ACTION HISTORY OF RTI REQUEST No.WLIOI/R/2018/50017

Applicant Name	gaurav bansal
Text of Application	Sir, Please provide the information of the following points under section 06 of the Right to Information Act 1. Whether Your Institute has carried out any study with regard to the mortality of Wildlife on NH 74 which crosses from Haridwar division. 2. If yes please provide certified Copies of the Summary Report as well as Final Report of the study carried out by your institute in connection with Mortality of Wildlife on NH 74, which also crosses from Haridwar Division. Note: In order to save Public Exchequer, applicant requests you to please provide the soft copies of the Summary Report as well as Final Report on the applicants email id which is advocategauravkumarbansal@gmail.com. Further, the applicant also requests your goodself to kindly use the window available on the RTIONLINE for additional payment, in case it is required. Regards Gaurav Kumar Bansal Advocate 09811164777
Reply of Application	Since the information sought by you are very big, contains in pdf files and cannot be uploaded on the RTI portal, hence the same are being sent separately at your email id advocategauravkumarbansal@gmail.com

SN.	Action Taken	Date of Action	Action Taken By	Remarks
1	RTI REQUEST RECEIVED	06/06/2018	Nodal Officer	
2	REQUEST FORWARDED TO CPIO	07/06/2018	Nodal Officer	Forwarded to CPIO(s) : (1) Anju Baroth
3	REQUEST DISPOSED OF	12/06/2018	Anju Baroth-(CPIO)	

Print

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RIGHT TO
INFORMATION

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

ONLINE REPLY

No. WII/RTI/CPIO/2018-19 (Qtr-I)/23 **Dated 12.06.2018**

To,

Shri Gaurav Bansal,
A-26 Basement, Jangpura Extension,
Near DAV School,
New Delhi – 110 014

Sub: Information under Right to Information Act, 2005- reg.

Ref: Your Online RTI Request vide registration No. WLIOI/R/2018/50017 dated 06.06.2018.

Sir,

Please refer to your **RTI Request** on the above cited subject and reference under RTI Act, 2005. In this context, the point-wise reply to your queries has been received from concerned authority of the Institute and the same is attached herewith in **.pdf file**.

If you are not satisfied with the aforesaid reply, you may file an appeal before the First Appellate Authority i.e. ***"Dr. V.B.Mathur, Director, Wildlife Institute of India, P.B.18, Chandrabani, Dehradun – 248 001, Ph. 0135-2640910 or 2646102"*** within a period of one month.

Thanking you,

Yours faithfully,

12/06/18

(Dr. Anju Baroth)
CPIO & NO, RTI

Attached - .pdf files.

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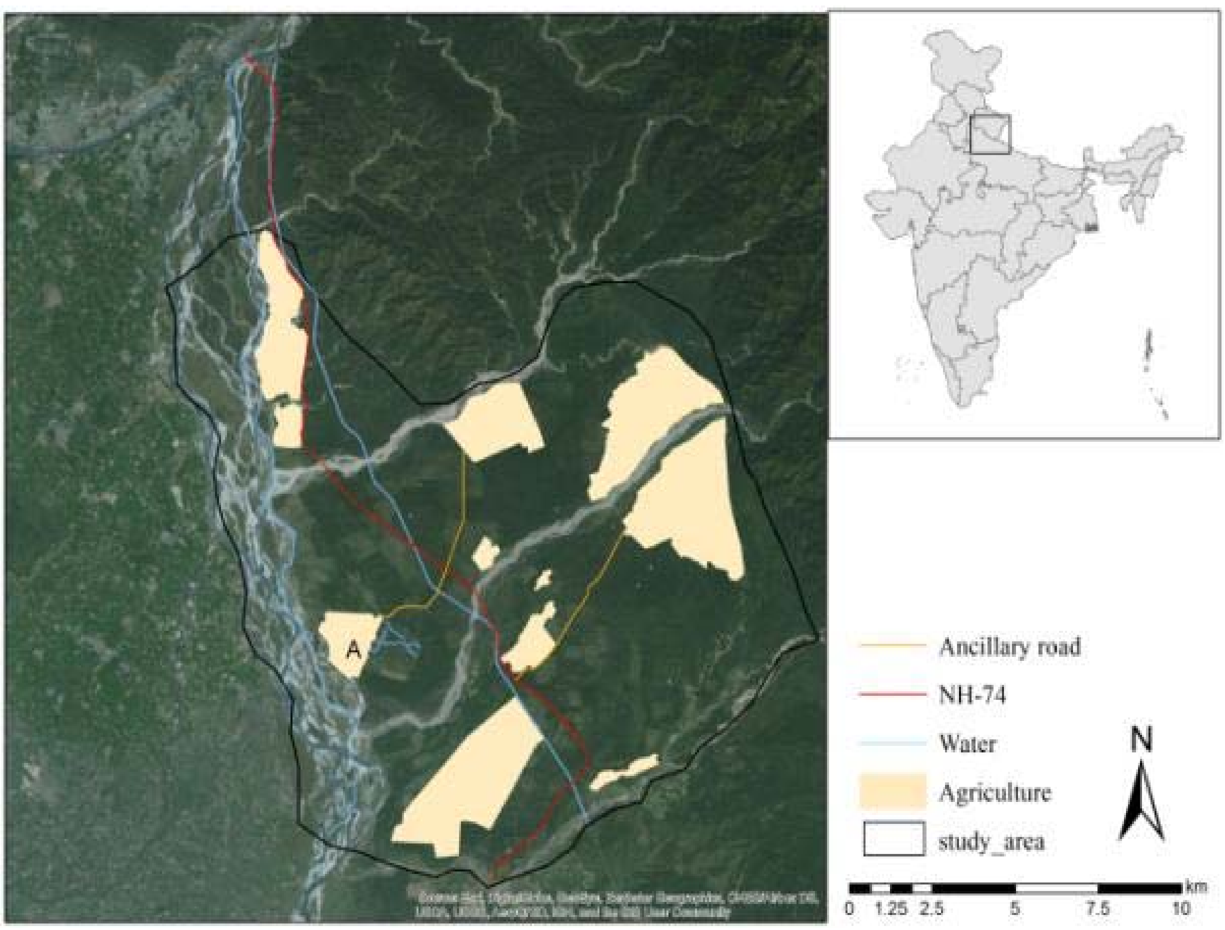
An assessment of impacts of National Highway 74 and the suggested mitigation measures to reduce the impacts

A 30km stretch of National Highway-74 cuts through Shyampur, Rasiyabad & Chidiyapur forest ranges of the Haridwar Forest Division. These ranges are contiguous with the eastern part of the Rajaji Tiger Reserve. The highway connects Chandi Bridge in Haridwar to Kotawali Bridge in Chidiyapur and experiences a huge daily traffic volume which appears to have increased over the years. A lot of wildlife mortalities have been recorded on the highway in the past. Records maintained by Haridwar Forest Division report death of 26 leopards and one tiger on this stretch of NH-74 since the last decade.



Study area: The 30 km stretch of NH74 along with an irrigation canal bisects the study area that comprises of multiple landuse categories. A represents Jhilmil Jheel Conservation Reserve

Considering the heavy mortality of wildlife due to vehicular collision as recorded in the past and the future impending road widening, this study was carried out to understand the pattern and extent of wildlife mortality as well as to suggest measures that can minimise the impact of NH-74 on wildlife in the area. Permission to carry out field work was provided by the Chief Wildlife Warden, Government of Uttarakhand. The study was done as part of M.Sc dissertation by Shri Sultan under the supervision of Dr. Bivash Pandav and Dr. Bilal Habib.

STUDY DESIGN AND FIELD METHODS:

Systematic information on road kills was collected from September 2016 till April 2017. Sampling for wild ungulate abundance estimation and road side habitat use was carried out between December 2016 and April 2017.

Recording wildlife mortalities on the highway

The highway was divided into 500m segments and information on segment specific characteristics such as

- On-road visibility per 100m (in metres) – was measured using a rangefinder. Based on this I calculated the average on-road visibility for every 500m segment.
- Road feature (straight, undulating and curved) - road feature categories were ranked, where curved segments were ranked the highest and straight segments the lowest
- Number of animal trails intersecting the highway- All such trails were walked and the track log was maintained using a GPS.

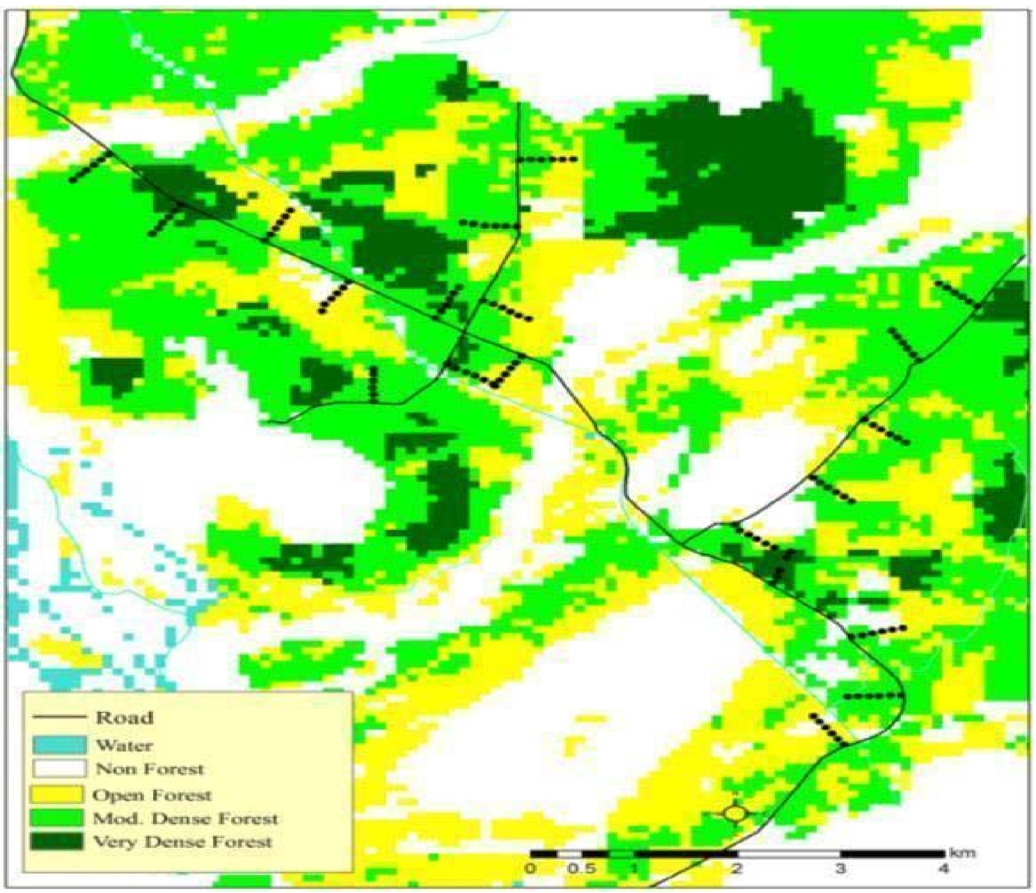
The highway was systematically surveyed daily on a motorbike at a constant speed of 15 km/h at dawn (0600 hrs- 0800 hrs) to look for wildlife mortalities. Species, location, distance to cover and broad vegetation type were recorded at every road kill location.

Information on daily traffic volume and traffic heterogeneity was also collected. This was done by 4 teams, which observed the traffic continuously for 6 hrs each. Tally counters were used to count number of vehicles of each type (Light vehicle, Heavy vehicle and Two-wheeler).

Use of roadside habitat by large mammals

Intensity of habitat use was estimated in plots that were laid at increasing distance from the road. Pellet plots of 20 m x 2 m were laid at six distance classes of 0m, 100m, 200m, 300m, 400m and 500m away from the road on transects perpendicular to it. A total of 20 such transects were laid on either side of the road, each separated from other by 1km. Twenty such sets of plots were laid with transects separated by 1km on the road. To assess if vehicular traffic has any impact on the habitat use, ten transects were perpendicular to the NH-74 (High traffic volume) and ten transects perpendicular to the two ancillary roads (Negligible traffic volume).

