IMPACTS OF ROAD RELATED DISTURBANCES ON MAMMALIAN AND VEGETATIONAL ASSEMBLAGES: A CASE STUDY OF SH-33 PASSING THROUGH NAGARAHOLE TIGER RESERVE, KARNATAKA

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT, IN PARTIAL FULFILLMENT OF THE MASTER'S DEGREE IN

WILDLIFE SCIENCE

Submitted by

SIVA.R

Under the Supervision of

Dr. Bilal Habib

Mr. Sanjay Gubbi

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

June 2019

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CERTIFICATE

This is to certify that **Mr. Siva. R** of the Wildlife Institute of India has carried out a piece of original research work entitled **"Impacts of road related disturbances on mammalian and vegetational assemblages: a case study of SH-33 passing through Nagarahole Tiger Reserve, Karnataka"**, in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under my supervision at the Wildlife Institute of India from December 2018 to June 2019. I also certify that this work has not been submitted for any other degree of any university.

Date: June 30, 2019
Dehradun

Dr. Bilal Habib
Scientist E/HoD
Supervisor

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DECLARATION

I, **Siva. R**, hereby declare that the research work entitled **"Impacts of road related disturbances on mammalian and vegetational assemblages: a case study of SH-33 passing through Nagarahole Tiger Reserve, Karnataka",** carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of **Dr. Bilal Habib**, at the Wildlife Institute of India and **Mr. Sanjay Gubbi**, at the Nature Conservation Foundation from December 2018 to June 2019. I hereby declare that this work has not been submitted for any other degree of any university.

Date: June 30, 2019 Mr. Siva. R
Place: Dehra Dun (XVI M.Sc. Course)

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No acknowledgment is ever complete, if I have missed anyone, dear friends, it was not deliberately and I plead your pardon.

Finally, I would like to dedicate my thesis to my late sister R. Surya Devi.

Siva.R

EXECUTIVE SUMMARY

Upcoming economies such as India need to strengthen their road network for the socioeconomic development of the country. While roads are important to the country, they are a threat to wildlife when they pass through the protected areas and other ecologically sensitive areas. Multiple impacts of roads on wildlife range from habitat loss, edge effects, vehicular traffic, pollution, animal mortality, barrier effect to invasion by alien flora and fauna. This project revealed the impacts of road-related disturbances on mammals and vegetation in Nagarahole Tiger Reserve, Karnataka. Mysore-Mananthavadi road (SH-33) is passing through the southern part of Nagarahole Tiger Reserve that has two segments in which one segment is decommissioned and another segment is closed for the vehicular traffic during the night. Here, I have compared the habitat use of mammals in these two segments using camera traps and assessed the impact of road-related disturbances on vegetation in this road by vegetation sampling. Vehicular density was estimated using the camera traps in these two segments.

For camera trapping and vegetation sampling, 0.5 Sq.km (700 m × 700 m) grids were made up to 2.1 km on either side of the road. A total of 111 camera traps were deployed along the road by fixing one camera in each grid. Camera trapping was done from March 2019 to April 2019 with an effort of 1583 camera trap days and 1132 camera trap days in the decommissioned and night traffic closed road respectively. Vegetation sampling was done in 326 vegetation points randomly as well as in camera trap points. In these random points and in camera trap location, three different size plots of 1×1 m, 5 m radius, 10 m radius were laid for herbs & grasses, shrubs, and trees respectively. Other than these, diameter at breast height and canopy cover of trees were measured in 10 m radius plots and invasive species cover was measured in 5m radius plot.

The number of vehicles per hour is calculated from the number of vehicles per day. Activity pattern and encounter rates for nine mammals were calculated using ‘Camera-trap R’ package in ‘R’ and confidence intervals were estimated using the Monte Carlo simulations with 10,000 bootstraps. The Shannon-Wiener diversity index

is used to calculate the species diversity between the decommissioned road and night traffic closed road and vegetation composition across different distance gradients (A – 0 to 499 m, B – 500 to 999 m and C – 1000 to 2100 m) was analyzed by using ANOVA test.

The mean number of vehicles were higher in the night traffic closed road (56.0 ± 2.0 /h) than the decommissioned road (1.8 ± 0.1/h). The activity pattern of mammals seems to be similar in these two segments. But the encounter rates of Barking deer, Chital, Elephant, Sambar, Tiger and Wild pig were higher the decommissioned road than the night traffic closed road, not for Indian gaur and Leopard.

Species Diversity was higher in the night traffic closed road than the decommissioned road for herbs and shrubs but lower for trees. Herb diversity did not differ across the distance gradients for both roads. Shrub diversity changed with distance from the road for night traffic closed road but not for the decommissioned road.

Canopy cover was significantly higher for night traffic closed road across all distance categories and increased with distance from the road but not for the decommissioned road. Invasive species cover was significantly higher for the decommissioned road as compared to night traffic closed road and it decreased with increasing distance from the road only for to night traffic closed road.

The study results revealed the avoidance of vehicular traffic segment by the mammals and activity pattern seems to be relatively unaffected by the vehicular traffic. It also shows the change in the vegetation composition and spread of invasive species due to road related disturbances.

