duration of carcass persistence on road was estimated using Kaplan-Meier estimator (Percent Survival) in GraphPad Prism 8 Software. The Log-rank (Mantel-Cox) value and Gehan-Breslow- Wilcoxon test values were used to verify differences in the median of carcass persistence probabilities in different taxonomic groups. Percent Survival curve was used to show differences in the median of persistence probabilities of classes.

The Kaplan–Meier estimator also known as the product limit estimator (Kaplan and Meier, 1958), is a non-parametric statistic used to estimate the survival function from lifetime data. The survival function is-

$$S(t_i) = \prod_{t_i \le t}\left(1 - \frac{d_i}{n_i}\right)$$

-where t= observed times, d=number of events at time t and n=number of survivors at time t.

d. Detectability

The bias in detectability were estimated by evaluating differences between carcass numbers encountered by the two observer teams. Students paired t-test was used for evaluating significant differences.

Paired t-test: A parametric test, the paired t test provides a hypothesis test of the difference between population means for a pair of random samples whose differences are approximately normally distributed. The test statistic is calculated as:

$$t = \frac{\bar{d}}{S_d / \sqrt{n}}$$

where d bar is the mean difference, sd is the sample variance, n is the sample size and t is a Student t quantile with n-1 degrees of freedom.

e. Variation in ungulate group-size and composition

Distance data were positively skewed with unequal variance, therefore data on individual observations were analysed with non-parametric statistics. Animals within a group were considered non-independent; therefore only one distance value was calculated for each group. The differences in the mean of group sizes with the distances to roads were calculated using Kruskal Wallis Test. Only species which had more than 15 observations were analyzed. This includes Hog Deer.

Kruskal Wallis Test: The Kruskal Wallis test is the non-parametric alternative to the One Way ANOVA. Non parametric means that the test doesn't assume your data comes from a particular distribution. The test determines whether the medians of two or more groups are different. Here the distance of each groups of ungulates from the road with group-size composition were used to evaluate significant differences among them using test statistic-

$$H = \left[\frac{12}{n(n+1)} \sum_{j=1}^{c} \frac{T_j^2}{n_j} \right] - 3(n+1)$$

where n = sum of sample sizes for all samples, c = number of samples, T = sum of ranks in the sample, n = size of the sample.

f. Variation in habitat use patterns of wild ungulates

The habitat use pattern of areas adjacent to highway in the nine corridors by wildlife which were studied by ungulate pellet (or other animal sign) presence were analysed using Logistic Regression. Logistic Regression is part of a larger class of algorithms known as Generalized Linear Model (glm). Logistic Regression is a very powerful statistical tool when the analysis contains dependent variable that is binary or dichotomous in nature (i.e. it can take only two values). The independent variable can be either continuous or categorical in nature. The response variable thus takes the value 0 or 1. Binomial logistic regression first calculates the odds of the event happening for different levels of each independent variable, and then takes its logarithm to create a continuous criterion as a transformed version of the dependent variable.

5. RESULTS

a. *Quantification of wildlife-vehicle collisions on NH 715*

A total of 1176 wildlife roadkills were recorded along the study route between Jan-Dec, 2019. Among the 1176 roadkill observed, reptiles were the most affected accounting for 50%, followed by birds 35%, small mammals 11%, and large mammals 3.48% (Table 1). Amphibians were the least affected at 0.85%. Out of the total species recorded, Common Myna (*Acridotheres tristis*) (n=202) was the most recorded species of roadkill followed by House Mouse (*Mus musculus*) (n=99), Painted Bronzeback Tree Snake (*Dendraphilus pictus*) (n=52), Hog deer (*Axis porcinus*) (n=35), Buff Striped Keelback (*Amphisma stolatum*) (n=35) (Table 2). Vehicles killed threatened animals belonging to reptiles and mammals like Hog Deer *(Axis porcinus*) (n=35), Sambar Deer (*Rusa unicolor*) (n=1), Slow Loris (*Nycticabeus bengalensis*) (n=1), Capped Langur (*Trachypithecus Pilatus*) (n=2) , Burmese Python (*Python bivittatus*) (n=8), Spotted pond turtle (*Geoclenys hamiltonni*) (n=3), Indian Soft- shelled Turtle (*Nilssonia gangetica*) (n=1) and rare Eastern Cat Snake (*Boiga gokul*) (n=10) (Figure 2). A total of 402 individuals of the total roadkill recorded were identified up to class level but not to species level (Table 2).

Table 1: Summary of roadkill among different animal classes on NH 715

Class	*Number of roadkill*
Amphibia	10
Bird	411
Large mammal	41
Reptile	585
Small mammal	129
Total	**1176**

Table 2: List of species and number of each taxonomic category found in wildlife-vehicle collisions

Species	Scientific name	Number of occurrences
Birds		
Asian Barred owlet	*Glaucidium cuculoides*	1
Black Headed Oriole	*Oriolus xanthornus*	2
Cattle Egret	*Bubulcus ibis*	1
Common Hoopoe	*Upupa epops*	1
Common Myna	*Acridotheres tristis*	202
Black Drongo	*Dicrurus macrocercus*	1
Greater Coucal	*Centropus sinensis*	1
House Sparrow	*Passer domesticus*	4
Indian Roller	*Coracias benghalensis*	2
Jungle Myna	*Acridotheres fuscus*	20
Red Vented Bulbul	*Pycnonotus cafer*	34
Spotted Dove	*Spilopelia chinensis*	1
Stork Billed Kingfisher	*Pelargopsis capensis*	1
White Breasted Waterhen	*Amaurornis phoenicurus*	14
Black-Rumped Flameback WoodPecker	*Dinopium benghalense*	1
Pigeon	*Columba livia domestica*	2
Owlet (Unidentified)		11
Bird(Unidentified)		113
Reptiles		
Banded krait	*Bungarus fasciatus*	11
Black Krait	*Bungarus niger*	1
Buff Striped Keelback Snake	*Amphiesma stolatum*	36
Burmese Python	*Python bivittatus*	8
Checkered Keelback Snake	*Xenochrophis piscator*	6
Common Wolf Snake	*Lycodon capucinus*	2
Copper Headed Trinket Snake	*Coelognathus radiates*	22
Eastern Cat Snake	*Boiga gokool*	14
Indian Rat Snake	*Ptyas mucosa*	1
Indian Water Snake	*Cerberus rynchops*	4
Indo-Chinese Rat Snake	*Ptyas korros*	2
Ornate Flying Snake	*Chrysopelea ornate*	12
Painted Bronzeback Tree Snake	*Dendrelaphis pictus*	52
Red Necked Keelback Snake	*Rhabdophis subminiatus*	10
Red Tailed Pit Viper	*Trimeresurus erythrurus*	2
White Lipped Pit Viper	*Trimeresurus albolabris*	2
Water Monitor Lizard	*Varanus salvator*	1
Bengal Monitor Lizard	*Varanus bengalensis*	1
Spotted Pond Turtle	*Geoclemys hamiltonii*	3
Indian Softshell Turtle	*Nilssonia gangetica*	1