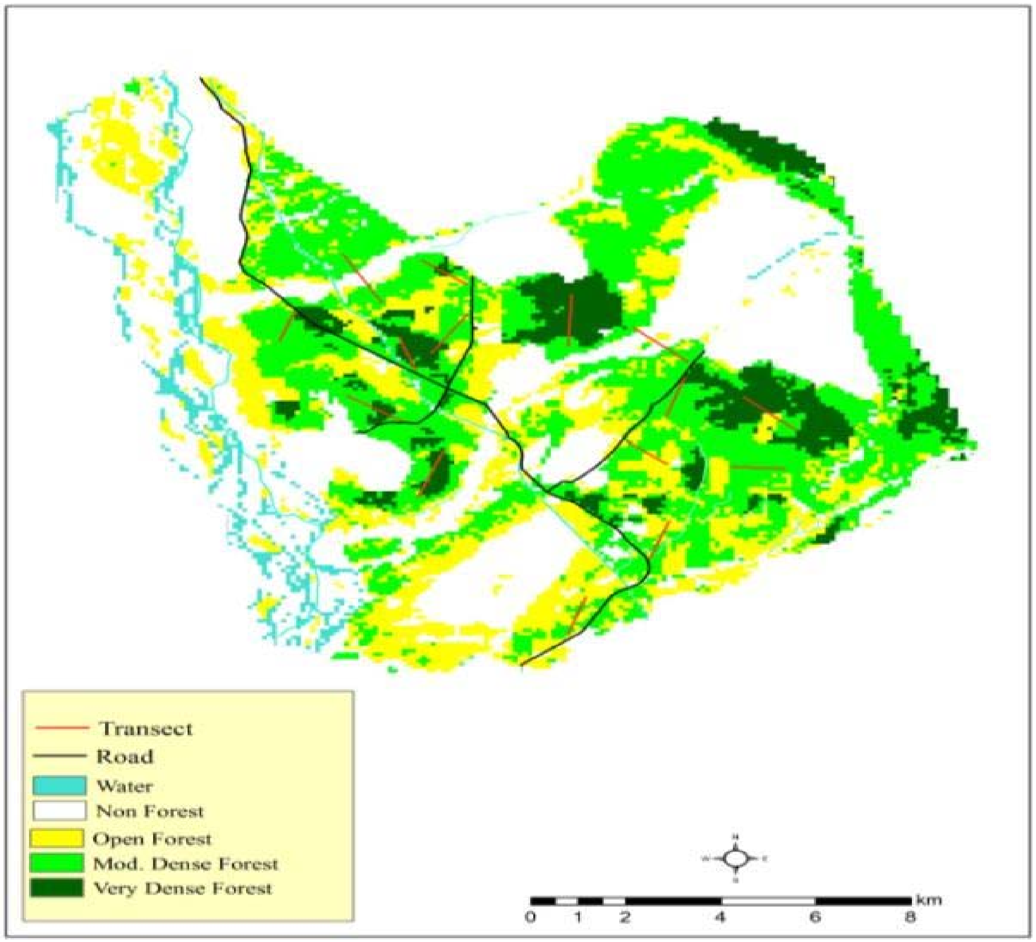
Within each plot number of pellets (total count) of chital (*Axis axis*), sambar (*Rusa unicolor*), black-naped hare (*Lepus nigricollis*), wild pig (*Sus scrofa*), elephant (*Elephas maximus*), rhesus macaque (*Macaca mulatta*) and Terai langur (*Semnopithecus hector*) were noted.



Pellet plots laid perpendicular to the road at increasing distance classes (0m, 100m, 200m, 300m, 400m and 500m)

Density estimation of wild ungulates:

15 spatially explicit line transects were laid across the study area (1 transect/4sq km grid). Transect lengths varied from a minimum of 1.2 km to maximum 2 km. Each transect was walked thrice during the study period. The total survey effort was 68.10 km. Transects were walked by a team of two observers in the mornings (06:00 to 09:00). Information on species, group size, sighting angle (measured using a hand-held compass) and sighting distance (measured by a laser range-finder) were recorded.



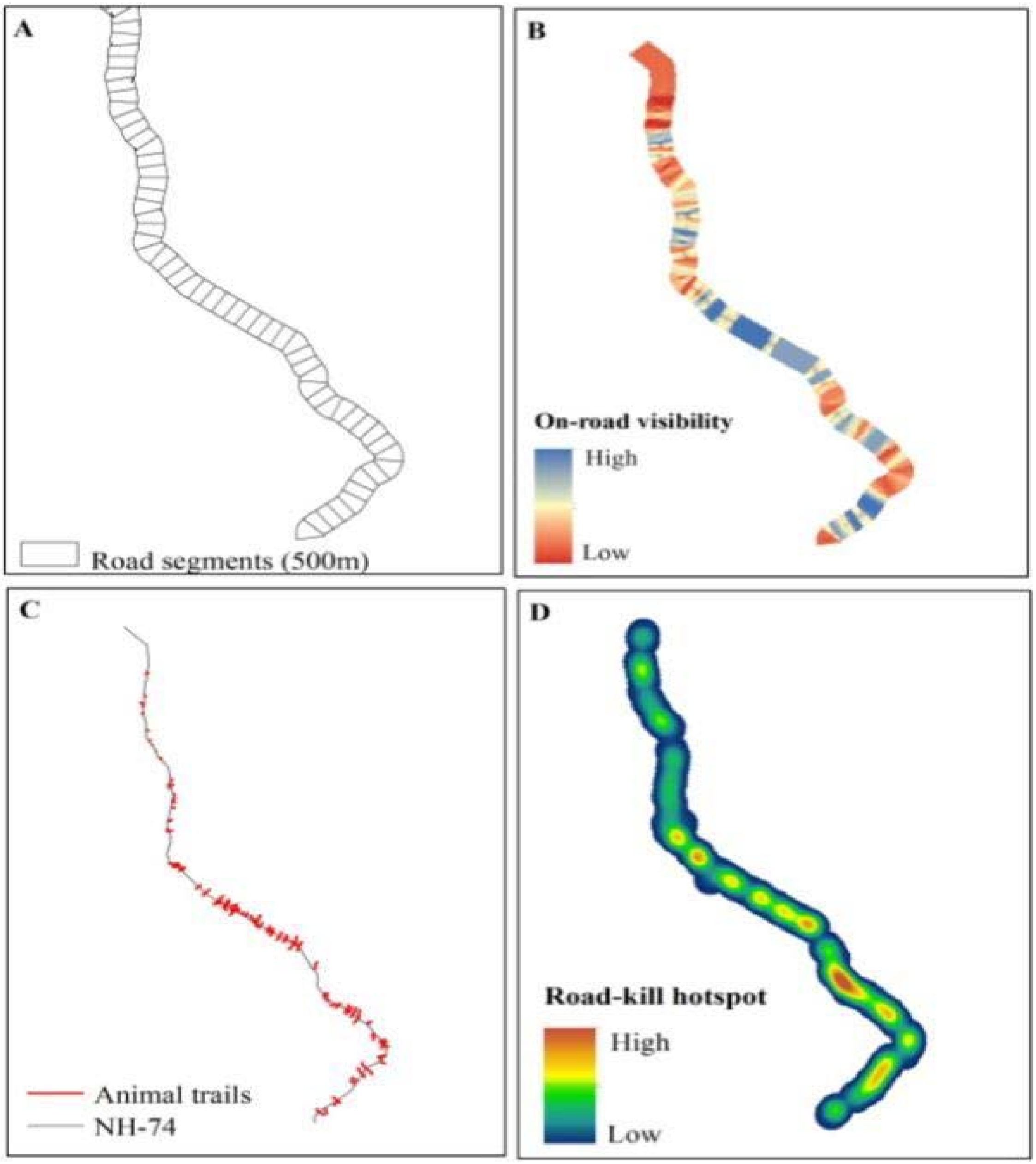
Location of 15 line transects sampled in the study area to estimate wild ungulate abundance

RESULTS:

Wildlife Mortality:

A total of 222 road-kills of four different taxa (reptiles, amphibians, birds and mammals) were recorded from 5th September 2016 to 18th April 2017 (Appendix II). Total road-kills detected on the NH-74 comprised of 37 species (Reptiles= 8, Birds= 12, Mammals=17). In terms of number of road-kills, mammals (n=127) were detected the most followed by birds (n=56) and reptiles/amphibians (n=31).

Based on location of animal mortalities a roadkill heatmap was generated. Number of animal trails intersecting the highway was found to be the primary factor governing the number of roadkills per road segment.



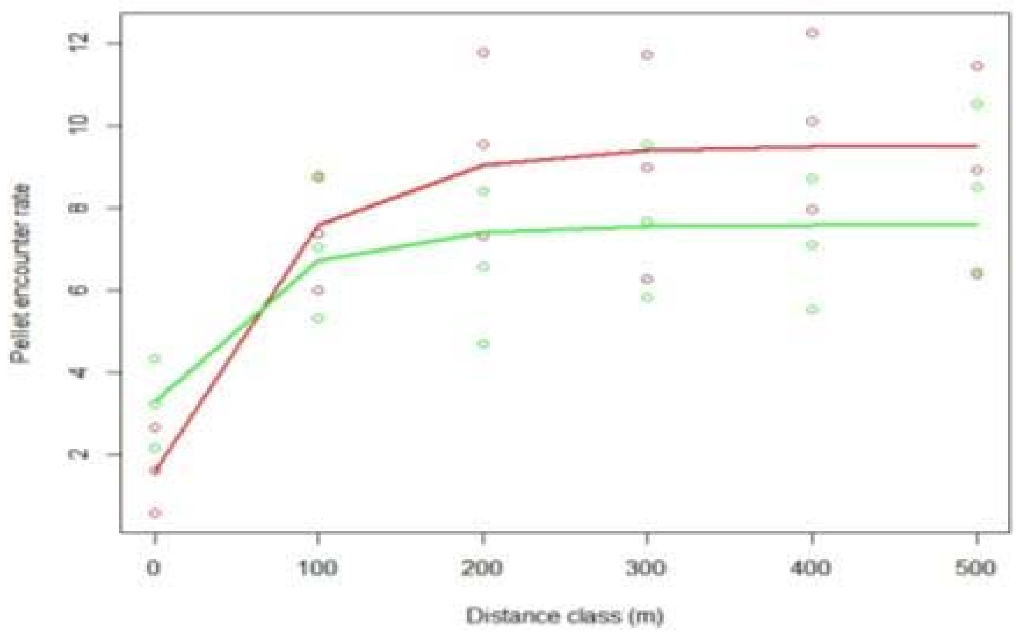
A represents NH-74 subdivided into 500m segments; B represents on-road visibility (in metres) in each segment; C represents number of animal trails intersecting the highway and D shows road-kill hotspots on NH-74

Ungulate density estimate:

It was found that Sambar and Chital occur at high densities in the study area. The estimates for Sambar and Chital are 14.92 (± 7.28) & 24.16 (± 7.09) respectively.

Pellet encounter rate as a proxy for intensity of habitat use:

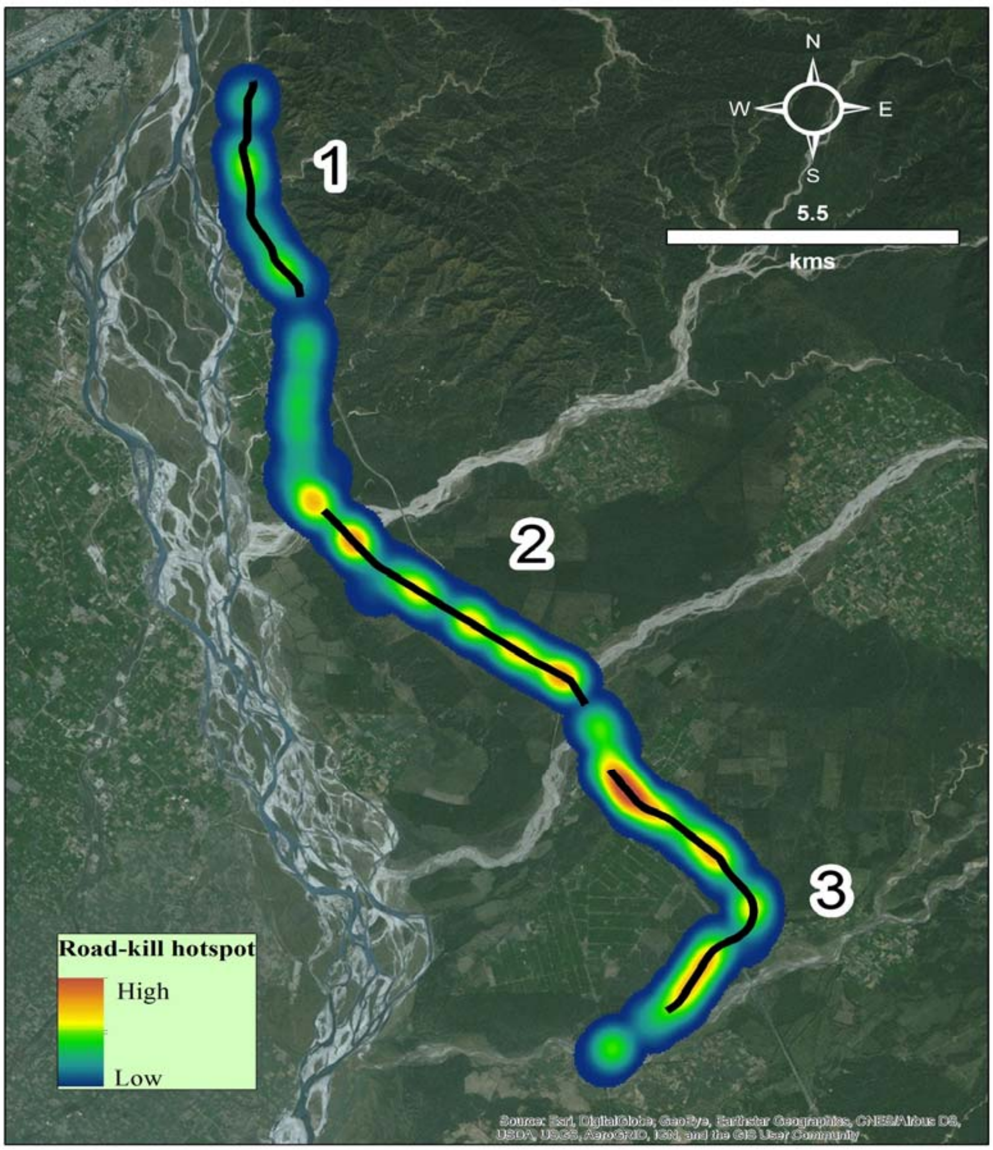
Our results show that pellet encounter rate for both highway (red) and ancillary road (green) increase up to a distance of 200m from the road and then satiates for higher distance classes. This implies that ungulates (Sambar & Chital) use the immediate road edges (upto 200m) less intensively and show gap avoidance behaviour.