1. INTRODUCTION:

Roads are known to cause impacts on wildlife which range from habitat loss, edge effects, vehicular traffic, pollution, animal mortality, barrier effect to invasion by alien flora and fauna (Andrews, 1990; Forman et. al, 2003; Goosem, 2007). Roads and other infrastructure seem to negatively affect bird and animal abundance. Edges created by the roads affect the structure and composition of vegetation (Harper et. al, 2005) and roads also facilitate the spread of invasive species (Mortensen et. al, 2009). It is very important to understand the change in vegetation community and change in the behaviour of mammals in response to road-related disturbances.

Impacts of the road network can affect the herpetofauna, birds and mammal abundances negatively or positively and some of the animals never respond to the road (Fahrig & Rytwinski, 2009). In herpetofauna, species such as northern leopard frog (*Rana pipiens*), green frog (Rana clamitans) (Bouchard et al., 2009; Carr & Fahrig, 2001) and Black rat snake (*Elaphe obsoleta*) (Row, Blouin-Demers & Weatherhead, 2007) are negatively affected by the road. But some of the snake species like the Glossy snake and Pine snake tend to positively attracted towards road mainly for thermoregulation (Sullivan, 1981). They are also highly prone to getting killed by roadkill.

Roads and other infrastructure seem to negatively affect bird and animal abundances up to 1 km and 5 km respectively (Benítez-López, Alkemade & Verweij, 2010). Birds abundances near road decrease due to traffic noise (Polak et. al, 2013) especially for songbirds when they breed (Halfwerk, Holleman & Slabbekoorn, 2011) but it also increases some of the ground-dwelling birds (Li et. al, 2010). Since roads are providing availability of dead animals due to roadkill, attracts other wildlife resulting in enhanced mortalities (Beckmann & Shine, 2011; Dean & Milton, 2003; Lambertucci et. al, 2009). Roadkill carcasses are scavenged by mammalian scavengers such as Red fox (*Vulpes vulpes*), Weasel (*Mustela nivalis*) and Eurasian badger (*Meles meles*) and also by raptors and other scavenging birds (Mata, Ruiz-Capillas & Malo, 2017; Schwartz et. al, 2018; Slater, 2002).

Most of the studies have been focused on the hotspots of animals to be likely killed based on the roadkill data (Gomes et. al, 2009; Hobday & Minstrell, 2008; Langen, Ogden & Schwarting, 2009) and based on the models (Malo, Suárez & Diez, 2004; Seiler, 2005). Some of the studies suggested that vehicle-animal collision could be related life history strategies of the animals (Litvaitis & Tash, 2008; Rytwinski & Fahrig, 2012) and diet and body size of the animals (Cook & Blumstein, 2013).

Barrier effects of roads widely have been documented across taxa from herpetofauna (Shepard et. al, 2008), carnivores (Riley et. al, 2006; Schwab & Zandbergen, 2011), ungulates (Dyer et. al, 2012; Frantz et. al, 2012), small mammals (Ascensão et. al, 2016; Gerlach & Musolf, 2000; McGregor, Bender & Fahrig, 2008; Rico, KindlmAnn & Sedlacek, 2007), arboreal mammals (Goosem, Weston & Bushnell, 2005) and birds (Laurance, Stouffer & Laurance, 2004). Habitat permeability of carnivore community significantly reduced than the ungulate community on high traffic roads (Alexander, Waters & Paquet, 2005).

Vehicular traffic is one of the major impacts of the road. It alters the behaviour of animals and it is responsible for road kills. The pollution coming from the vehicle affects the health of plants and animals. Road traffic has altered the behaviour of Prairie dog (Shannon et. al, 2014), Elk deer (Clair & Forrest, 2009; Gagnon et. al, 2007), Moose (Laurian et. al, 2008), Red deer (D'Amico et. al, 2016), Grizzly bear (Northrup et. al, 2012; Waller & Servheen, 2005), Lynx (Baigas et. al, 2017) and Red fox (Baker et. al, 2012) spatially as well as temporally.

Movement of medium-sized mammals are hindered by roads and they had the high amount of mortalities with respect to the widening of the road (Litvaitis et. al, 2015; Oxley et. al, 1974). Edges created by roads are providing habitat for small mammals (Adams & Geis, 1983; Bissonette & Rosa, 2009) adjacent to the roads which alter the species composition.

Studies have documented impacts of roads on vegetation composition around the world (Avon et. al, 2010; Gelbard & Belnap, 2003; Johnston & Johnston, 2004; Müllerová, Vítková & Vítek, 2011; Watkins et. al, 2003). Since canopy is absent in road clearings, light-loving species and weeds are growing more adjacent to the road which alters plant species composition previously present in the habitat (Angold, 1997; Goosem, 2007; Johnston & Johnston, 2004; Laurance & Goosem, 2008; Müllerová, Vítková & Vítek, 2011; Parendes & Jones, 2000). Physical and chemical conditions are different in road edges than in the natural conditions and species diversity is higher near to the road while comparing to the natural conditions (Müllerová, Vítková & Vítek, 2011; Johnston & Johnston, 2004). This is because of alterations during the construction and maintenance of the road and dust deposition and exhausts from the vehicles (Angold, 1997; Cape et. al, 2004). The light-demanding species and invasive plants make the shift in native plant community and outcompete the native vegetation especially the understory vegetation (Johnston & Johnston, 2004; Kolb et. al, 2002; Watkins et. al, 2003). There is a decreasing trend of invasive plant species with the increasing distance from the road shoulder due to less light availability (Amor & Stevens, 1976). The edge effect found up to 200 meters from the road (Angold, 1997).