Turtle(Unidentified)		1
Lizard(Unidentified)		25
Snake(Unidentified)		363
Mammals		
House Mouse	*Mus musculus*	99
Jungle Cat	*Felis chaus*	4
Leopard Cat	*Prionailurus bengalensis*	1
Slow Loris	*Nycticebus bengalensis*	1
Hoary Bellied Squirrel	*Trachypithecus pileatus*	2
Rhesus Macaque	*Macaca mulatta*	2
Capped Langur	*Viverricula indica*	3
Sambar	*Rusa unicolor*	1
Hog Deer	*Axis porcinus*	35
Small Indian Civet	*Viverricula indica*	2
Shrew (Unidentified)		1
Squirrel (Unidentified)		9
Small Cat(Unidentified)		8
Bat(Unidentified)		4
Frog(Unidentified)		8
Toad(Unidentified)		2

Temporal variation in roadkill occurrence

A significant variation in the frequency of occurrence of wildlife-vehicle collisions between months was examined by chi-Square test(χ^2=376.4, df=11, $P<0.0001$) during the study period with highest number of record in August, followed by July (flooding month), November, October, June, September. January being least susceptible for wildlife vehicle collisions (See Table 3, Figure 3).

Table 3: Month-wise variation in roadkill on NH 715

Month	Number of roadkill
January	5
February	9
March	26
April	21
May	66
June	143
July	177
August	224
September	107
October	149
November	180
December	69
Total	**1176**

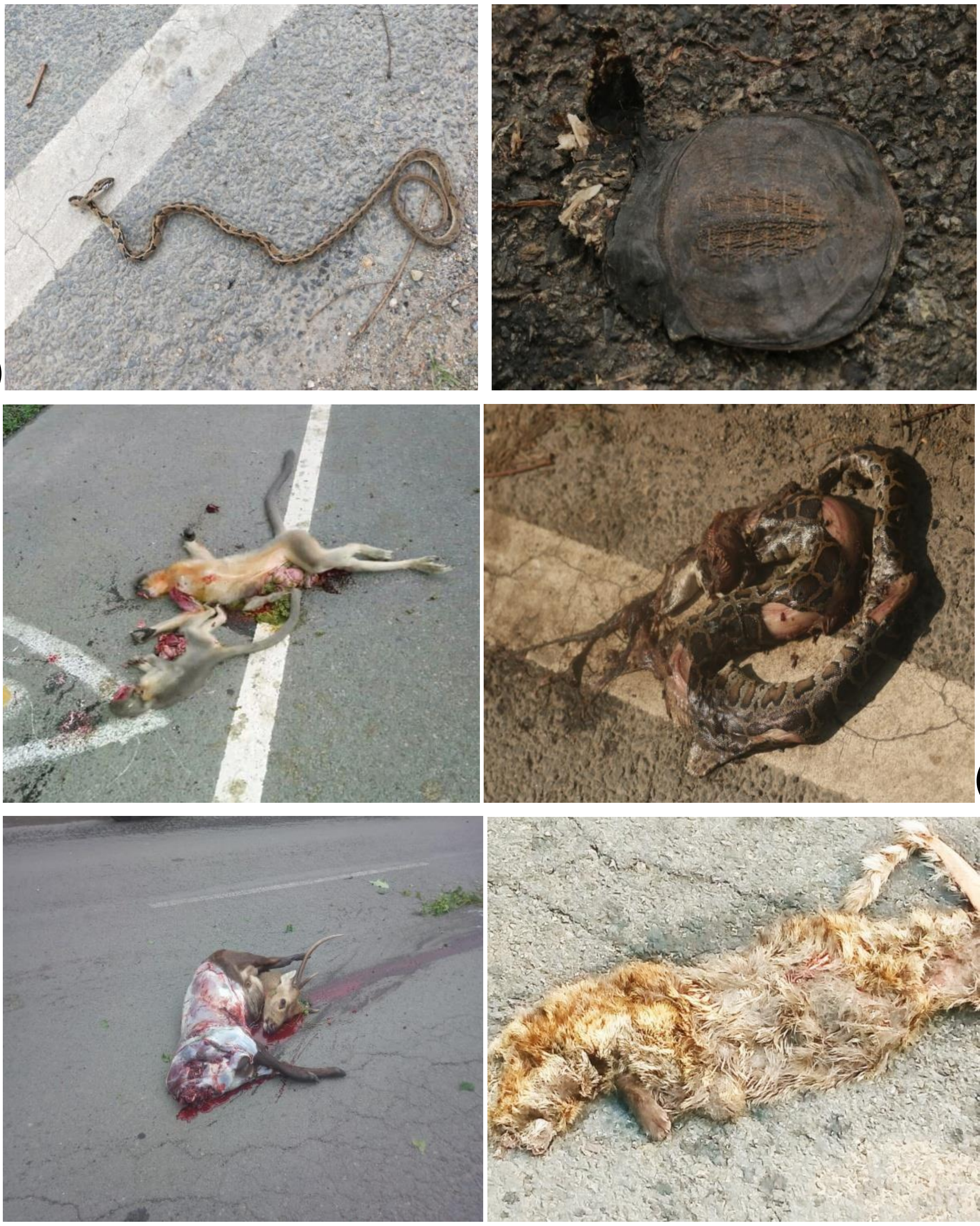

Figure 2: Images of the roadkills of some rare species of reptiles and mammals recorded on NH 715: (a) Eastern Cat snake (*Boiga gokul*) (b) Indian Soft-Shelled Turtle (*Nilssonia gangetica*) (c) Capped Langur (*Trachypithecus pilatus*) (d) Burmese Python (*Python bivittatus*) (e) Hog Deer (*Axis porcinus*) (f) Jungle Cat (*Felis chaus*).