Pellet encounter rate as a function of increasing distance from the road. Red and green curves depict National Highway 74 and ancillary road respectively.

Mitigation:

Since the major roadkill hotspots found in our study are clumped in 5-6 km stretches, any point based mitigation measures (rumble strips, wildlife fencing, overpasses and underpasses) seem ineffective. Therefore, I suggest three stretches where mitigation structures are crucial to reduce the road kills. They are: 1) Chandi Bridge to Tedhi puliya 2) Peeli river to Rawasan river and 3) Gendikhata to Chidiyapur



Mitigation: Building of flyovers suggested through 3 stretches on NH-74.

1- Chandi Bridge to Tedhi puliya 2- Peeli river to Rawasan river 3- Gendikhata to Chidiyapur

In the identified stretches, construction of flyovers can help wildlife moving underneath the structure while vehicles can pass unhindered over the flyover. Further, till flyover is fully commissioned, as a stopgap measure, it is important to erect speed control humps in locations where many wildlife trails intersect the road. Furthermore, there is an urgent need to put up more signages alongside the entire stretch of the road alerting motor vehicle drivers of animal crossings.

THE SERPRNTINE DEVIL: ROADS IN THE WOOD

A STUDY ON THE IMPACTS OF A NATIONAL HIGHWAY ON WILDLIFE IN HARIDWAR FOREST DIVISION

Dissertation submitted to

Saurashtra University, Rajkot

In partial fulfillment of

Master's Degree in Wildlife Science

By

Sultan

XV MSc, Wildlife Science

Wildlife Institute of India

Under the supervision of

Dr. Bivash Pandav and Dr. Bilal Habib

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

June 2017

Dedicated to

All the animals which have lost their lives on National Highway 74

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Acknowledgement

First and foremost, I would like to thank my parents for believing in me and allowing me to enter the realm of wildlife and my brother Kanishk and sister Nitasha for persuading them.

I would like to thank Dr. V.B. Mathur, Director, Wildlife Institute of India and Dr. G.S. Rawat, Dean, Wildlife Institute of India for providing me the opportunity to join this prestigious institute and carrying out my research. I am grateful to the Course Director and Associate Course Director for efficient conduction of the course and for supporting me in all sorts of situation.

Special thanks to my supervisor Dr. Bivash Pandav for encouraging me to take up this study and providing continuous support before, during and after the study. Thanks a lot for frequently visiting me on the field and providing regular and invaluable inputs. I would also like to thank my co-supervisor Dr. Bilal Habib for providing relevant literature, for helping me in designing the study and analysing the data.

My sincere thanks to Shri Qamar Qureshi and Shri Ajay Desai for their invaluable inputs in designing the study.

I am grateful to the Uttarakhand Forest Department and HK Singh, DFO Haridwar Forest Division for granting me permission to work in Haridwar Forest Division. I am thankful to RFO Shyampur Range, RFO Rasiyabad Range and RFO Chidiyapur Range for their support during the study. Special thanks to Mr. Pradeep Uniyal, RFO Rasiyabad Range for a luxurious accommodation in Jhilmil Jheel Conservation Reserve.

I would like to thank the entire forest department staff for helping me carry out my field work especially Johnny and Gulam of Shyampur Range; Gunsai ji, Buddh Singh and Rawat ji of Chidiyapur Range. Special thanks to the staff of Jhilmil Jheel Conservation Reserve who were like a family for me for four months, namely: Negi ji, Bhandari ji, Badola ji, Dhumman ji, Jitendra bhai, Ravinder ji, Bhopal bhai, Saddam bhai, Zakir bhai, Niyaju bhai, Pawan ji, Shyam Singh ji and Naveen ji. I have learned a lot from each one of them.

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I cherish each and every moment spent with the *Gujjar boys* - always active, resourceful and full of enthusiasm and humour.

Back at the institute I would like to thank Akanksha Saxena for her invaluable inputs from the beginning till end. She has been the backbone of my study. Thanks a lot for being there for me at all times.

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Once again I would like to thank my family for their unconditional love and support.

Last but not the least; I would like to thank all my lovely batch mates. It has been one hell of a journey. Over these two years I have learned a lot from all of them. I consider myself very fortunate to have these people in my life. Peace. Love. Respect.

One for all. All for one. XV beautiful people. XV MSc Batch (2015-2017).

Sultan

Summary:

1. The ongoing and reckless development of linear infrastructure around the world can well be compared to sweet venom. Sweet for humans, venom for wildlife. Roads in particular, entail wide ranging impacts on wildlife. The most conspicuous of all is wildlife mortalities due to collision with vehicles. Of the indirect impacts i.e., barrier effects are the most widely acknowledged. For wild animals, these effects can lead to the development of avoidance behaviour (road avoidance, vehicle avoidance and traffic emission avoidance). Road densities around the world are expected to increase rapidly in the near future which will magnify the impact on natural habitats. It is therefore imperative to study the ill effects of roads, factors influencing them and suggest effective mitigations measures.

2. My study aimed to understand the impacts of a 30km stretch of National Highway 74 on wildlife in Haridwar Forest Division. The highway bisects the intensive study area (150 sq km.), cutting through three wildlife rich forest ranges of the Haridwar Forest Division. The highway carries a huge traffic volume and a high number of road-kills have been reported in the past.

3. The study was carried out with the following objectives:

i. to understand the extent of wildlife mortalities and the factors governing them

ii. to understand ungulate habitat use and density distribution with respect to road

iii. to suggest effective mitigation measures that can minimise the impact of NH-74 on wildlife in the study area

4. The following sampling techniques were employed: (i) The 30km stretch of NH-74 was surveyed daily in the morning to look for road-kills. Species and location of road-kills was recorded. The highway was divided into 500m segments. Information on per segment on-road visibility, road feature class (straight, undulating and curved), number of animal trails and distance to water was also collected. A 24 hour monitoring of vehicular traffic was carried out to record traffic volume and vehicular heterogeneity. (ii) Pellet plots were laid on transects perpendicular to the highway and ancillary roads at increasing distance from the road (0m,100m,200m,300m,400m,500m). Twenty such transects were laid separated by

1km. Pellet encounter rate of chital and sambar was estimated at each of the 120 plots. (iii) 15 line transects were laid across the study area to estimate ungulate densities. Each transect was sampled thrice. Transects were then subdivided into equal segments of 200m. The whole study area was also gridded by 200m×200m cells. Per segment density was estimated and modelled as a function of spatially explicit habitat covariates using generalised additive models (GAMs). The best supported models were used to generate density surface maps for chital and sambar in relation to roads (highway and ancillary roads).

5. A total of 222 road-kills were recorded belonging to four taxa: mammals, birds, reptiles and amphibians. Mammals road-kills (n=127) were detected the most, followed by birds (n=56) and reptiles/amphibians (n=31). A road-kill hotspot map was generated which indicate high mortality in segments with high on-road visibility and more number of animal trails. Pellet encounter rates of chital and sambar when modelled against increasing distance from the road implied reduced usage of roadside habitat by both the species. NH-74 and ancillary roads create a road-effect zone of at least 200m regardless of the traffic volume. Chital and sambar densities in the study area (Reserved Forest) are comparable with their densities in the adjacent Rajaji Tiger Reserve (Protected Area).

6. To reduce the impacts of NH-74 the suggested mitigation measures include building flyover at three identified stretches on the highway, speed breakers at locations where many animal trails intersect the highway and erecting sign boards to make vehicle drivers aware of the animal crossings.

1.0 INTRODUCTION:

Just as humankind suffers from dilemmas so do wild animals. The only difference is that their dilemma is far too simple. To cross a road, or not to? Whatever the choice, the consequences are dire.

Roads that cut through forested habitats are a serious threat to biodiversity (Laurance et al. 2009; Coffin 2007). They can alter natural habitats through pollution (noise and chemical), habitat fragmentation & degradation and facilitate proliferation of invasive species (Forman et al. 2003; Laurance et al. 2006). But wildlife road-kills and barrier effect are the most serious and widely acknowledged impacts of roads on wild fauna (Seiler 2003; Oxley et al. 1974). In their review on ecological impacts of roads, Forman and Alexander 1998 stated that during the last three decades wildlife mortalities due to vehicles has emerged as the leading cause of vertebrate mortality, surpassing even hunting. Impacts of roads are not limited only alongside the road, but penetrate much deeper into habitats and alter behavioral responses of species (Forman and Deblinger 2000; Mcgregor et al. 2008; D'Amico et al. 2015). Such altered species response can be categorised as 1) road avoidance (surface or gap avoidance), 2) vehicle avoidance and 3) traffic (emissions) avoidance (Jaeger et al. 2005; Trombulak and Frissell 2000). These behavioral responses can cause fragmentation of large and connected population (Mulero-Pázmány et al. 2015; Laurance et al. 2009). The resulting small and isolated populations thus become vulnerable to demographic, genetic and environmental stochasticity, that may lead to local extinctions (Carr and Fahrig 2001; Donaldson and Bennett 2004).

The intensity of the deleterious effects of the roads increases with increase in road density, road width and traffic volume (Seiler and Helldin 2006). Road intrusion into previously undisturbed natural habitats acts as a catalyst for further development in the area thereby reducing overall habitat quality (van der Ree et al. 2015) . Improved access in such areas has been known to aid illegal poaching and wildlife trade (Mclellan and Shackleton 1988; Kerley et al. 2002). Roads can also have detrimental impacts on mammal and bird abundance in edge habitats (Rytwinski and Fahrig 2011; Reijnen et al. 1995; Reijnen et al. 1996)

1.1 Literature Review:

Extensive amount of work has been done to understand the ill effects of roads on ecosystems and landscape. Comprehensive books have been written which target multidisciplinary audience (scientists, engineers, planners, economists, transportation agencies) (Forman et al. 2003; van der Ree et al. 2015). Reviews have been published, documenting in detail, a variety of ecological effects of roads on ecosystems and landscapes (Donaldson and Bennett 2004;Forman and Alexander 1998;Trombulak and Frissell 2000; Coffin 2007). So far, the extent and patterns of the most visible impact (i.e., road-kills) have received more emphasis in majority of such studies. Wildlife mortality due to vehicle collisions is considered to be highly detrimental for animal populations, especially for endangered species such as the Florida Panther *(Felis concolor coryi)* (Maehr et al. 1991) and Iberian lynx *(Felis pardina)* (Ferreras et al. 1992). Species which are attracted to roads also fall under high risk category. For example, species like granivorous birds, rodents are attracted to grain-spills; scavengers like vultures, kites, jackals, foxes are attracted to carrion of previously road-killed animals; snakes are attracted for thermoregulation (Goosem 1997; Rudolf et al. 1999). Although, Amphibians and reptiles are considered to be the most affected taxa due to road mortality in terms of the extent of road-kills (Fahrig *et al*. 1995), large mammals are also highly vulnerable because they often occur at low densities and have low reproductive rates (Kerley et al. 2002). Other than road-kills, avoidance behaviour of certain species due to noise and other effects (high traffic volume, human activity) have also been well documented for wolves (*Canis lupus)* (Thurber et al. 1994), bobcats (*Felis rufus)* (Lovallo and Anderson 1996), for black bears, (*Ursus americanus)* (Brody and Pelton 1989), grizzly bears (*Ursus arctos)* (McLellan and Shackleton 1988), caribou (*Rangifer tarandus)* (Klein 1979), mule deer (*Odocoileus spp.*) and elk (*Cervus canadensis*) (Rost and Bailey 1979). For example, according to Brody & Pelton (1989) Black bears, rather than altering their movement patterns within pre-established home ranges responded to roads by shifting the location of home ranges. Similarly, Gray wolves (*Canis lupus*) shift territorial boundaries to avoid heavily traveled roads (Thurber et al. 1994). . Bird communities in both grassland and forested habitats are also found to avoid road edges owing to traffic noise especially in breeding season (Reijnen et al. 1995; Reijnen et al. 1996).

Recently, the incorporation of remotely sensed information to understand the effects of roads has led to new insights and more precise estimates of the scale at which roads impact ecosystems and landscapes (Torres et al. 2016; D'Amico et al. 2016) .

But so far, the field of road ecology lies nascent in the Indian scenario. Being a tropical country with rich biodiversity and on the other hand with pressing development demands, Indian forests are highly susceptible to impacts of linear infrastructure (Raman 2011). The Indian protected area network forms only 4.7 % of the total geographic area of the country. A majority of the last remaining wildlife refuges are small and isolated. Many of these are already fragmented with roads and suite of other linear infrastructure. Many await further fragmentation, by pending road development proposals; others fear up-gradation of the existing ones (Rajvanshi et al. 2001).