Roads facilitate the spread of invasive species in natural areas (Gelbard & Belnap, 2003; Mortensen et. al, 2009; Parendes & Jones, 2000). Vehicles act as dispersers of seeds for plants (Tikka, Högmander & Koski, 2009; Zwaenepoel, 2006) from one place to another place which includes invasive alien plants (Ansong & Pickering, 2013; Lonsdale & Lane, 1994; Von der Lippe & Kowarik, 2007). Mostly smaller size seeds like grass seeds are dispersed by the vehicle tires in which seeds are attached with the mud (Schmidt, 1989).

India, a megadiverse country is a home to nearly 4 global biodiversity hotspots out of 34 hotspots in the world and it harbours 45,000 species of plants and 91,000 of animals with only 2.4% of the world's land area (Pande & Arora, 2014). Simultaneously, Upcoming economies such as India need to strengthen their road network for development and over the last two-and-a-half decades have yielded a significant expansion of road network (56.03 lakh km) in the country (Government of India, 2016). Roads cut through the Protected Areas that cover only 4.9% of the geographical area of our country India (WII, 2018) and other ecologically sensitive areas.

A large number of roadkill studies from India have only explained the visible patterns found in the impact of the road network (Baskaran & Boominathan, 2010; Jeganathan et. al, 2018; Kumara et. al, 2000; Selvan et. al, 2012; Vijayakumar, Vasudevan & Ishwar, 2001) and very few studies explained the process behind the impact of the road (Pragatheesh, 2011; Vidya & Thuppil, 2010; Gubbi, Poornesha & Madhusudan, 2012). Among them, two studies looked into the behaviour of large mammals and one study was about Rhesus macaque behaviour.

Studies that assess the impact of roads on vegetation composition and behaviour of mammals that are inadequate. Here I have compared the impacts of the road on mammals the vegetation community. This study will add further knowledge about the impacts of road and it will help the engineers and policymakers while planning for construction of new or upgrading of the existing road network.

In case of the impact of the road on vegetation, there has been only one study on native and non-native plants richness and diversity in relation to the use of roads (Sharma & Raghubanshi, 2009).

1.1. Objectives:

The specific objectives of the study are

i) To understand the habitat use of mammals along the Mysore-Mananthavadi road passing through Nagarahole Tiger Reserve at different gradients and in both decommissioned road and night traffic closed road; and

ii) Explore how the road related disturbances affect the vegetation composition and spread of invasive plants across different gradients from the road in both decommissioned road and night traffic closed road.

1.2. Hypotheses:

i) The habitat use of mammals may be affected more when the traffic level is high

ii) The road related disturbances affect the vegetation composition and facilitate the spread of invasive species.

1.3. Research Questions:

i) How the habitat use by mammals varies at different gradients and in these two segments?

ii) How the vegetation composition changes due to road related disturbances and invasive plant species across different distances from the road?

2. STUDY AREA:

Nagarahole Tiger Reserve is situated as a part of Western Ghats between 11°50’-12°15’ N and 76°0’ -76°15’ E in the state of Karnataka in Southern India. Nagarahole is contiguous to the Bandipur Tiger Reserve in the south that is an another well-protected National Park. The mean annual rainfall ranges from 900 mm in the east to 1500 in the west. The forest type of this Tiger Reserve includes tropical moist-deciduous, tropical dry deciduous forests, teak dominant forests and mosaic habitats.