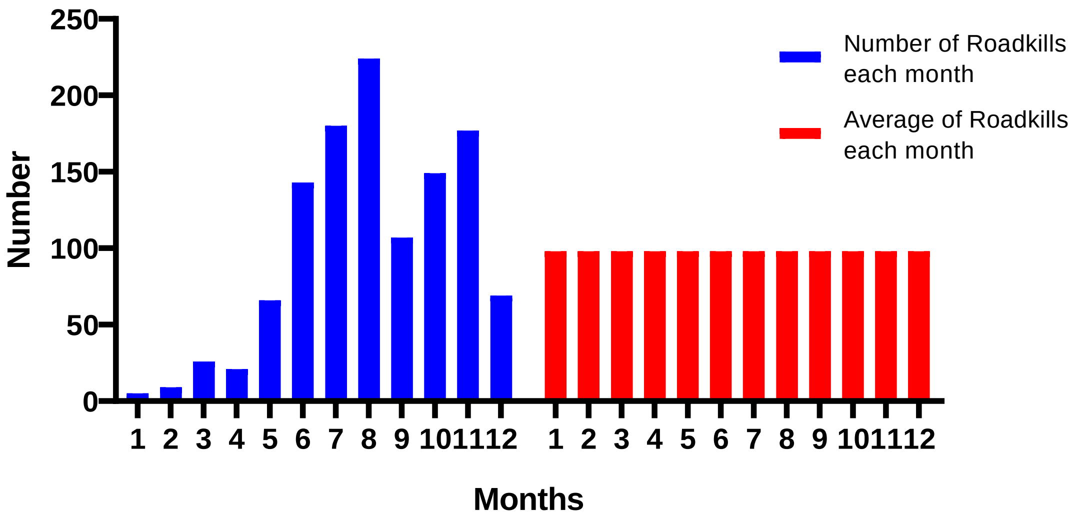

Figure 3: Number of monthly occurrence of wildlife-vehicle collisions. August had the highest frequency of roadkill and January the least.

The monthly differences in the relative frequencies of occurrence of wildlife-vehicle collision for the taxonomic groups were statistically significant for reptiles ($\chi^2 = 249.4$, df = 11, $p < 0.0001$) that occurred the most on August and July, followed by birds ($\chi^2 = 120.8$, df = 11, $P < 0.0001$) that occurred mostly on August. Small mammals ($\chi^2 = 68.08$, df = 11, $P < 0.0001$) occurred the maximum on November and large mammals ($\chi^2 = 21.14$, df = 11, $P = 0.0320$) occurred the most on July (annual flood) and due to the less encounter in amphibian roadkill, monthly variation could not be analysed (Table 4, Figure 4).

Table 4: Mean, max and standard deviation of the number of wildlife-vehicle collisions of each taxonomic classes between months.

Class	Mean	Max	S.D.
Amphibia	0.83	3	1.193
Bird	34.25	73	25.69
Large Mammals	3.416	14	4.31
Reptile	48.75	129	43.76
Small Mammals	10.75	40	2.40

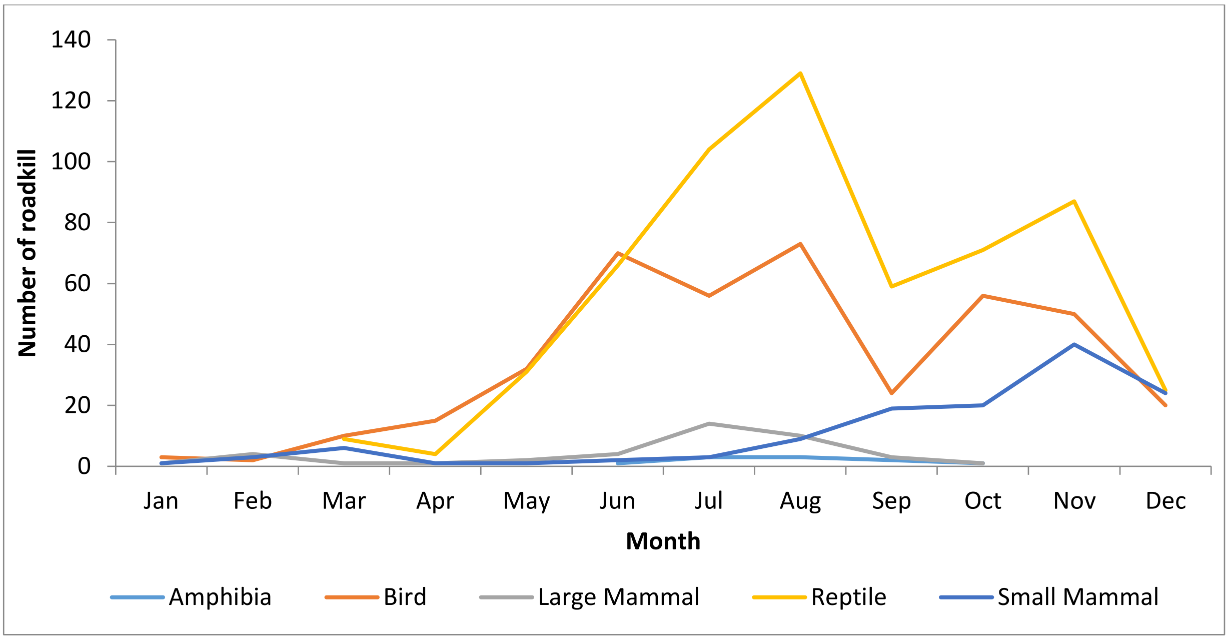

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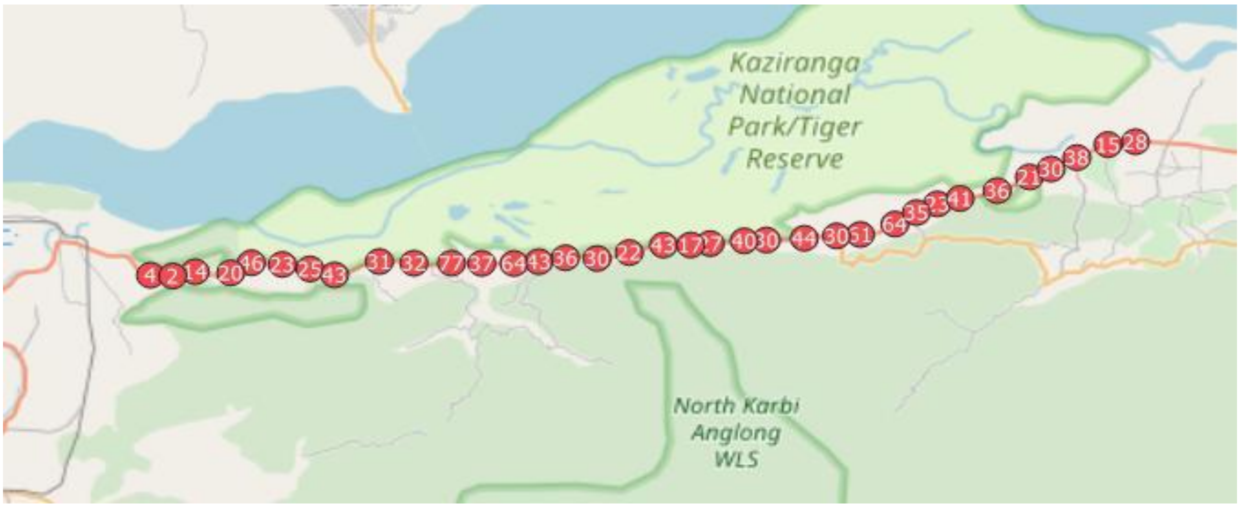
Figure 4: Variation in monthly occurrence of wildlife-vehicle collision of amphibian, bird, large mammal, reptile and small mammal species on NH 715.

b. Identification of wildlife-vehicle collision hotspots on NH 715

Roadkill encounter number varied within the nine designated wildlife corridors of NH715 (Figure 5). Highest numbers of roadkill were recorded at Haldhibari corridor (n=123), followed by Kanchanjuri corridor (n=83), Panbari corridor (n=60), Deosur corridor (n=50), Chirang corridor (n=49), Amguri corridor (n=40), Harmoti corridor (n=34) and lowest at Hatidandi and Bagori corridor (n=29).