So far, most studies on roads from India have only looked at the number and distribution of road-kills (Baskaran and Boominathan 2010; Das et al. 2007; Behera and Borah 2010; Selvan 2012: Rao and Girish 2007; Seshadri and Ganesh 2011). A few studies tried to assess the impacts on behavioral response of animals (Pragatheesh 2011;Vidya and Thuppil 2010; Gubbi et al. 2012). Studies that can decipher the factors governing spatial and temporal patterns of road kills and behavioral responses are yet to come up.

In this study, I attempted to do so.

1.2 Objectives:

Considering the heavy mortality of wildlife due to vehicular collision as recorded in the past and the future impending road widening, I chose this study site (NH-74) to carry out an intensive study with the following objectives:

i. To understand the extent of wildlife mortalities and the factors governing them

ii. To understand the patterns of habitat use and density distribution of ungulates in relation to road

iii. To suggest effective mitigation measures that can minimise the impact of NH-74 on wildlife in the study area

2.0 STUDY AREA:

My study was conducted in an area spanning 150 sq km (29°55'-29°44'N and 78°12'-78°19'E) in the reserved forests of Shyampur, Rasiabad and Chidiyapur ranges of the Haridwar forest division. The study area experiences sub-tropical climate. Annual temperature in the area varies from a minimum of 2°C in winters to a maximum of 44°C in summers. Annual rainfall and relative humidity in the area range from 1050-1550 mm and 45-80%, respectively. Elevation ranges from 200m-250m above MSL.

The study area is contiguous to Rajaji Tiger Reserve in the north and east, in the south-eastern side lies the reserved forests of Uttar Pradesh and in the west the study area is bound by river Ganga, which is the only perennial source of water in the area. The study area is located at the transition zone of Bhabar and Terai tract and is characterized by lush grass growth in the forest floor. Jhilmil Jheel Conservation Reserve (37.83 sq km) forms part of the study area .Tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), Himalayan black bear (*Ursus thibetanus*), striped hyaena (*Hyaena hyaena*) chital (*Axis axis*), sambar (*Rusa unicolor*), swamp deer (*Rucervus duvaucelii duvaucelii*) wild pig (*Sus scrofa*) and elephant (*Elephus maximus*) are the large mammal species found in the study area.

The study area is a mosaic of tropical mixed moist deciduous forest, Eucalyptus and Teak plantations, tall and short grasslands and secondary scrub forest. The reserved forests in the area are perforated with human settlements (villages and small towns) and agriculture. Major biotic disturbances in the forests here include rampant firewood collection and livestock grazing.

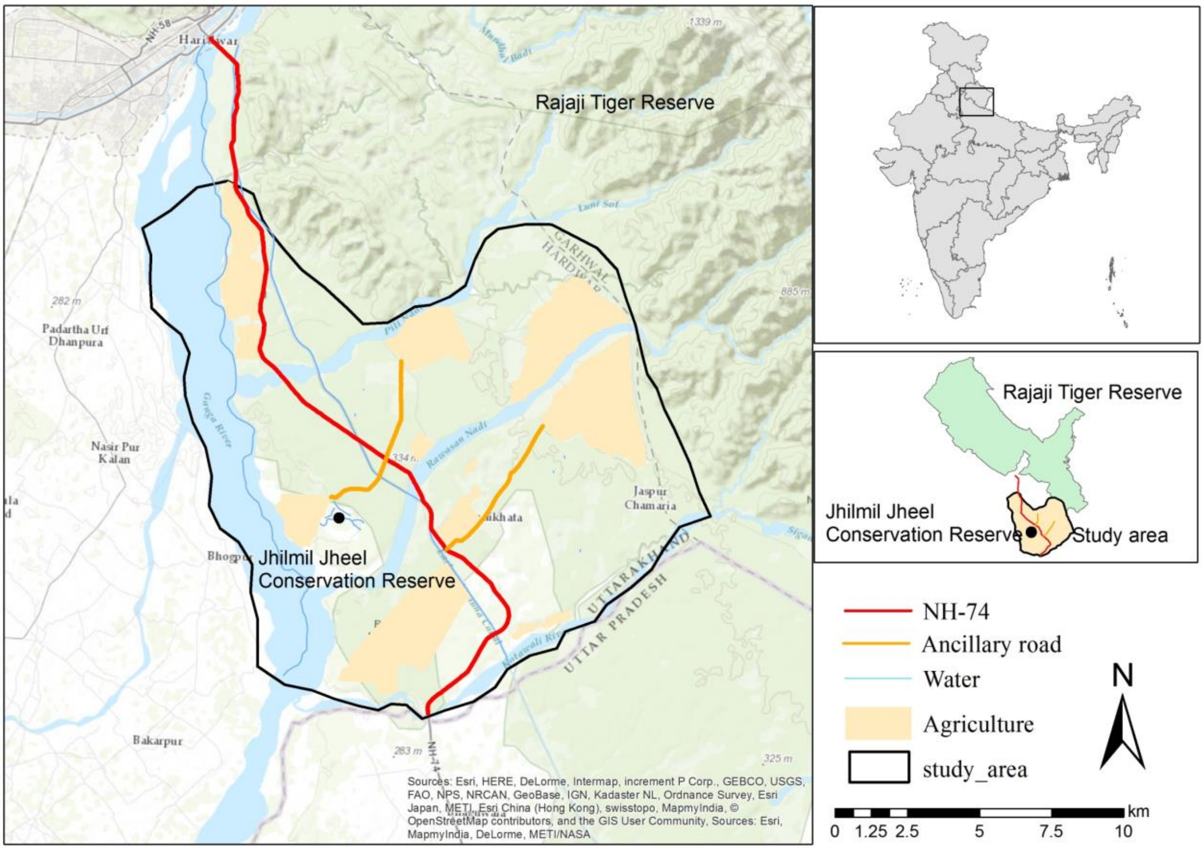

Figure 1: Study area: The 30 km stretch of NH74 along with an irrigation canal bisects the study area that comprises of multiple land-use categories.

30km stretch of NH-74 from Kotawali River in the Uttarakhand-Uttar Pradesh interstate border to the Ganga bridge near Chandi temple, Haridwar cuts through three wildlife rich forest ranges (Shyampur, Rasiabad and Chidiyapur). The road experiences a huge daily traffic volume which appears to have increased over the years. A lot of wildlife mortalities have been recorded on the highway in the past. Records maintained by Haridwar Forest Division report death of 26 leopards and one tiger on this stretch of NH-74 during the past 10 years.

3.0 STUDY DESIGN AND FIELD METHODS:

Systematic information on road kills was collected from September 2016 till April 2017. Road-kill data from September to November was collected by my field assistant. Sampling for wild ungulate abundance estimation and road side habitat use was carried out between December 2016 and April 2017.

3.1 Wildlife mortalities on the highway:

The highway was divided into 500m segments and information on segment specific characteristics such as:

- On-road visibility (in metres) – was measured using a rangefinder at each of the 300 points separated by 100m on 30 km stretch of the highway. On-road visibility is defined as the farthest distance one can see from a point on the road. Based on this I calculated the average on-road visibility for every 500m segment.
- Road feature (straight, undulating and curved) - road feature categories were ranked, where curved segments were ranked the highest and straight segments the lowest
- Number of animal trails intersecting the highway- All such trails were walked and the track log was maintained using a GPS. Trails where we did not find any direct or indirect signs of animals were not included. For the purpose of inference, the trails were categorised as: one sided trails and two sided trails. The former refers to trails that are present only on one side of the highway. The later are the trails which have a counterpart trail on the other side of the highway as well. From now on, such trails will be referred as stated above.

The highway was systematically surveyed daily on a motorbike at a constant speed of 15 km/h at dawn (0600 hrs- 0800 hrs) to look for wildlife mortalities. Species, location and broad vegetation type were recorded at every road kill location.

Information on daily traffic volume and traffic heterogeneity was also collected. This was done by 4 teams, which observed the traffic continuously for 6 hrs each at a single observation post. We used tally counters to count number of vehicles of each type (light vehicle, heavy vehicle and two-wheeler).

3.1.1. Analysis:

I used Generalised Linear Modelling (Crawley 2007) of Poisson family to model the number of road-kills per segment (500m) as a function of the following variables: visibility, road feature, distance to water and number of animal trails intersecting the highway. All the analysis was done in R version 3.2.3.

A road-kill hotspot map was generated using "Heatmap" command in ArcMap 10.2.2. **(Figure 5)**

3.2 Use of roadside habitat by large mammals:

Intensity of habitat use was estimated in plots that were laid at increasing distance from the road. Pellet plots of 20 m x 2 m were laid at six distance classes of 0m, 100m, 200m, 300m, 400m and 500m away from the road on transects perpendicular to it (**Figure 2**). Twenty such sets of plots were laid with transects separated by 1km on the road. To assess if vehicular traffic has any impact on the habitat use, I laid ten transects perpendicular to the NH-74 (High traffic volume) and ten transects perpendicular to the two ancillary roads (Negligible traffic volume).

Within each plot, I enumerated pellets of chital (*Axis axis*), sambar (*Rusa unicolor*), black-naped hare (*Lepus nigricollis*), wild pig (*Sus scrofa*), elephant (*Elephas maximus*), rhesus macaque (*Macaca mulatta*) and Terai langur (*Semnopithecus hector*). Number of pellets (total count) and the species were noted.

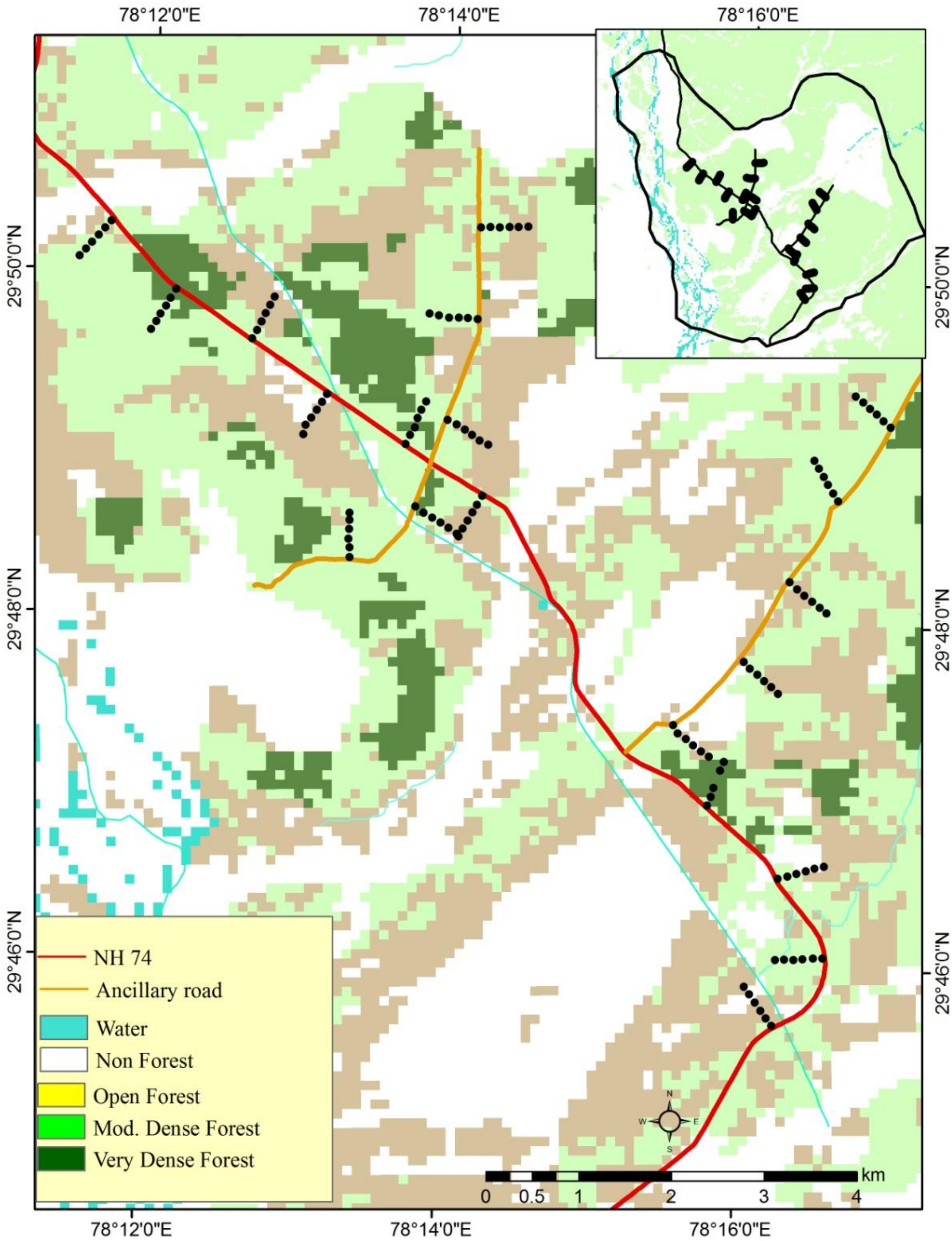

Figure 2: Location of pellet plots laid perpendicular to the road at increasing distance classes (0m, 100m, 200m, 300m, 400m and 500m). Base map is the forest type map (FSI).

3.2.1 Analysis:

Pellet encounter rate data came out to be insufficient for most species, except chital and sambar. For the purpose of the analysis, data for chital and sambar were pooled together.