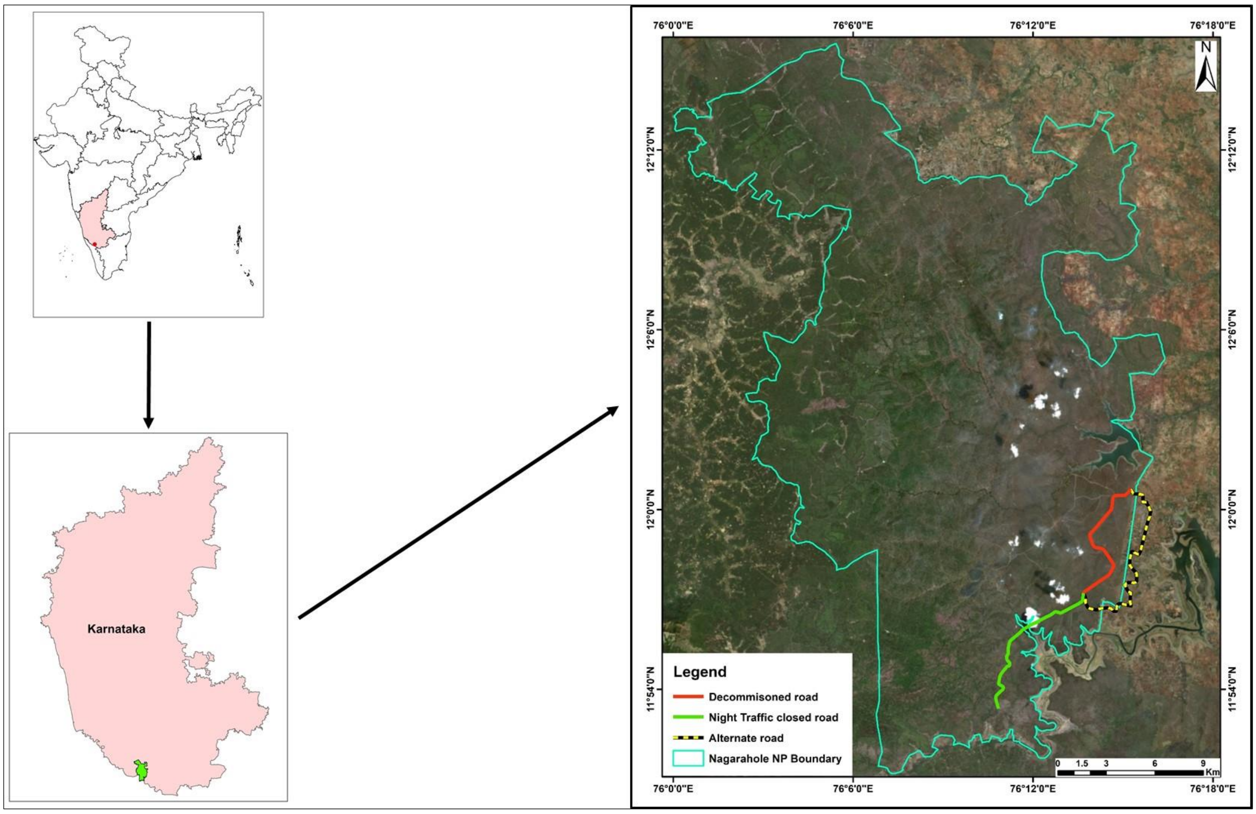


Figure 1 Location map of Nagarahole Tiger Reserve

Nagarahole holds the good prey population such as Chital, Sambar, Indian muntjac, Indian gaur, Indian wild pig, Four-horned antelope (Karanth and Sunquist, 1992), and the Indian elephant (Goswami, Madhusudan & Karanth, 2007) and large carnivores that includes Tigers, dholes and leopard (Gubbi, Poornesha & Madhusudan, 2012; O'Connell, Nichols & Karanth, 2010).

It also harbours small mammals such as Small Indian Civet, Asian Palm Civet, Brown Palm Civet, Common Mongoose, Ruddy Mongoose, Stripe-necked Mongoose and Brown Mongoose (Kumara & Singh, 2007). The details of the Nagarahole Tiger Reserve have been documented in other studies (Goswami, Madhusudan & Karanth, 2007; Karanth & Sunquist, 1992; Karanth & Sunquist, 2000).

In this Tiger Reserve, Mysore-Mananthavadi Highway (NH-33) passes through the homogeneous forest area in the southern part that has two segments.

Vehicular traffic has been closed for 10 years (with exceptions for park vehicles and public emergencies) in Segment 1 (7.4 km) and also has an alternate road outside the park. Segment 2 (11.7 km) has been closed for night traffic (6 pm to 6 am) (Gubbi, Poornesha & Madhusudan, 2012).

This gave me an opportunity to do a comparative study of road and vehicular traffic impacts between segment 1 and segment 2 as control and treatment, respectively. My study area comprises of two ranges of Nagarahole Tiger Reserve that are Antharasanthe Range and D.B.Kuppe Range. The decommissioned section falls under the Antharasanthe Range and night traffic closed road lies under the D.B.Kuppe Range. I have selected 9 km from the decommissioned section, 10.5 km from the night traffic closed road and 55.5 sq.km including either side of the road along with these two segments. My study area has Taraka backwaters on the North-eastern side and Kabini backwaters on the eastern side. These reservoirs are a major source of water for the animals during the summer season.

3. METHODS:

3.1. Field methods:

3.1.1. Estimation of Vehicular traffic in both decommissioned road and night traffic closed road segments:

I used the camera trap to measure the vehicle volume in these two segments for 14 days. The camera was set in FAP mode to get vehicle captures with a time stamp.

3.1.2. Camera trapping to understand the encounter rate and activity pattern in both decommissioned road and night traffic closed road segments:

To study habitat use by mammals along this road in these two segments, on either side of the road 0.5 Sq.km (700 m × 700 m) grids were made up to 2.1 km. Totally 111 grids were laid along the road in these two segments by using the software Arc Map 10.5. Among these 51 grids were laid in the decommissioned section and 60 grids were laid in the night traffic closed road. I fixed the single-sided camera traps inside the grid to maximize capture. Camera trapping was done from March 2019 to April 2019 in these two segments.