Roadkill hotspots among different animal classes were also discernible from the data (Figure 6). While reptile and bird roadkill hotspots were spread evenly across the study route, small and large mammal roadkill hotspots were concentrated.

a)



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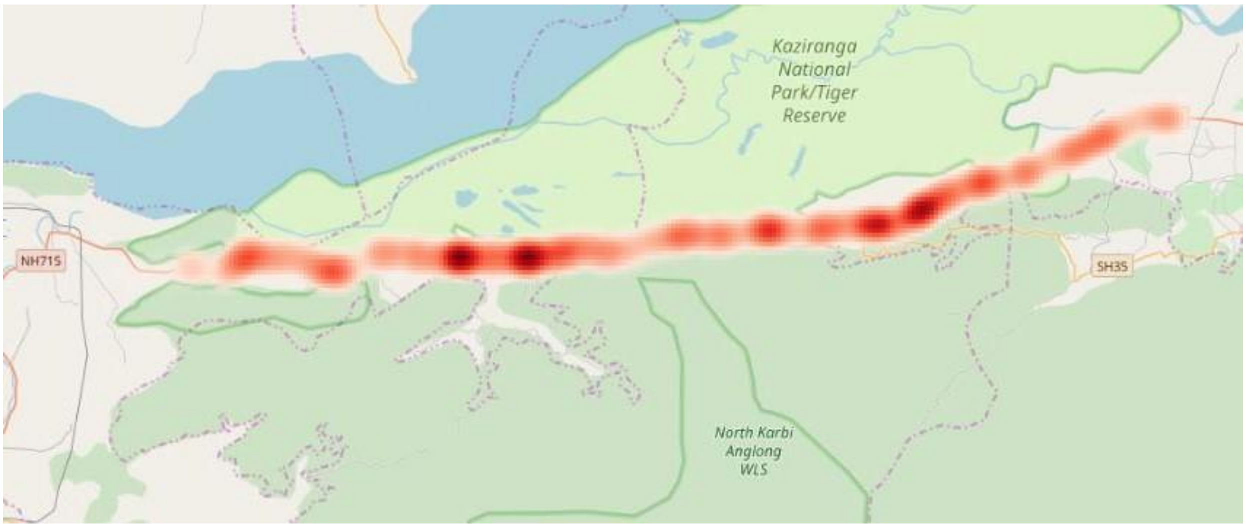
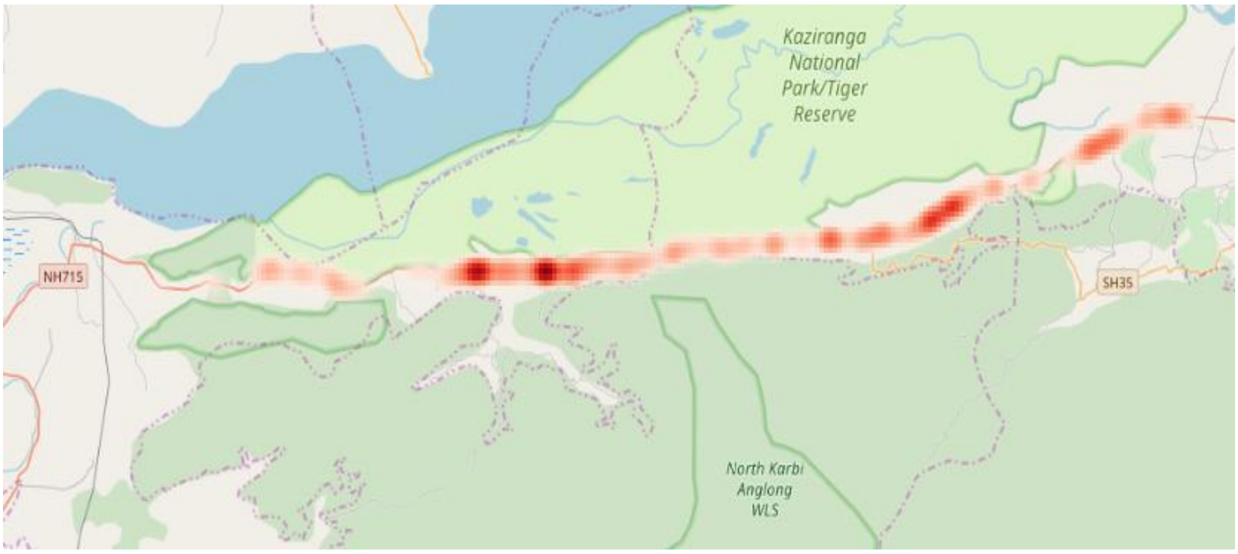


Figure 5: Locations of wildlife–vehicle collisions along the study route NH 715 a) Cluster of occurrences of wildlife–vehicle collisions at each location b) Kernel density hotspots of wildlife- vehicle collisions.

a)