Since the data on pellet encounter per plot were zero inflated, I generated summary statistics for each distance class. I calculated the mean encounter rate and standard errors per distance class and plotted it. Visual assessment suggested a fit for non-linear regression. I fitted Exponential Association ($y = a + (b - a) * (1 - \exp(-K * x))$) model on the count data. Model comparisons were based on AIC scores.

3.3 Density estimation of wild ungulates:

15 spatially explicit line transects were laid across the study area (1 transect/4sq km grid) (**Figure 3**). I placed stratified random transects. Transect lengths varied from a minimum of 1.2 km to maximum 2 km. Each transect was walked thrice during the study period. The total survey effort was 68.10 km. Transects were walked by a team of two observers in the mornings (06:00 to 09:00). Information on species, group size, sighting angle (measured using a hand-held compass) and sighting distance (measured by a laser range-finder) were recorded.

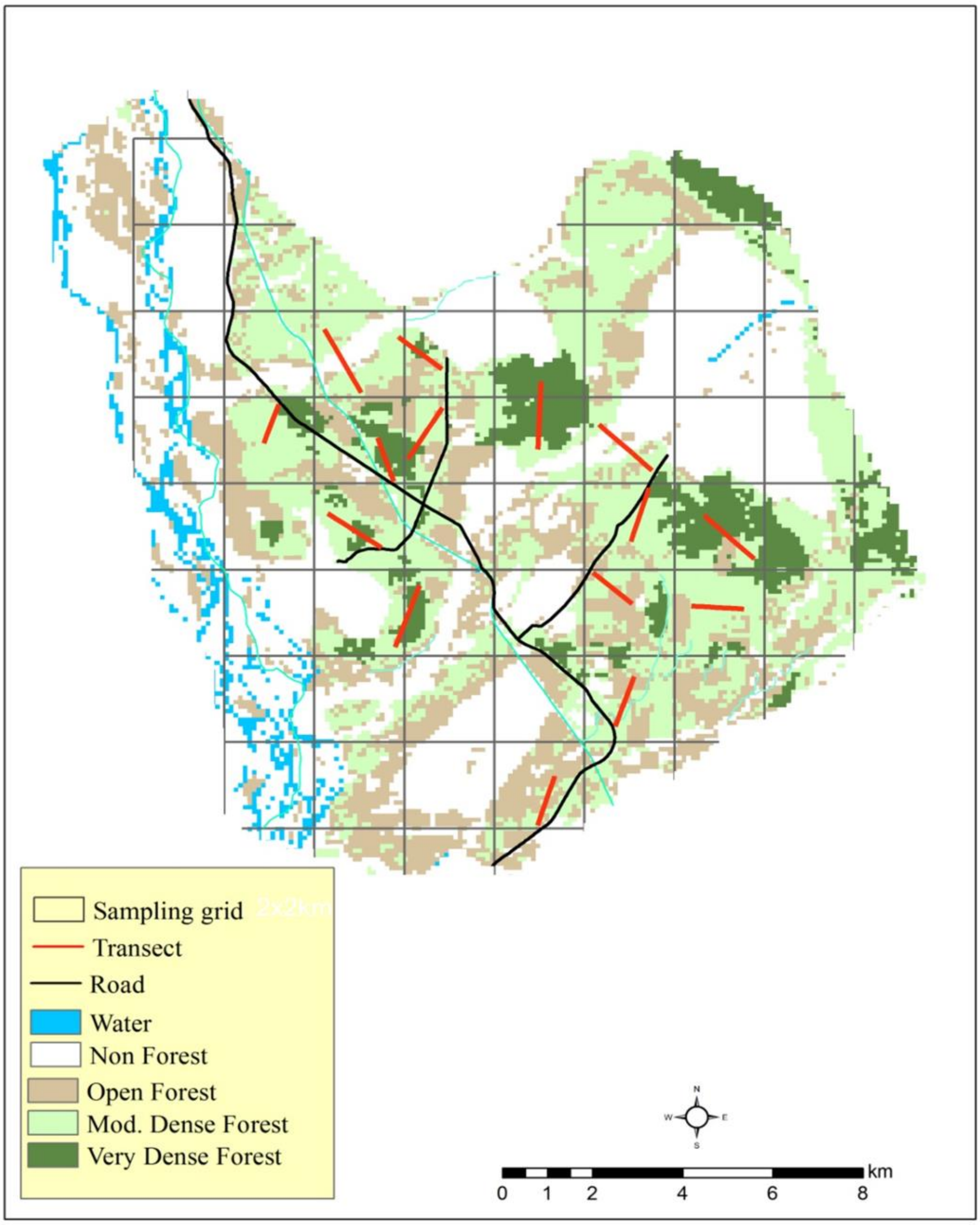

Figure 3: Location of 15 line transects sampled in the study area to estimate wild ungulate abundance. Base map is the forest type map (FSI).

3.3.1 Analysis:

For the purpose of generating spatially explicit ungulate density surface, I overlaid 200m^2 grids on the entire study area. Line transects were subdivided into equal segments of 200 m. Species detections were assigned to the respective segments. Using generalized additive models (GAMs) (Miller et al. 2013), species detections (counts) were modelled as a function of spatially explicit habitat covariates (Miller et al. 2013). The spatial covariates chosen for density surface modelling were: (i) NDVI (obtained from LANDSAT 4-5 Thematic Mapper imagery of 30×30 m resolution), (ii) distance from road, water and agriculture (calculated as Euclidean distances) using shape files of these variables in ArcMap10.2 and (iii) distance from open forest, medium dense forest, very dense forest and non forest areas (calculated as Euclidean distances) using forest type map (FSI) of the study area. The models also incorporated area of the segment as an offset term.

A two stage approach was employed for Density Surface Modelling:

(1) Absolute densities of chital and sambar were estimated under the distance sampling approach using the program Distance 6.2 (Hedley and Buckland 2004). Because of less number of detections, other species were excluded from the analysis. For both chital (n=56) and sambar (n=36), half-normal key with no adjustment was found to be the best fit detection model based on Akaike Information Criterion (AIC) and goodness-of-fit (GOF-p) tests (**Table 2**). These detection functions were then imported to obtain per segment count or abundance estimates in the program R (version 3.2.3).

(2) The species count per segment was then modelled as a sum of functions of the segment-specific and spatially explicit habitat covariates (predictor variables). Generalised Additive Models (GAMs) were run using different combinations of predictor variables. Best models were selected based on percent deviance explained and generalised cross validation (GCV) scores. All these analyses were done in R (version 3.2.3) using the package *dsm* (Miller et al. 2013).

The best generalised additive models (GAMs) for chital and sambar were used to generate a density surface map for both species (**Figure 7 & Figure 8**).

4.0 RESULTS:

4.1 Wildlife Mortality:

A total of 222 road-kills of four different taxa (reptiles, amphibians, birds and mammals) were recorded from 5th September 2016 to 18th April 2017 **(Appendix I)**. Total road-kills detected on the NH-74 comprised of 37 species (Reptiles= 8, Birds= 12, Mammals=17). In terms of number of road-kills, mammals (n=127) were detected the most followed by birds (n=56) and reptiles/amphibians (n=31).

Seasonal variation in number of road-kills was also observed. The pattern was most obvious for birds where most of the road-kills (n=39) took place during December to January (**Figure 4**). Amphibians and reptiles had peak mortalities during September to October. Small mammals witnessed a steady increase in the number of road-kills from October to March. Number of large mammal road-kills remained almost constant across months.

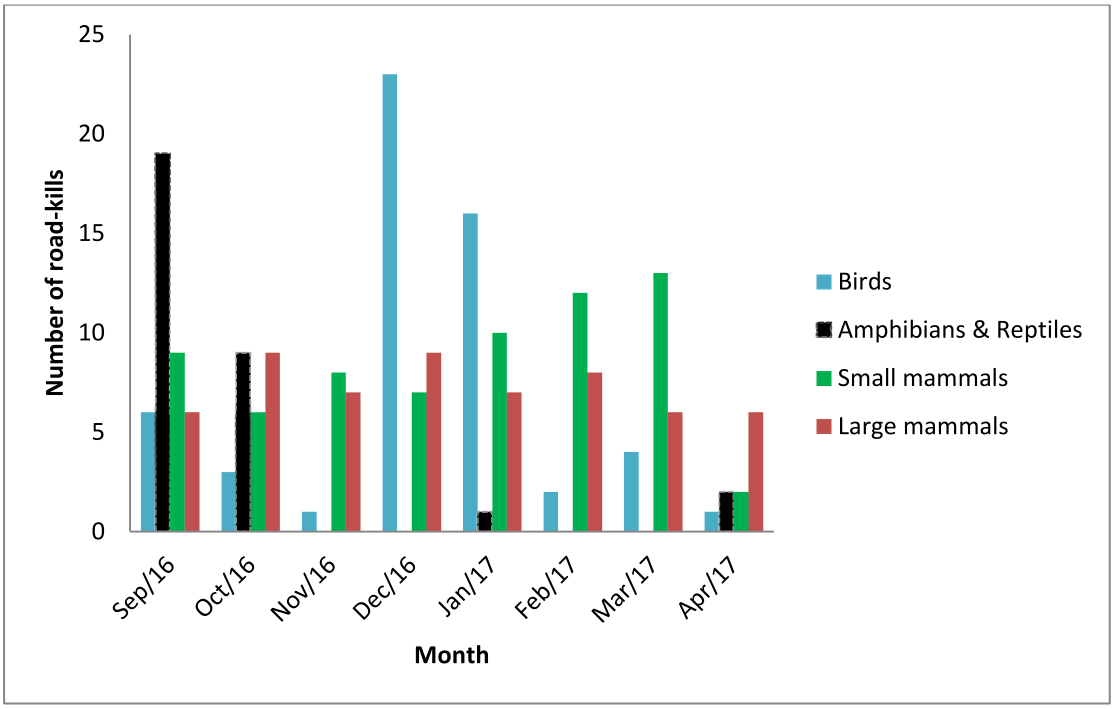

Figure 4: Seasonal variation in the number of road-kills for each taxon.

4.2 Variables influencing road-kills:

Number of road-kills per 500m section was best explained by a 4 parameter model (of the Poisson family) having the additive effects of visibility, road feature, distance to water and number of animal trails. The model was given by: *Number of road-kills per section = 2.2801 -1.13*visibility -0.94*road feature -0.22*distance to water +0.07*number of animal trails*

According to the best model, number of road-kills were found to be negatively correlated with visibility, road feature and distance to water and positively correlated with number of animal trails.

Table 1: Model selection statistics and parameter estimates of the best model relating number of road-kills per road section (500m) to visibility (vs), road feature (rf), distance to water (dw) and number of animal trails (nt).

Model	Intercept	vs (SE) (p-value)	rf (SE) (p-value)	dw (SE) (p-value)	nt (SE) (p-value)	AIC
vs+rf+dw+nt	**2.2801**	**-1.13 (0.37) (0.002 **)**	**-0.94 (0.25) (0.000 ***)**	**-0.22 (0.41) (0.58)**	**0.07 (0.02) (0.007 **)**	**269.8**
vs+nt	1.2710	-0.34 (0.29) (0.23)	-	-	0.10 (0.02) **(0.000***)**	280.69
dw+nt	1.0124	-	-	0.09 (0.38) (0.80)	0.10 (0.02) **(0.000***)**	282.04
vs + dw + nt	1.2829	-0.35 (0.30) (0.24)	-	-0.03 (0.40) (0.93)	0.10 (0.02) **(0.000***)**	282.68
vs+dw	1.6467	-0.42 (0.29) (0.15)	-	-0.15 (0.37) (0.68)	-	294.99