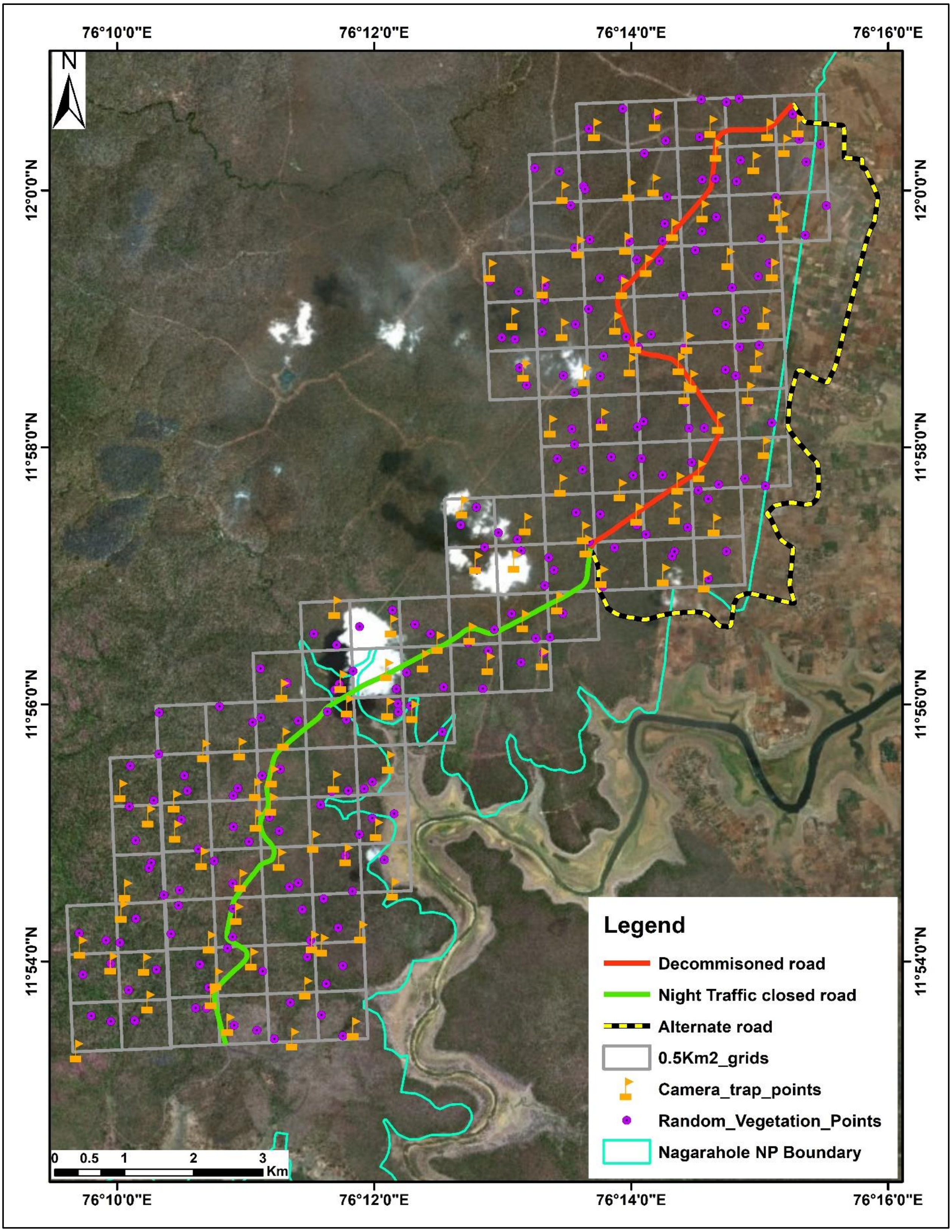


Figure 2 Locations of camera traps deployed and random vegetation points in the study area

3.1.3. Vegetation sampling to understand the vegetation composition in the decommissioned road and night traffic closed road:

To comprehend the species composition and quantify the spread of invasive species, randomly two points were laid in every 0.5 sq.km grids with camera trap location as the third sampling point within the grid. By using the software Arc Map 10.5, 222 random points were created in 111 grids. Some of the points falling in the agricultural lands, human habitation, waterhole and outside the boundary were not sampled. Removing these 7 points, totally 326 points were sampled.

In these random points and in camera trap location, three different size plots of 1×1 m, 5 m radius, 10 m radius were laid for grasses, shrubs, and trees respectively. Herb species and percentage cover of grasses were measured in four 0.25 m^2 quadrat to get a variation. Species richness, the abundance of shrub and invasive species spread were quantified in 5 m radius plot. Tree species richness, abundance, diameter at breast height and canopy cover were measured in 10 m radius plots. The vegetation sampling and pellet count was done from January 2019 to April 2019.

3.2. Analytical Methods:

3.2.1. Estimation of vehicular traffic in both decommissioned road and night traffic closed road segments:

The camera trap images segregated into day wise and number of vehicles per hour is calculated from the number of vehicles per day.

3.2.2. Camera trapping to understand the encounter rate and activity pattern in both decommissioned road and night traffic closed road segments:

The camera trap images were analyzed using the Camera-trap R package in ‘R’ software. The activity pattern obtained using the Activity overlap command in ‘R’ software. Encounter rates were obtained using Monte Carlo simulations with 10,000 bootstraps.