Kaziranga
National
Park/Tiger
Reserve
NH715
SH35
North Karbi
Anglong
WLS

b)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North Karbi
Anglong
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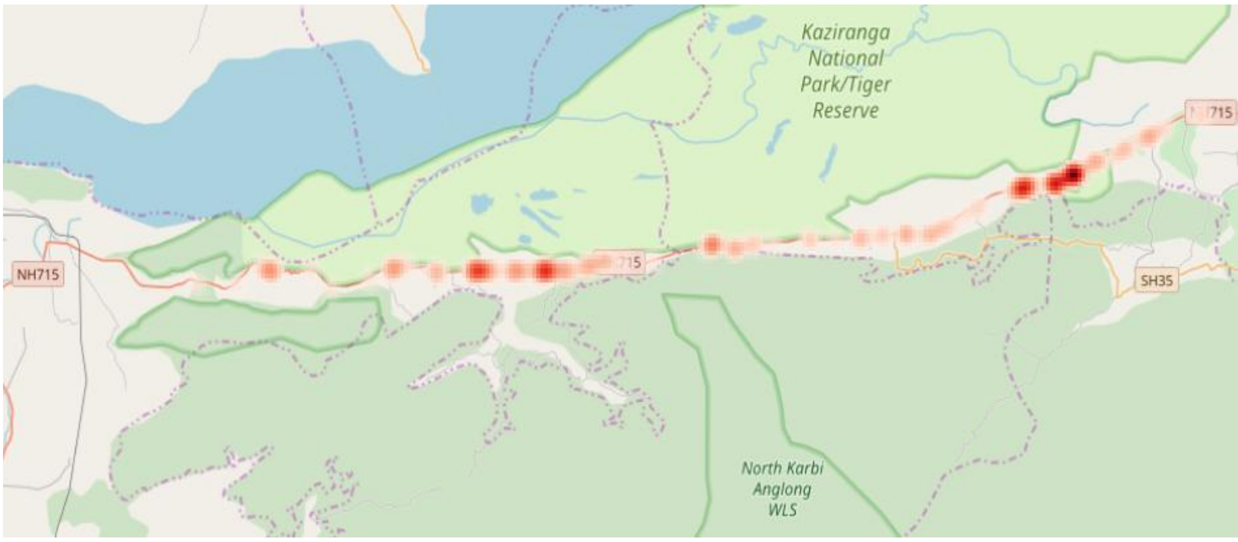
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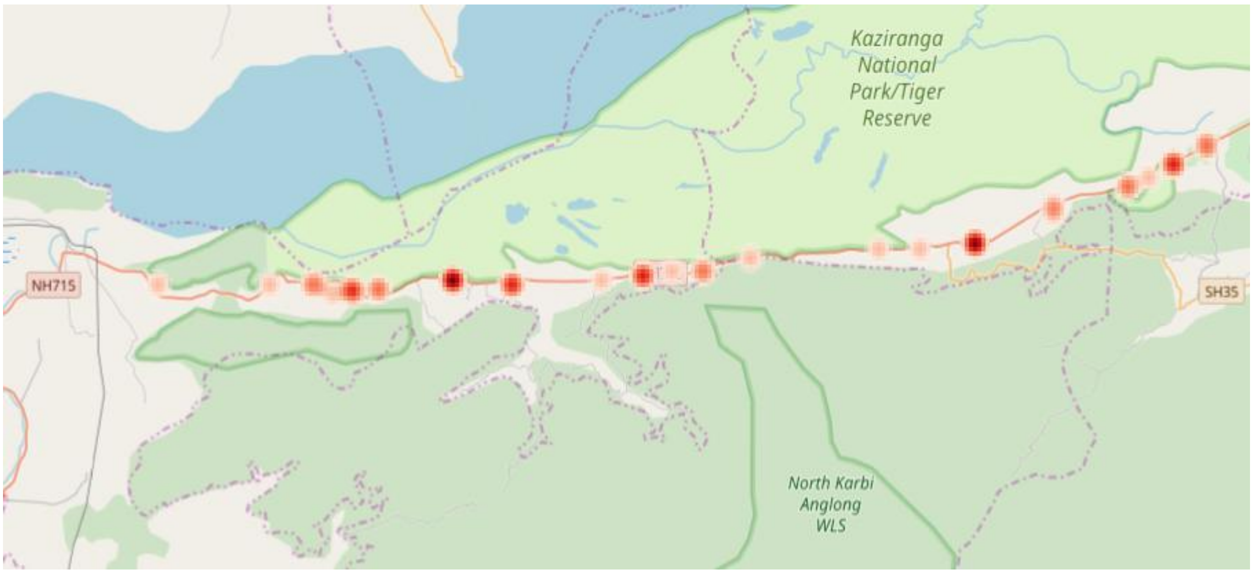

Figure 6: Kernel density hotspots of wildlife-vehicle collision occurrences based on class- a) Reptile b) Bird c) Small Mammal d) Large Mammal on major corridors intersected by NH 715

c. Assessment of persistence and detectability of roadkill on NH 715:

Persistence:

Data from 639 wild road-killed animals were collected of which 5.48% were Large Mammals (Hog Deer and Primates) (n=35), 4.068% were Small Mammals (n=26), 40.22% Birds (n=257), 48.9% Snakes (n=316) and 0.78% Amphibians (n=5). Most animal carcasses persisted on the road for one day or less after being killed by a vehicle (Figure 7). Very short persistence time was characteristic of Large Mammals (Hog Deer and Primates) (<12 hours). All the Small Mammals persisted till 12 Hours but 77% disappeared within 24 hours and 23% persisted and of the total only 3.7% persisted for 36 hours. Amphibians with least encounter rates had 60% disappearance within 12 hours and 20% persisted till 24 hours and disappeared within 36 hours. Large birds, Birds of Prey and some reptiles had the longest persistence time on road (>72 hours). About 99% birds persisted for 12 hours of which 62% disappeared within 24 hours and 18% persisted for 36 hours, 10% persisted till 48 hours, 3.11% for 60 hours and only 1.2% of the total birds persisted till 72 Hours. Of all the reptiles, 93.3% persisted for 12 hours of which 91% disappeared and 9.8% persisted for 24 hours, 2.2% persisted for 36 hours, 1.5% for 48 hours, 0.63% for 60 and the least at 0.31% for 72 hours. Survival curves provided the classification of each taxonomic groups according to persistence time. The Log-rank (Mantel-Cox) test showed a significant difference in the percent survival of each taxonomic categories (χ^2=618.6, df=4, P<0.0001). Gehan-Breslow-Wilcoxon test also showed a difference in the percent survival of different taxonomic groups (χ^2=624.3, df=4, P<0.0001).

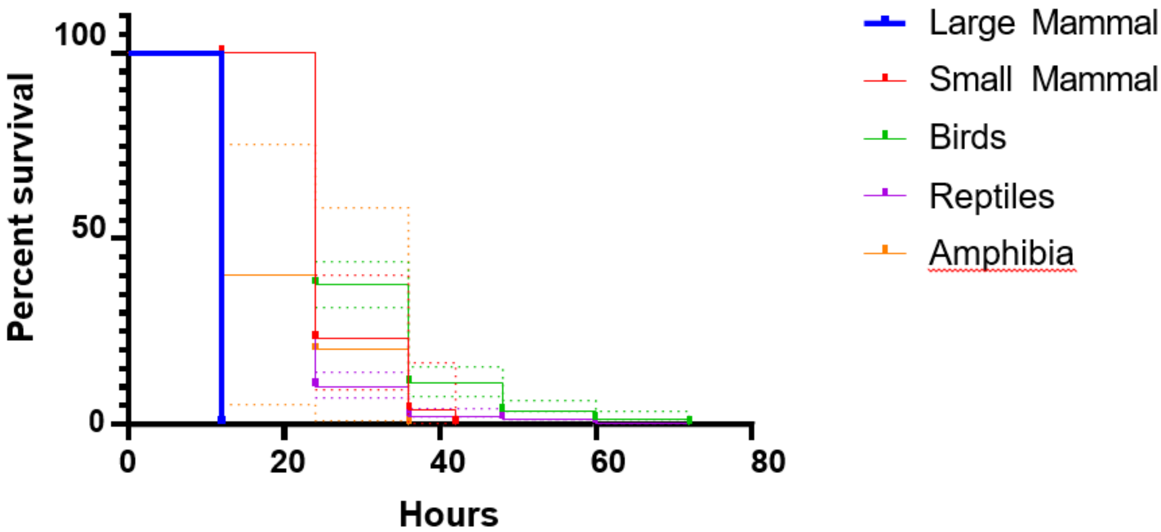

Figure 7: Kaplan-Meier estimates for individual survival functions of Large Mammals, Small Mammals, Birds, and Snakes and Turtles showing the persistence probability and 95% confidence intervals (the length of time axis is limited to a maximum of 72 Hours=3 days, when available, to allow comparison between groups).