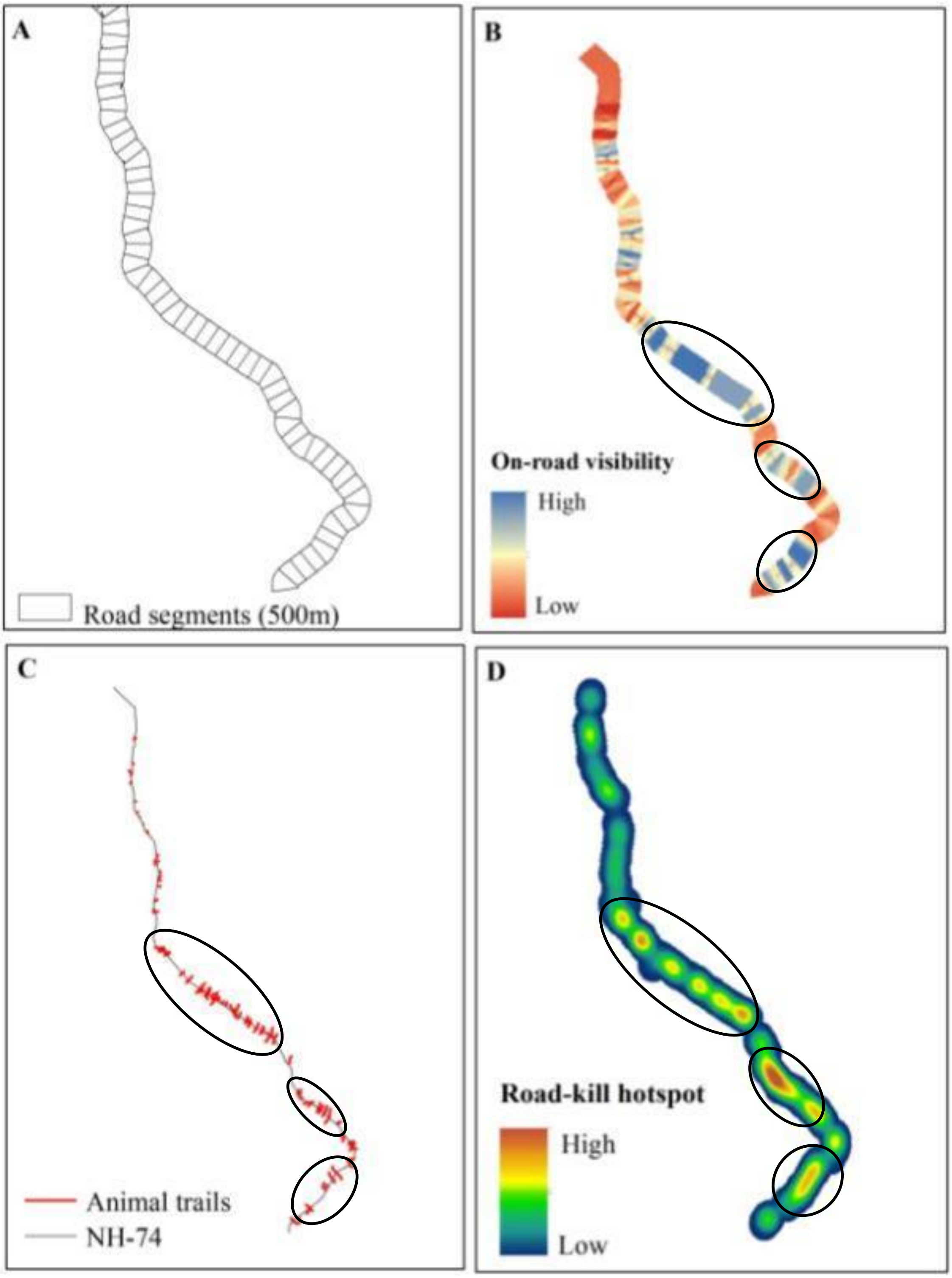

Figure 5: A represents NH-74 subdivided into 500m segments; B represents on-road visibility (in metres) in each segment; C represents number of animal trails intersecting the highway and D shows road-kill hotspots on NH-74

Figure depicted above reveals interesting patterns. A majority of road-kill hotspots are located in segments where on-road visibility is higher (**Figure 5**). The rest of the hotspots are located in curved segments of the highway.

Also note that a high number of road-kills occurred in segments with high animal trail density (number of trails/segment). Interestingly, the segments with two sided trails experienced the most number of road-kills as compared to one sided trails.

One time survey to estimate daily traffic volume showed a very high traffic plying on the road. In all, we counted 13405 vehicles for a day. Light vehicles (6241) formed the major chunk of the observed traffic. Heavy vehicles (3514) and two-wheelers (3650) contributed almost equally to the overall traffic volume (**Figure 6**).

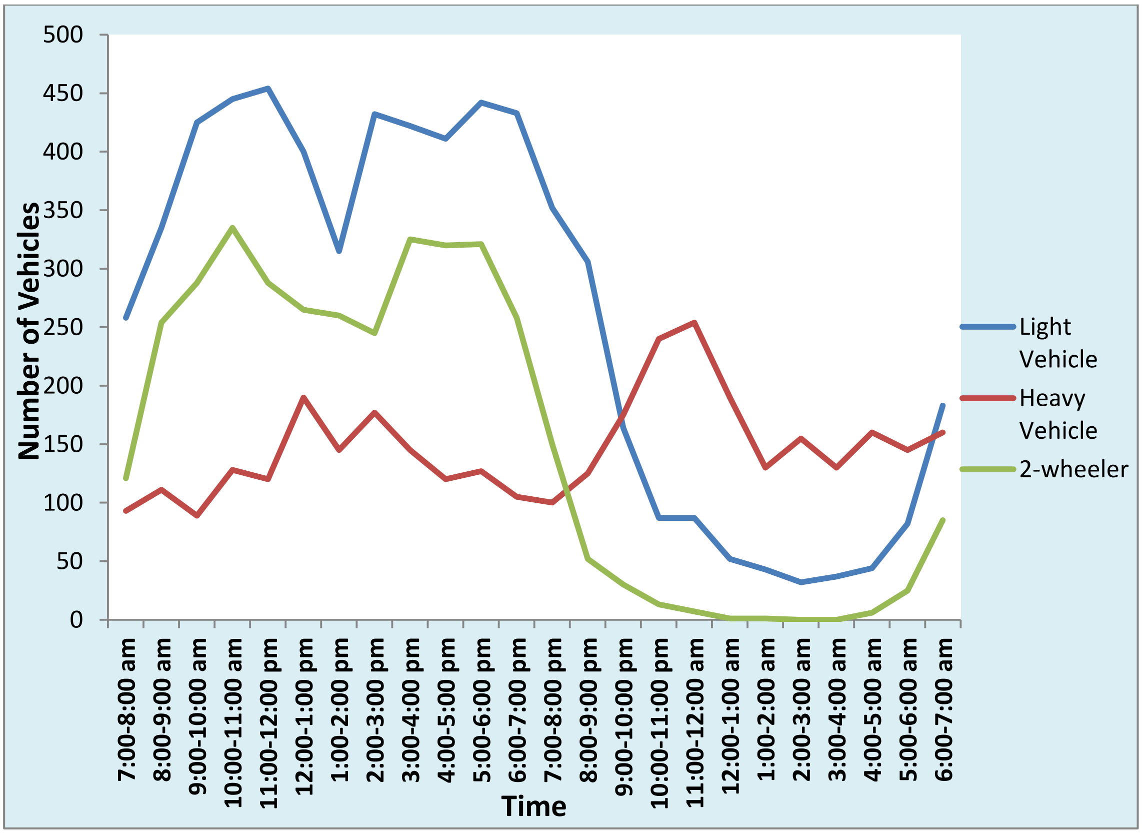

Figure 6: Temporal fluctuations in traffic volume of the three vehicle types: Light vehicles, Heavy vehicles and two-wheelers.

4.3 Density Surface Maps for chital and sambar:

The GAM results (**Table 2**) show that distance from moderate dense forest (mdf) and NDVI mean (pca3_mean) had significant effect on sambar densities. While chital densities were significantly influenced by four variables: distance from road (road_mean), distance from water (water_mean), distance from open forest (open_for) and distance from moderate dense forest (mdf). The GAM response curves for sambar and chital are shown in **Appendix II**.

Table 2: The best-supported model for each species. Presented per species are the number of detections (n), the best-fit detection model with goodness-of-fit statistics [GOF-p (d.f.)], the significant smooth functions (with estimated degrees of freedom) included in the final generalized additive model, percentage deviance explained by the final model and overall density (individuals per km^2) with associated standard errors (SE) of each species

Species (n)	**Sambar (36)**	**Chital (56)**
Detection model	Half-normal	Half-normal
GOF-p [d.f.]	0.7087 [2]	0.9185 [3]
Generalized additive models		
Intercept	-18.02***	-12.04***
s(road_mean)	-	7.65***
s(water_mean)	-	6.84***
s(agri_mean)	-	-
s(non_for)	-	-
s(open_for)	-	2.01***
s(mdf)	9.570e-01**	0.96***
s(vdf)	-	-
s(pca3_mean)	2.536e+00**	-
Deviance explained (%)	56.5%	61.9%
Overall density ± (SE) (individuals per km2)	14.92 ± 7.28	24.16 ± 7.09

Using the best-supported GAM we then extrapolated sambar and chital densities across the study area. The resulting density surface maps for both species are depicted below.