3.2.3. Vegetation sampling to understand the vegetation composition across various distances from the roads and both in the decommissioned road and night traffic closed road:

3.2.3.1. Species diversity*:*

The Shannon-Wiener diversity index is used to calculate the species diversity between the decommissioned road and night traffic closed road. It is calculated for the two sections of the road using the formula

$$H = -\Sigma \, Pi \, Ln \, Pi$$

Where,

H = Shannon index of diversity

Pi = the proportion of the i^{th} species in the landscape element

Ln Pi = Natural logarithm of the proportion of each species

3.2.3.2. ANOVA test*:*

The vegetation points are classified into three categories based on the distance from the road. The distances of Section A, Section B and Section C are 0-499 m, 500-999 m and 1000-2100 m respectively. ANOVA test is done to compare the vegetation diversity across three distance classes.

4. RESULTS:

4.1. Estimation of Vehicular traffic in both decommissioned road and night traffic closed road segments:

Vehicular traffic estimated in decommissioned road and night traffic closed road. The mean number of vehicles is 1.8 ± 0.1 per hour in Decommissioned road. The mean number of vehicles in night traffic closed road is 56.0 ± 2.0 per hour. The active hours of vehicular traffic were broadly similar in these two segments but decommissioned road peaked in the morning hours from 10:00 AM to 11:00 AM and night traffic closed road peaked in the evening hours at 6:00 PM (Dhat=0.86). It is given in figure 4.

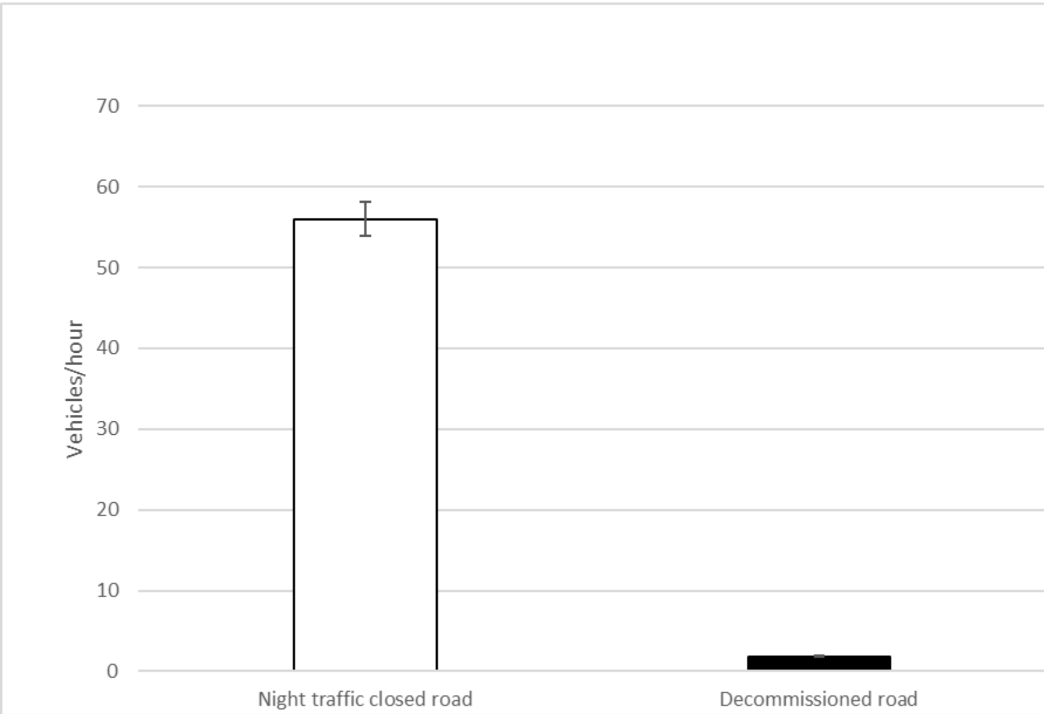


Figure 3 Number of vehicles per hour in the decommissioned road and night traffic closed road