d. Detectability:

Observer 1 detected a total of 211 roadkill (Birds-116, Reptiles-88, Small Mammals-4, Large Mammals-2, Amphibia-1)and Observer 2 detected a total of 208 roadkill (Birds-112, Reptiles- 89,Small Mammals-4, Large Mammals-2, Amphibia-1) throughout the survey period. The mean encounter rates of roadkill by both Observer 1 and 2 were (4.05±3.2) individuals/day and (4.07±3.00) individuals/day (Table 5, Figure 8). There was no significant difference between the roadkill encounter rates of the two observers ($t=0.5351$, $df=51$, $p>0.05$).

Table 5. Table showing the mean, SD, SEM, 95% confidence interval and R square of the differences of two observers.

Mean of differences	-0.05769
SD of differences	0.7775
SEM of differences	0.1078
95% CI	-0.2741 to 0.1588
R squared (partial eta-squared)	0.005583

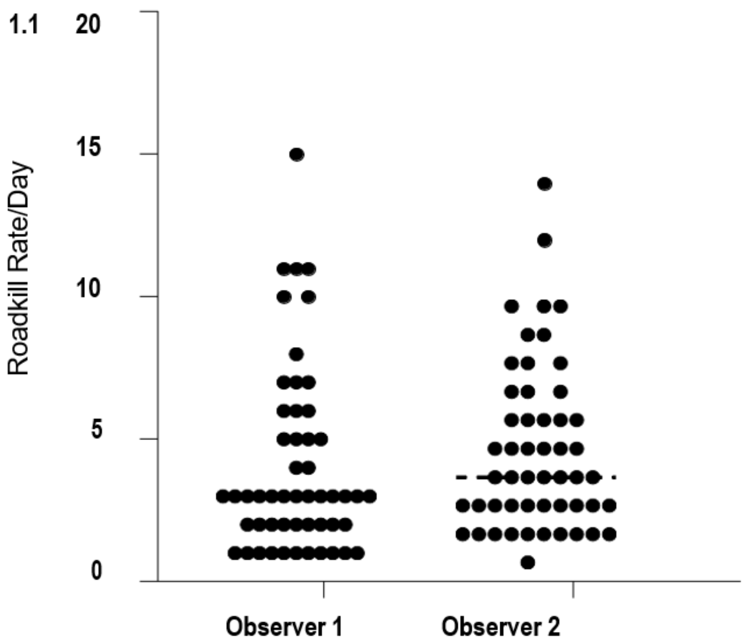

Figure 8: Roadkill rates (Numbers/Day) encountered by the two different observers- Observer 1 and 2 on NH 715 (54 km stretch).

e. Variation in ungulate group-size and composition:

The three most common ungulate species observed in the areas near NH 715 were Hog Deer, Sambar Deer and Barking Deer. But data for Sambar Deer and Barking Deer were not analysed because of the less number of observations. The group size of Hog Deer varied with the distance they were typically seen from the highway (Kruskall Wallis: K = 68.72, d.f. = 7, $P < 0.001$; Table 6). Distance of groups to roads were calculated on 50 m interval. No significant patterns in variation of group size were observed for hog deer (Figure 9).

Table 6: No of observations of ungulates groups with mean, max and min of group sizes at every 50 m interval from NH715.

Distance from road (in m)	Observations	Mean Group Size	Max	Min
0-50	45	2.6	17	1
50-100	45	6.53	19	1
100-150	21	5.52	15	2
150-200	44	7.31	26	1
200-250	48	8	31	1
250-300	37	9.13	28	1
300-350	9	7.88	26	2
350-400	13	16.46	35	2

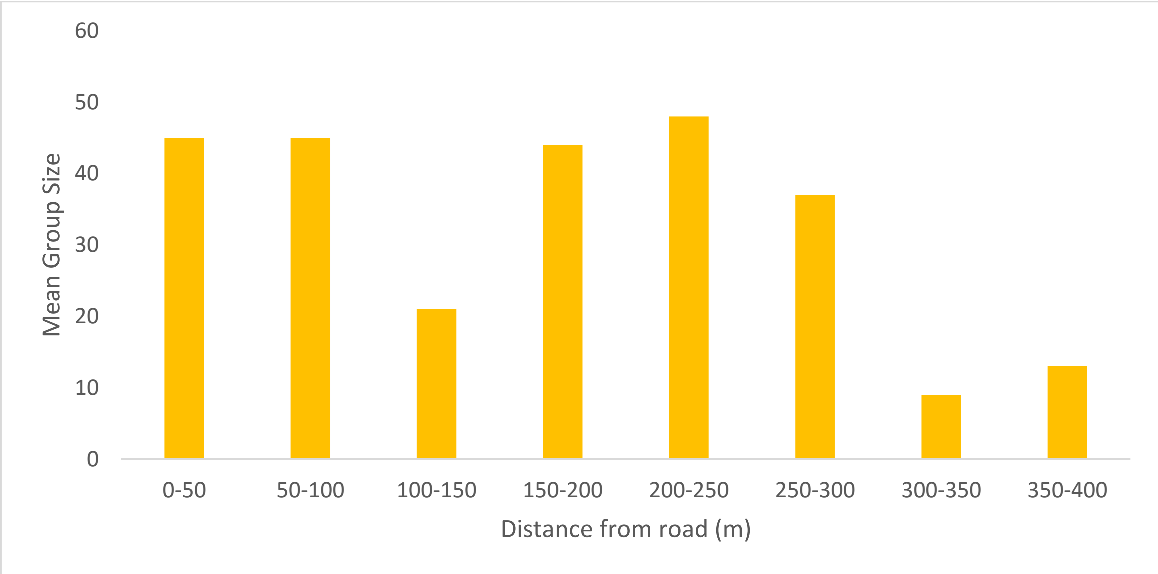

Figure 9: Variation in mean group-size of Hog deer with distance to road.

f. Variation in habitat use patterns of wild ungulates:

Of the 258 sampled plots, 151 plots had pellet presence (or animal sign). The four covariates that influenced habitat use namely- herbs cover, shrubs cover, trees cover and bare ground were included which explained the presence or absence of pellets or any animal sign at selected plots. Presence or absence (0/1) of vehicular noise was included as a disturbance factor. The log regression models showed a significant difference in pellet availability with respect to the covariates and factors included (χ=67.682, df=252, AIC=255.409) (Table 7). All the covariates (herbs, shrubs, trees cover and bare ground) has a positive co-relation with pellet (animal sign) availability, whereas a negative co-relation exists between noise as a factor and pellet availability (Figure 10).