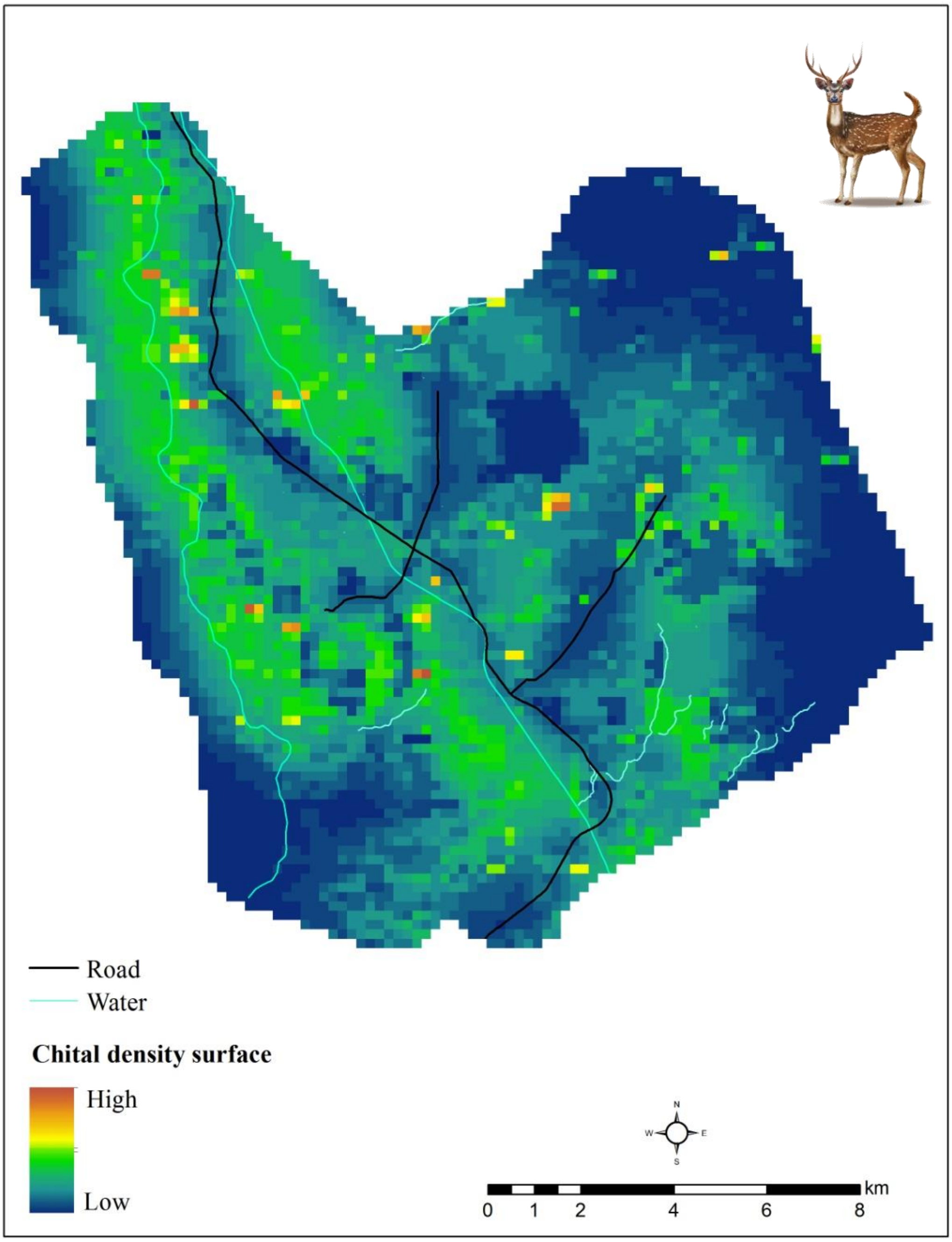

Figure 7: Density surface map for chital

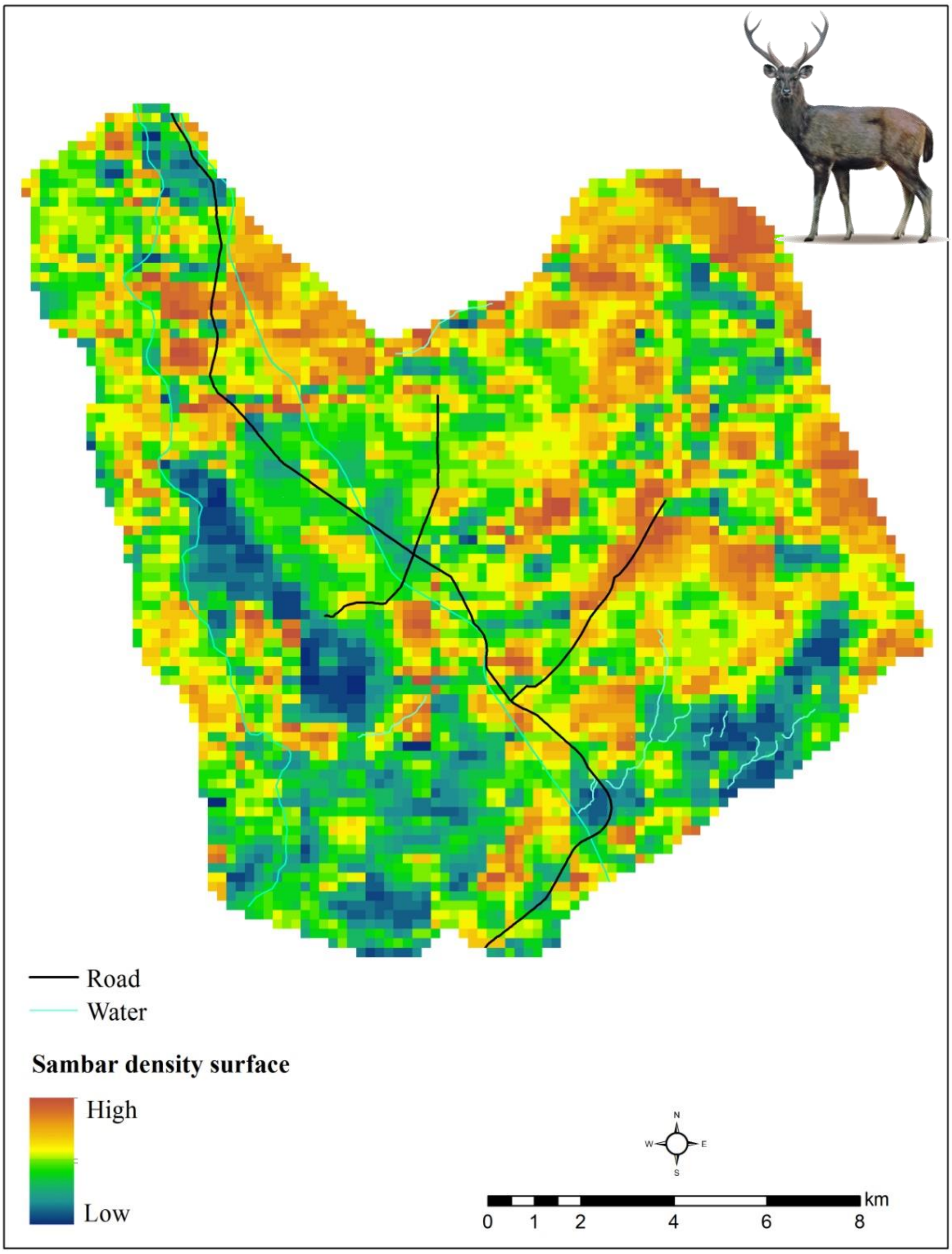

Figure 8: Density surface map for sambar

4.4 Pellet encounter rate as a proxy for intensity of habitat use:

Pellet encounter rate can well represent the time spent by a particular species in a given area. So, higher pellet encounter rates would indicate more time spent by a species in a particular area. Pellet encounter rates thus can be used as a proxy for intensity of habitat use.

Non-linear regression analysis was done between pellet encounter rate and distance class using exponential association curve which is given by:

$$y = a + (b-a)*(1-\exp(-K*x))$$

Table 3: Non linear regression analysis results between pellet encounter rate and distance class for Highway and ancillary road, where 'a' is intercept, 'b' is plateau and 'K' is rate of change per distance class.

Road Type	Coefficient	Estimate	P - value	Correlation coefficient (r)
Highway	a	-22.90 ± 21.92	0.31	0.85
	b	9.52 ± 0.68	5.03e-10 ***	
	K	1.41 ± 0.67	0.05 .	
Ancillary Road	a	-13.42 ± 26.26	0.61	0.71
	b	7.60 ± 0.55	7.21e-10 ***	
	K	1.58 ± 1.24	0.22	

For the two road types, highway as well as ancillary roads, pellet encounter rate was found to be significantly correlated with distance class i.e., 0.85 (highway) and 0.71 (ancillary roads) **(Table 3)**. Our results show that pellet encounter rate for both highway (red) and ancillary road (green) increase up to a distance of 200m from the road and then satiates for higher distance classes (**Figure 9**).

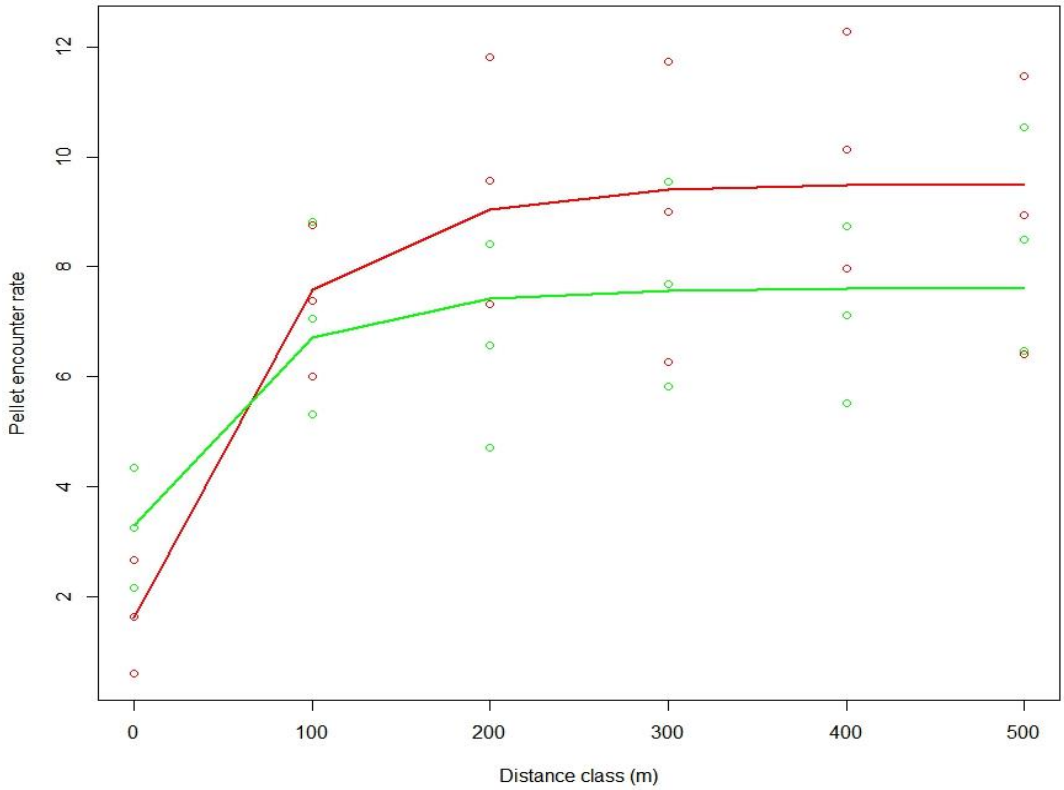

Figure 9: Pellet encounter rate as a function of increasing distance from the road. Red and green curves depict National Highway 74 and ancillary road respectively.

5.0 DISCUSSION:

A priority site for conservation:

My results suggest high densities of chital and sambar (**Table 2**) in the study area. The densities that I have estimated in the study area (reserved forest) are comparable with the densities estimated within the protected areas in the landscape. For example, in the adjoining Rajaji Tiger Reserve, individual density estimates of chital and sambar are 16.02 (±5.79) and 12.06 (±3.75) respectively (Jhala et al. 2015). My results establish clearly that the area, although being managed as reserved multiple-use forests, still support rich wildlife. The prey densities that the area supports indicate that it can potentially support a good density of the endangered tigers. Therefore, the study area qualifies to be a high-priority site for long-term tiger conservation in the greater Terai Arc Landscape. My results reiterate the need to accord conservation priorities to the study area and my assessment of road kill is a first step towards it.

Ungulates use habitats along the roadside less intensively:

My results also indicate that the road profoundly influence habitat use patterns of ungulates, whereby, the intensity of habitat use decreased alongside the road. This finding is intuitive and expected as roads induce barrier effects (road avoidance, vehicle avoidance and emission avoidance) (Rondinini and Doncaster 2002). Contrary to my expectation, similar trends were observed for both roads (National Highway and ancillary road) regardless of the traffic volume. Based on the results, it can be inferred that both chital and sambar exhibited road avoidance behaviour. Since both the roads (highway and ancillary) were paved, the road avoidance behaviour shown by both the species is specifically gap avoidance behaviour. Because vehicular emissions were not quantified, effects of the same on avoidance behaviour cannot be told apart. This finding is further corroborated by the pattern of density distribution of both species in relation to road (**Figure 7 & Figure 8**). Chital had low densities (in immediate edge) along the highway as well as ancillary roads. Higher chital densities were observed with increasing distance from the road. Such patterns for sambar were less prominent and were observed only along certain stretches of the road.

Patterns of correlates of road-kills:

NH-74 cuts through forested areas which support high densities of chital and sambar (**Figure 7 & Figure 8**). Such high densities in these areas indicate that an individual of a species is bound to encounter the road, mainly to gain access to resources on the other side of the road. Patterns of animal movement in forests are mainly guided by paths of the least resistance (trails), especially for large mammals. In such a scenario, these animals become more susceptible to mortality because of wildlife vehicle collisions. Interestingly, chital (n=11) and sambar (n=19) mortalities account for 50% of all the large mammal road-kills (n=60) (**Appendix I**).

The results show that the most number of mortalities were observed in segments with a higher number of trails intersecting. The same trend was observed in segments when there was more number of two-sided trails on the highway. Since such trails act as entry and exit points on the road it is likely that large mammals use them more often and hence become more vulnerable to road-related mortality.

Visibility and road feature were also seen to influence patterns of road-kill. But their effects were confounding because high mortalities occurred in the straight as well as curved segments (**Figure 5**). Such high mortalities could be because of presence of a high number of trails in those stretches. Over-speeding of vehicles in straight segment could also be affecting mortalities.

Apart from the best model (**Table 1**), other models also show a significant relationship between road-kills and number of trails. All these patterns indicate that trail density is the key determinant influencing road-kills on NH-74.

Of all the mortalities, mammals constitute 56.95%, birds 25.56% and reptiles/amphibians 13.9%. High percentage of mammal road-kills can be attributed to their terrestrial affinity. Further, mammal mortalities are comparatively easier to detect. Relatively less number of bird road-kills suggested that most species can easily avoid collisions with vehicles. But low flying, ground dwelling species and scavengers may be exceptions (Benítez-López et al. 2010). Such species are considered to be more prone to vehicle collisions. Our data appears to support this argument, as almost all the bird species road-kills fell into at least one of the above mentioned categories (**Appendix I**). High number of bird species road-kills during peak winters can be explained by local increase in bird abundances during winters due to local migration of birds. Relatively lower activity can explain the low number of reptile/amphibian road-kills from November to March.

In all, species ecology and behaviour, its distribution and abundance, road, traffic and habitat characteristics, are known to together determine the probability of road-kills (Seiler 2003). It appears that NH-74, besides directly causing mortalities, also created an effect zone of about 200m.

5.1 Mitigation:

Road ecology studies carried out around the world have suggested many effective mitigation measures to reduce wildlife mortalities. Some of the most effective mitigation techniques are: wildlife fencing, rumble strips, overpasses or underpasses, banning night traffic, lower speed limits, warning signs, mirrors and reflectors (Romin and Bissonette 1996). Effectiveness of any of the above measures can be highly specific to site and species. Mitigation measures should ideally increase permeability without increasing road-kill probability.

During our study rumble strips were installed on NH-74. However, the rumble strips were soon damaged and therefore rendered ineffective, owing to the high volume of heavy vehicles plying the highway. We didn't find any significant reduction in road-kills during the duration.

My results suggest that there are three major road kill hot spots. Since the major road-kill hotspots found in our study are clumped in 5-6 km stretches, I suggest three sectors where mitigation structures are crucial to reduce the road kills. They are: 1) Chandi Bridge to Tedhi puliya 2) Peeli river to Rawasan river and 3) Gendikhata to Chidiyapur (**Figure 10**). Although the first stretch recorded only moderate number of road-kills, it is widely used by Elephants. In the identified stretches, construction of flyovers can help wildlife move underneath the structure while vehicles can pass unhindered over the flyover. Further, till flyover is fully commissioned, as a stopgap measure, it is important to erect speed control humps in locations where many wildlife trails intersect the road. Furthermore, there is an urgent need to put up more signages alongside the entire stretch of the road alerting motor vehicle drivers of animal crossings.