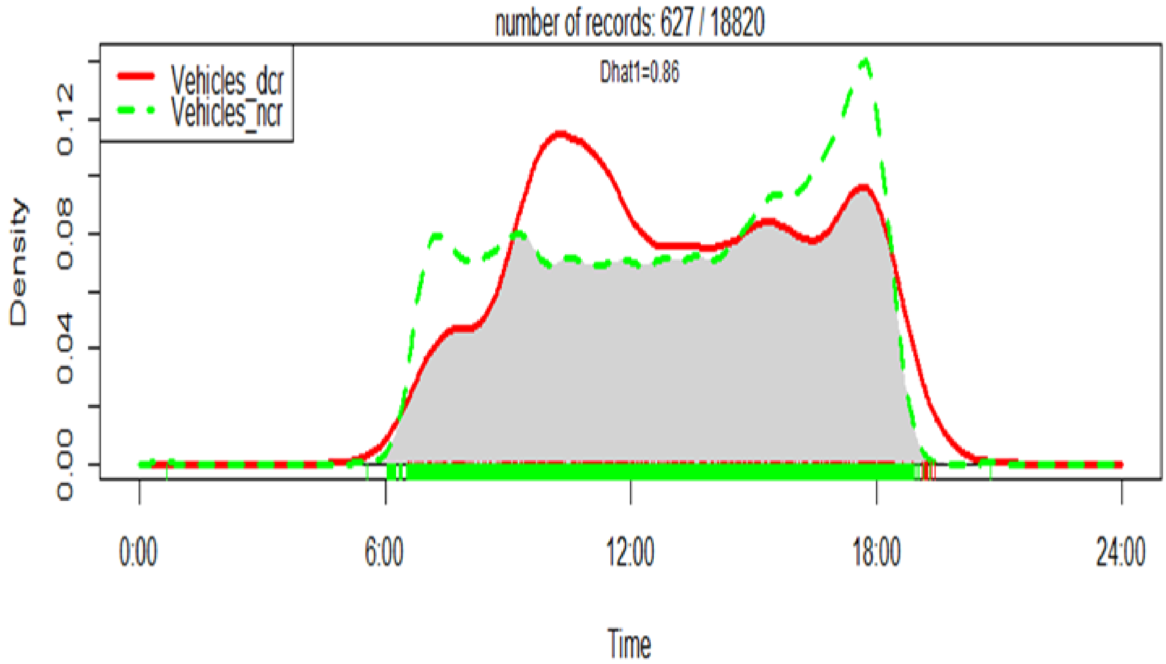


Figure 4 The time-activity pattern of vehicles in the decommissioned road (dcr) and night traffic closed road (ncr)

4.2. Camera trapping to understand the encounter rate and activity pattern in both decommissioned road and night traffic closed road segments:

A total of 105 camera traps were deployed along the road as well as close to the road in these two segments for 20 days with an effort of 2715 camera trap days. A total of 51 were put in the decommissioned road for 20 days with an effort of 1583 camera trap days. A total of 56 camera traps were put in the night traffic closed road for 20 days with an effort of 1132 camera trap days.

4.2.1. To understand the encounter rate in both segments*:*

A total of 21 mammals were captured in these two segments. Among these 21 mammals and 19 mammals captured from decommissioned road and night traffic closed road respectively. Only seven large mammals were selected for comparison between the two sections of road based on the capture rates on both the sections.

The mean capture rates were high for Chital (78.29 ± 7.16) followed by Sambar (7.2 ± 0.8), Elephant (5.29 ± 0.7) and Barking deer (3.73 ± 0.4) in the decommissioned road. The mean capture rates were low for Jungle cat (0.05 ± 0.03) followed by Stripe-necked mongoose (0.13 ± 0.07), Wild dog (0.16 ± 0.06) and Leopard (0.16 ± 0.06) in the decommissioned road.

In night traffic closed road, the mean capture rates were maximum for Chital (114.08 ± 16.68) followed by Sambar (6.3 ± 1.03), Elephant (4.27 ± 0.82) and Common langur (2.73 ± 0.5). The mean capture rates were minimum for Sloth bear (0.08 ± 0.04) followed by Stripe-necked mongoose (0.1 ± 0.05) Wild dog (0.12 ± 0.06) and Common Palm Civet (0.18 ± 0.08) in the night traffic closed road. Encounter rates for mammals are summarized in Table 1.

Rusty-spotted cat and Jungle cat were captured only from the decommissioned road section and not from the night traffic closed road.

Table 1 Encounter rates of mammals in both decommissioned road and night traffic closed road

Mammals	**Mean number of captures (Mean ± SE)**		**Mean number of capture rates/day (Mean ± SE)**	
	Decommissioned road	**Night traffic closed road**	**Decommissioned road**	**Night traffic closed road**
Barking deer	3.73 ± 0.4	2.15 ± 0.47	0.86 ± 0.05	0.57 ± 0.08
Bonnet macaque	0.4 ± 0.19	0.37 ± 0.12	0.17 ± 0.06	0.25 ± 0.07
Chital	78.29 ± 7.16	114.08 ± 16.68	0.93 ± 0.04	0.77 ± 0.07
Common langur	2.51 ± 0.78	2.73 ± 0.5	0.64 ± 0.07	0.57 ± 0.08
Common Palm Civet	0.29 ± 0.14	0.18 ± 0.08	0.15 ± 0.05	0.13 ± 0.05
Elephant	5.29 ± 0.7	4.27 ± 0.82	0.86 ± 0.05	0.62 ± 0.08
Indian gaur	0.32 ± 0.15	2.34 ± 0.56	0.12 ± 0.05	0.55 ± 0.08
Indian hare	1.17 ± 0.23	0.81 ±0.3	0.57 ± 0.07	0.25 ± 0.07
Indian porcupine	0.5 ± 0.12	0.34 ± 0.13	0.34 ± 0.07	0.2 ± 0.06
Jungle cat	0.05 ± 0.03	0	0.05 ± 0.03	0
Leopard	0.16 ± 0.06	0.45 ± 0.16	0.15 ± 0.05	0.28 ± 0.07
Mouse deer	0.53 ± 0.17	0.2 ± 0.08	0.32 ± 0.07	0.15 ± 0.06
Ruddy mongoose	0.18 ± 0.07	0.47 ± 0.12	0.17 ± 0.06	0.35 ± 0.08