Table 7: Coefficients of log regression with covariates and factors used in analyzing habitat use by wildlife.

Coefficients							
Estimate		**SE**	**Odds ratio**	**Z**	**Wald Statistic**	**Df**	**P**
Intercept	-2.844	0.807	0.058	-3.525	12.423	1	4.241e -4
Tree cover	0.222	0.332	1.249	0.669	0.448	1	0.503
Shrub cover	0.783	0.394	2.187	1.989	3.955	1	0.047
Herb	2.326	0.766	10.241	3.035	9.212	1	0.002
Bare ground	0.130	0.360	1.138	0.360	0.130	1	0.718
Noise (1)	-1.606	0.328	0.201	-4.896	23.971	1	9.780e -7
Note. Pellet level '1' coded as class 1							

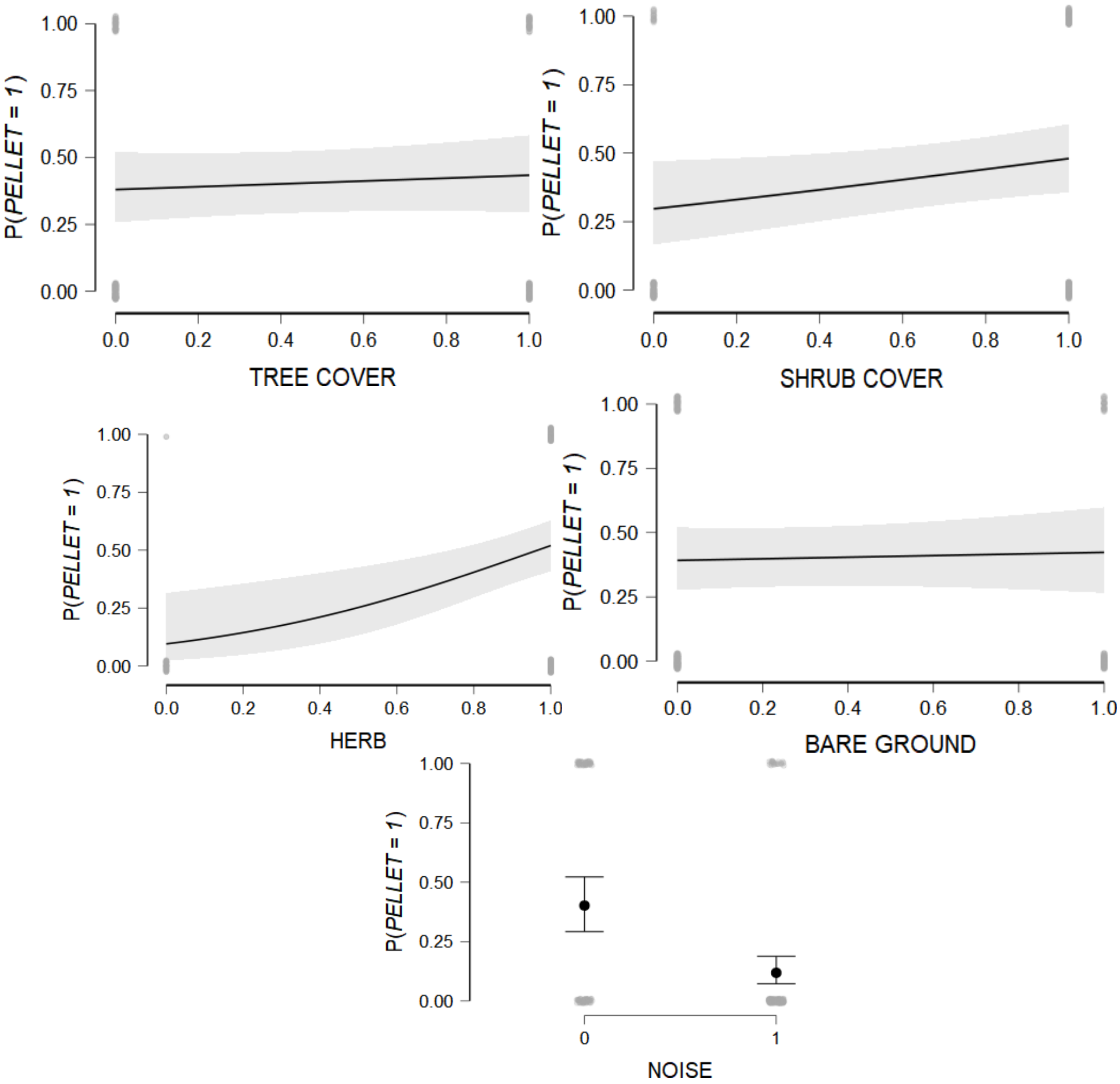

Figure 10: Positive and negative effects on the pellets or animal sign availability in the corridors by different vegetation types: a)Tree cover b) Shrub cover c) Herb cover d) Herb cover and as e) Noise (road related disturbance).

6. DISCUSSION

The number of roadkill that occurred due to wildlife-vehicle collisions were quantified. A total of about 1176 individuals were recorded including reptiles, birds, mammals and amphibians in the study period of Jan-Dec, 2019. Highest numbers of species being recorded for reptiles followed by birds, mammals and amphibians.