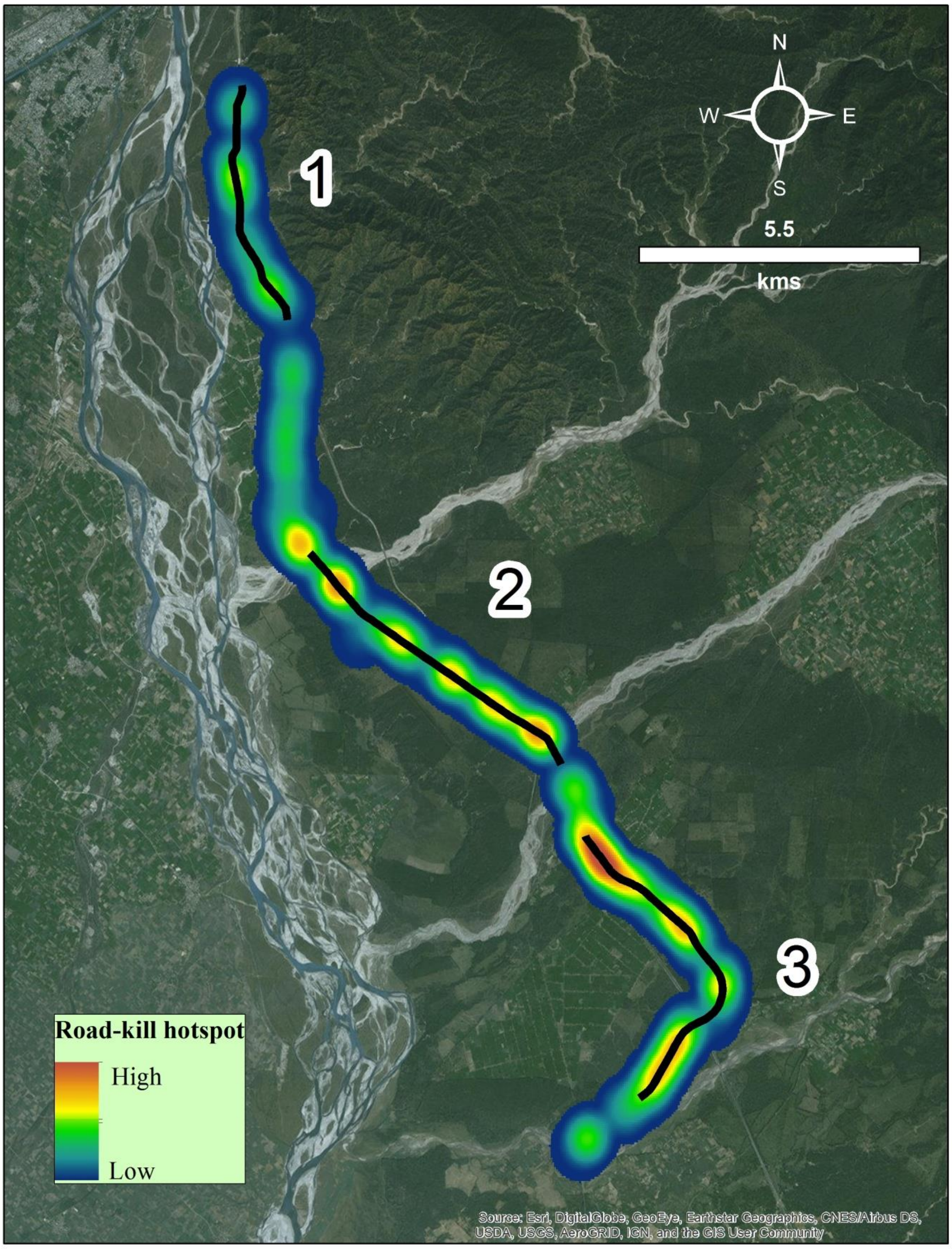

Figure 10: **Mitigation: Building of flyovers suggested through 3 stretches on NH-74. '1'- Chandi Bridge to Tedhi puliya '2'- Peeli river to Rawasan river '3'- Gendikhata to Chidiyapur**

6.0 CONCLUSION:

What has been done cannot be undone. The effects resonate for eternity. But appropriate and timely intervention can reduce the impacts of our wrongdoings. As a rapidly developing tropical country, India faces grave challenges in terms of conflict between its development goals and conservation of the remaining wildlife habitats. Therefore we need robust scientific database to 1) avoid construction of roads through protected areas and 2) in cases where such development is inevitable, suggest proper mitigation measures to reduce the deleterious effects of roads on wildlife (WII, 2016) and 3) develop suitable strategies to mitigate impacts of existing roads on wildlife.

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Plate 1: Large Mammal Road-kill. Clockwise from top-left: Golden Jackal, Sambar, Wild pig and Nilgai

Plate 2: Small Mammal Road-kill. Clockwise from top-left: Porcupine, Indian Pangolin, Small Indian Civet and Indian Fruit Bat

Plate 3: Bird Road-kill. Clockwise from top-left: Asian Koel, Collared Scops Owl, Common Myna and Black Kite

Plate 4: Reptile Road-kill. Clockwise from top-left: Indian rock python, Russell's viper, King cobra and Indian flap-shell turtle

Plate 5: Elephants crossing at Tedhi Puliya on NH-74

Appendix I:

Animal species road-kills recorded on National Highway 74

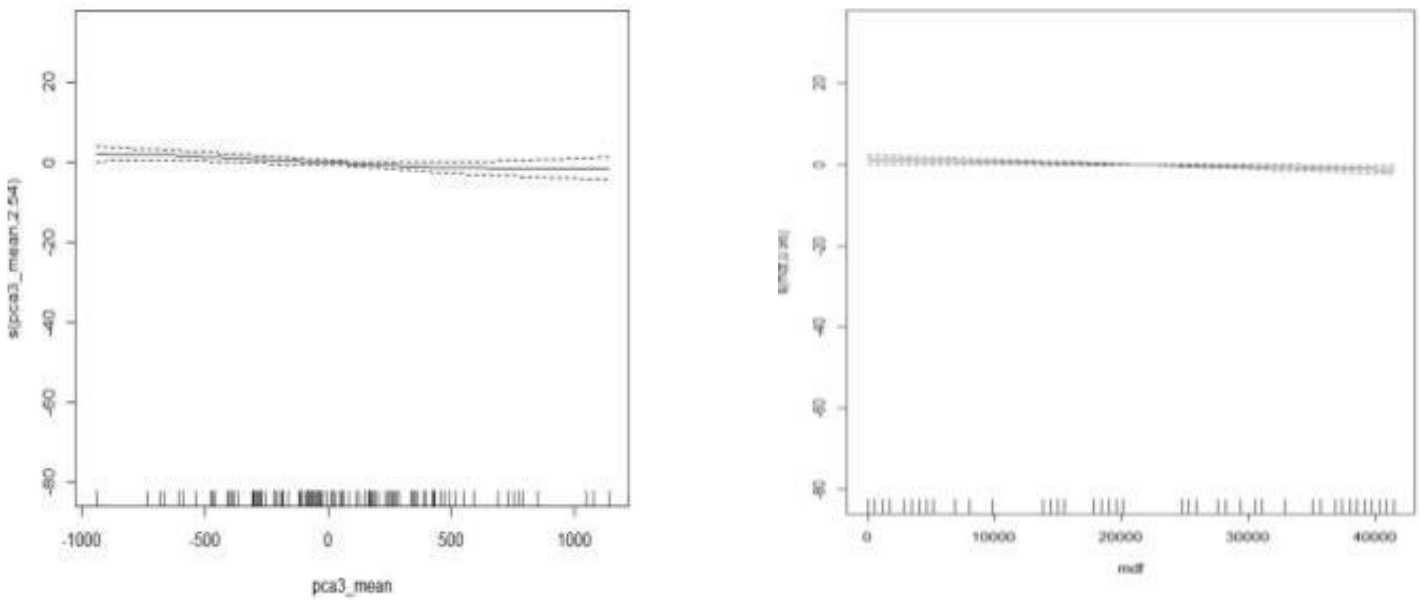
S.No.	**Common Name**	**Scientific Name**	**No. of road-kills**
Reptiles/Amphibians			
1	Common krait	*Bungarus caeruleus*	4
2.	Indian black turtle	*Melanochelys trijuga*	1
3.	Indian flap-shell turtle	*Lissemys punctata*	2
4.	Indian rock python	*Python morulus*	2
5.	King cobra	*Ophiophagus hannah*	4
6.	Monitor Lizard	*Varanus bengalensis*	3
7.	Russell's viper	*Daboia russelii*	5
8.	Striped keelback	*Amphiesma stolatum*	1
9.	Unidentified frogs/toads	-	3
10.	Unidentified lizard	-	1
11.	Unidentified snakes	-	5
		Total	**31**
Birds			
12.	Asian Koel	*Eudynamys scolopaceus*	2

S.No.	Common Name	Scientific Name	No. of road-kills
13.	Black Kite	*Milvus migrans*	1
14.	Collared Scops Owl	*Otus lettia*	5
15.	Common Myna	*Acridotheres tristis*	2
16.	Coucal	*Centropus sp.*	3
17.	Egret	*Egretta sp.*	2
18.	Himalayan Griffon Vulture	*Gyps himalayensis*	2
19.	Indian Pond Heron	*Ardeola grayii*	2
20.	Oriental Pied Hornbill	*Anthracoceros albirostris*	1
21.	Peacock	*Pavo cristatus*	2
22.	Red Jungle Fowl	*Gallus gallus*	1
23.	Red-vented Bulbul	*Pycnonotus cafer*	2
24.	Unidentified bird	-	8
25.	Unidentified Owlet	-	23
		Total	**56**
Mammals			
Small Mammals			
26.	Black-naped Hare	*Lepus nigricollis*	9

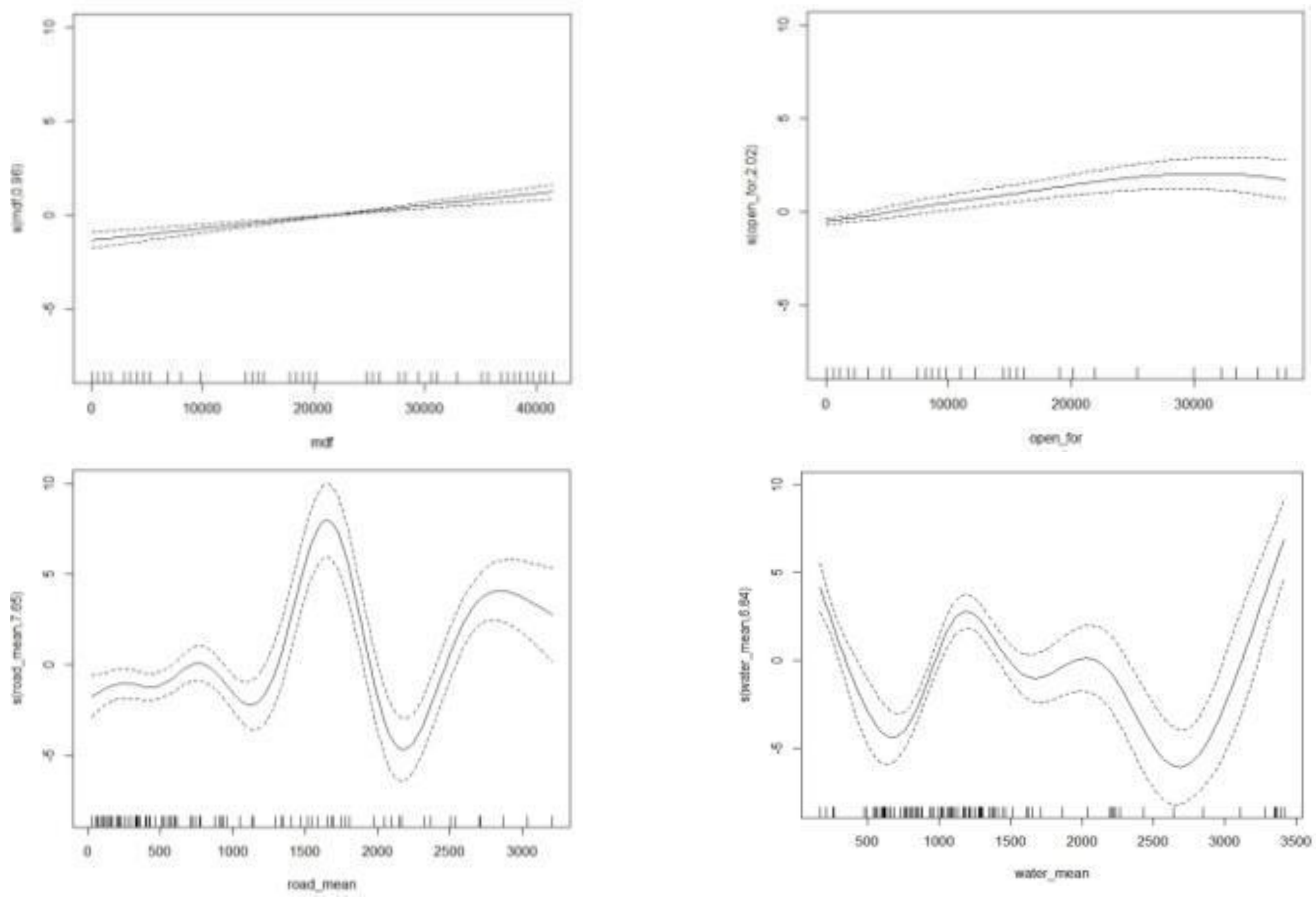
S.No.	Common Name	Scientific Name	No. of road-kills
27.	Common Palm Civet	*Paradoxurus hermaphroditus*	10
28.	Indian fruit bat	*Pteropus giganteus*	2
29.	Indian grey mongoose	*Herpestes edwardsii*	4
30.	Indian Pangolin	*Manis crassicaudata*	1
31.	Mouse	*Mus pp.*	16
32.	Porcupine	*Hystrix indica*	7
33.	Small Indian Civet	*Viverricula indica*	12
34.	Unidentified Small Mammal	-	5
35.	Yellow-throated marten	*Martes flavigula*	1
		Total	**67**
		Large Mammals	
36.	Chital	*Axis axis*	11
37.	Himalayan black bear	*Ursus thibetanus*	1
38.	Jackal	*Canis aureus*	3
39.	Leopard	*Panthera pardus*	2
40.	Nilgai	*Boselaphus tragocamelus*	1
41.	Rhesus macaque	*Macaca mulatta*	16

S.No.	Common Name	Scientific Name	No. of road-kills
42.	Sambar	*Rusa unicolor*	19
43.	Wild pig	*Sus scrofa*	7
		Total	**60**
44.	**Unidentified Species**	**Total**	**8**
		Grand Total	**222**

Appendix II:



Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit model for sambar.



Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit model for chital.