Herpetofauna were the most affected in reptiles on vehicle collision and the higher proportion of occurrences of reptilian roadkill including Snakes and Turtles (50.97%) could be assumed due to their slow mobility on the road, not reacting to vehicles and the fact that drivers are less likely to notice because of ignorance (Bhaskaran & Boominathan, 2010). Slow movement and use of roads as substrate for thermo-regulation could also be the cause for higher reptilian road mortality (Das et al., 2007). After herpetofauna birds comprised the most frequently recorded animals. Since most of the birds were resident birds as Common Maina (*Acridotheres tristis*) and Jungle Maina *(Acridotheres fuscus),* it might be possible for their frequent flight near or through roads for feeding on invertebrates or other items and their low height of flight from road and poor detectability or ignorance of speeding vehicles as they get accustomed to them (*pers. obs*). But mortality of other birds like Indian Roller *(Cracious benghalensis)*, White Breasted Waterhen *(Amaurornis phoenicurus*), Black Headed Oriole (*Oriolus xanthornus*), Common Hoopoe *(Upupa epops)* can be assumed as roads might simply cross a birds flight path (Foppen and Reijnen, 1994) and owlets swoop towards vehicle lights might be the reason of their mortality (Hodson, 1962). Mammalian mortality occurrence followed birds. Small mammals (House mouse, Squirrels, Civet cat, Jungle cat) and other mammals as Capped langur *(Trachypithecus pileatus*) and Rhesus macaque *(Macaca mulatta)* could be due to the wide distance of roads connecting species habitats coupled with confusion caused by the moving vehicles or because of food items offered or thrown by tourists alongside roads (Jeganathan et al., 2018). Ungulates such as Hog Deer (*Axis porcinus*) and Sambar (*Rusa unicolor*) were mostly killed by speeding vehicles in their escape route through NH715 from Kaziranga National Park to Karbi-Anglong Hills during monsoon floods (*pers. obs*). Besides this, proximity to forested areas often increases mortality risk in ungulates (Madsen et al., 2002; Seiler, 2005; Langbein and Putman, 2006). There are several reasons why smaller animals might be less influenced by infrastructure than large animals. Larger animals may be able to visually and aurally detect infrastructure at greater distances than smaller animals (Blumstein et al. 2005). Furthermore, the higher (per mass) energy requirements and small home ranges of small ungulates may reduce their ability to detect or flee disturbance (Blumstein et al., 2005; Lopez et al., 2010). The least occurrence of Amphibians might be recorded due to smaller body size leading to poor detectability and biasness during survey or due to the quick displacement by speeding vehicles. Proximity to water bodies may be related to the rate of amphibian roadkill (Santos et al., 2007; Colino–Rabanal and Lizana, 2012).

Statistical variation in the monthly occurrences of roadkill were recorded from Jan-Dec, 2019. Monthly differences in the occurrences of roadkill of each taxonomic groups might be recorded due to the environmental factors or seasonal differences of movement of animals according to needs across habitats. Reptiles (χ^2 =249.4, df = 11, $p < 0.0001$) and also amphibian species showed the highest occurrences in pre-monsoon, monsoon and pre-winter (June-November) with almost no to very few records towards winter. (Jan-Feb) which can be related to the hibernating activity of herpetofauna and less dispersal across roads. Bird(χ^2 =120.8, df = 11, $P < 0.0001$) and small mammals(χ^2 =68.08, df = 11, $P<0.0001$) also showed mortality variation with increasing frequencies towards summer, with lower occurrences towards winter which might be due to their frequent flights during breeding season near roads (Jeganathan, P., 2018). Large mammalian mortality(χ^2 =21.14, df = 11, P=0.0320) showed significant statistical variation of frequency and highest numbers of collisions of Hog Deer and Sambar were recorded during July (Annual flooding month) and August (Post-Flood) during their escape from flood towards Karbi-Anglong Hills from Kaziranga National Park through NH 715.

Carcass persistence might be a limiting factor in the road kill count. The carcass persistence probability of roadkills calculated by Log-rank (Mantel-Cox) (χ^2=618.6, df=4, P<0.0001) and Gehan-Breslow-Wilcoxon (χ^2=624.3, df=4, P<0.0001) by Kaplan-Meier survival estimator survival calculator showed a variation in the persistence time of carcasses in different taxonomic groups. Lower persistence probability rates of snakes and small mammals are affected directly by environmental conditions such as rain and speeding vehicles due to their smaller sizes. Large Snakes such as pythons persists for a maximum of 3 Days. Turtles persisted for a maximum of 48 Hours (2 Days) due to the hard shell that helps it from wear and tear. Higher persistence probability of roadkills was recorded for birds (72 Hours) due to the feathers that remain intact on the road although it remains unidentifiable to species level. Larger carcasses are expected to persist for longer periods (Slater, 2002). Unlike this, least persistence time of large mammals (<12 Hours) (Hog Deer, Sambar Deer, Langur) were observed in present study due to the removal of the carcass by humans and the Forest Department staffs as it hinders as a barrier to vehicles and to keep it out of reach for illegal consumption (pers. obs.). Moreover, the persistence is largely influenced by environmental variables and characteristics of the road itself, besides the size of the carcass (Santos et al., 2016). Regarding carcass detectability the present study did not reveal significant differences in roadkill counts between the two observers using same survey method. However, carcass detectability varies with the survey method used (e.g. driving or walking) (Santos et al., 2016).

Out of the three deer species, Hog Deer, Sambar Deer and Barking Deer, only Hog Deer had greater number of observations and its mean group-size composition showed a variation in group-size with the distance they were typically seen from roads (Kruskall Wallis: K = 68.72, d.f. = 7, P < 0.001). Anthropogenic and other disturbances from roads such as noise, light might create wariness in most of the wildlife that leads to their displacement from roads leading to fragmentation and potential composition. Ungulates are known to show considerable individual heterogeneity in response to human use (Papouchis et al., 2001).

Ungulate distribution showed significant variation in distribution with respect to vegetation and noise presence. Positive correlation existed between pellet availability with different vegetation types. But, negative correlation existed between vehicle noise presence and pellet (or animal sign) availability. Anthropogenic disturbances such as human-related presence, objects or sounds elicits anti-predatory behavior (Frid and Dill, 2002), whereas, ungulates are known to habituate to regular exposure to noise (Weisenberger et al., 1996). Human infrastructure and activity has a stronger effect on larger animals (Howe et al., 2012). Also, animals are more sensitive to human presence when in open vegetation (Stankowich 2008; Benitez-Lopez et al. 2010).

7. CONCLUSION

The purpose of this study was to analyze the impacts of NH 715 on the wildlife of Kaziranga-Karbi Anglong landscape. The study presents the number of wildlife mortality that occurred due to wildlife-vehicle collisions in NH715 Jan-Dec, 2019. Result shows that highways have adverse effects on the population of wildlife including endangered species of mammals and reptiles. Seasonal or monthly changes are the factors that influenced probability of roadkill numbers as it increased with the onset of summer and decreased towards winter. Annual monsoon floods in Kaziranga National Park from adjacent Brahmaputra River showed to be the main factor influencing large mammal mortality in wildlife-vehicle collisions. And heatmaps revealed locations where collisions centered the most which suggests further studies at those hotspots for factors. Apart from the direct impacts of roads on wildlife the indirect impacts like noise and disturbances associated with them impact significantly on the species that require an undisturbed or interior habitat. Similarly, present study exhibits variation in the group size composition of ungulates relative to distance from road. Group-size increased with respect to distance which indicates that anthropogenic effects of roads can lead to the habitat fragmentation of such species affecting population distribution. However, numbers and factors of wildlife-vehicle collisions may vary with site and condition.

With the above results of study it can be concluded that NH 715 passing through wildlife corridors connecting Kaziranga-Karbi Anglong Landscape has devastating impacts on its wildlife which suggests implementation of mitigation measures to reduce wildlife-vehicle collisions and increase habitat connectivity. The present study may be considered helpful in a variety of strategies when making decisions about the placement of wildlife-vehicle collision mitigation. These records can be useful to provide valuable information as to when and where wildlife-vehicle collisions are occurring in the network.

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