Rusty spotted cat	0.18 ± 0.06	0	0.17 ± 0.06	0
Sambar	7.2 ± 0.8	6.3 ±1.03	0.88 ± 0.05	0.63 ± 0.08
Sloth bear	0.84 ± 0.18	0.08 ± 0.04	0.47 ± 0.07	0.07 ± 0.04
Small Indian Civet	1.5 ± 0.36	0.57 ± 0.16	0.54 ± 0.07	0.33 ± 0.08
Stripe-necked mongoose	0.13 ± 0.07	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05
Tiger	1.04 ± 0.2	0.42 ± 0.1	0.58 ± 0.07	0.32 ± 0.07
Wild dog	0.16 ± 0.06	0.12 ± 0.06	0.15 ± 0.06	0.1 ± 0.05
Wild pig	2.39 ± 0.35	2.63 ± 0.45	0.76 ± 0.07	0.6 ± 0.08

A total of 9 species of mammals selected based on the capture rate and conservation importance for the comparison from the two segments. The photo capture rates of barking deer ($p<0.05$), chital ($p<0.05$), elephant ($p<0.05$), Indian gaur ($p<0.05$), sambar ($p<0.05$), tiger ($p<0.05$) and wild pig ($p<0.05$) were highly significant difference between the decommissioned road and night traffic closed road but sloth bear and leopard had very few captures in the one segment of the road. The photo capture rates per trap day of nine mammals are given in Figure 5.

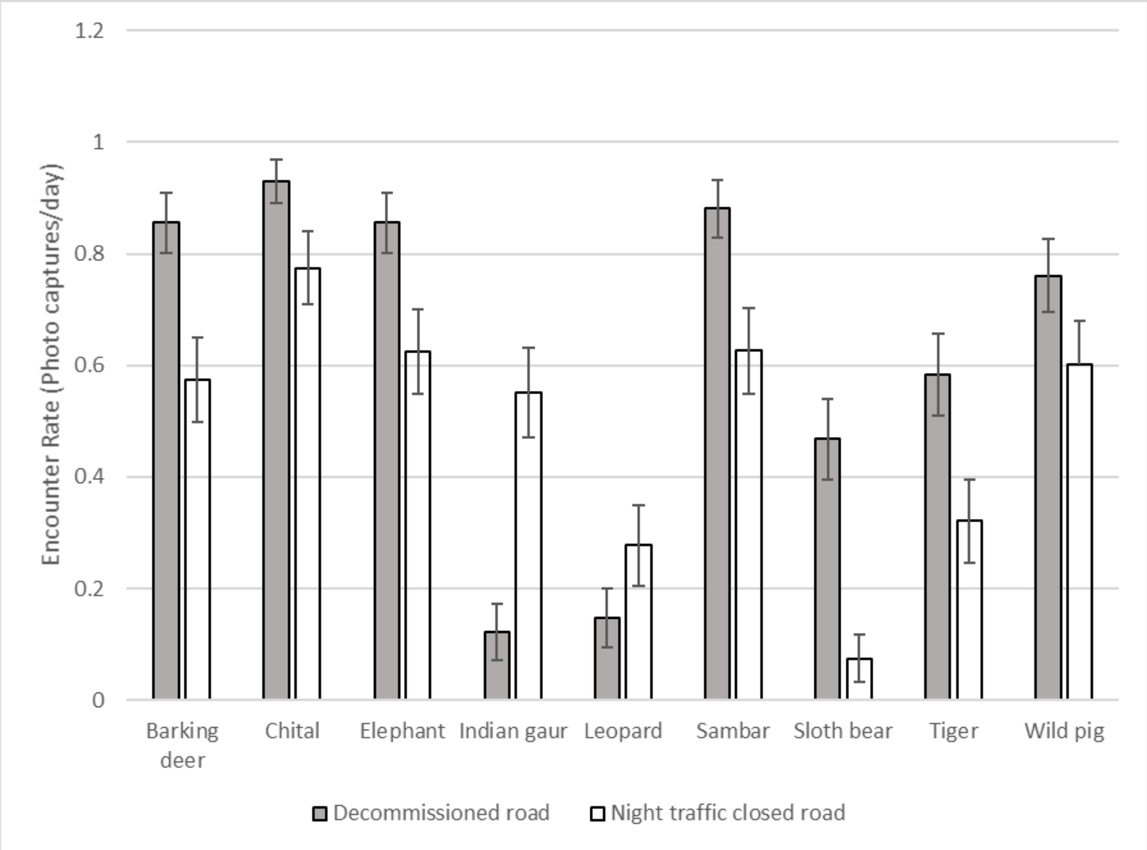


Figure 5 Encounter rates (photo captures/day) of nine mammal species between the decommissioned road and night traffic closed road

4.2.2. To understand the activity pattern of mammals in two segments of the roads*:*

Activity pattern of the nine mammals in the decommissioned road and night traffic closed road was compared. There are no differences in the activity pattern of barking deer (Dhat1=0.71), chital (Dhat1=0.84), elephant (Dhat1=0.8), Indian gaur (Dhat1=0.63), sambar (Dhat1=0.9), tiger (Dhat1=0.74), wild pig (Dhat1=0.67) and leopard (Dhat1=0.53) between the decommissioned road and night traffic closed road. The Sloth bear (Dhat1=0.32) had different activity pattern in these two segments of the roads. The activity pattern of nine mammals is given in Figure 6 and 7.

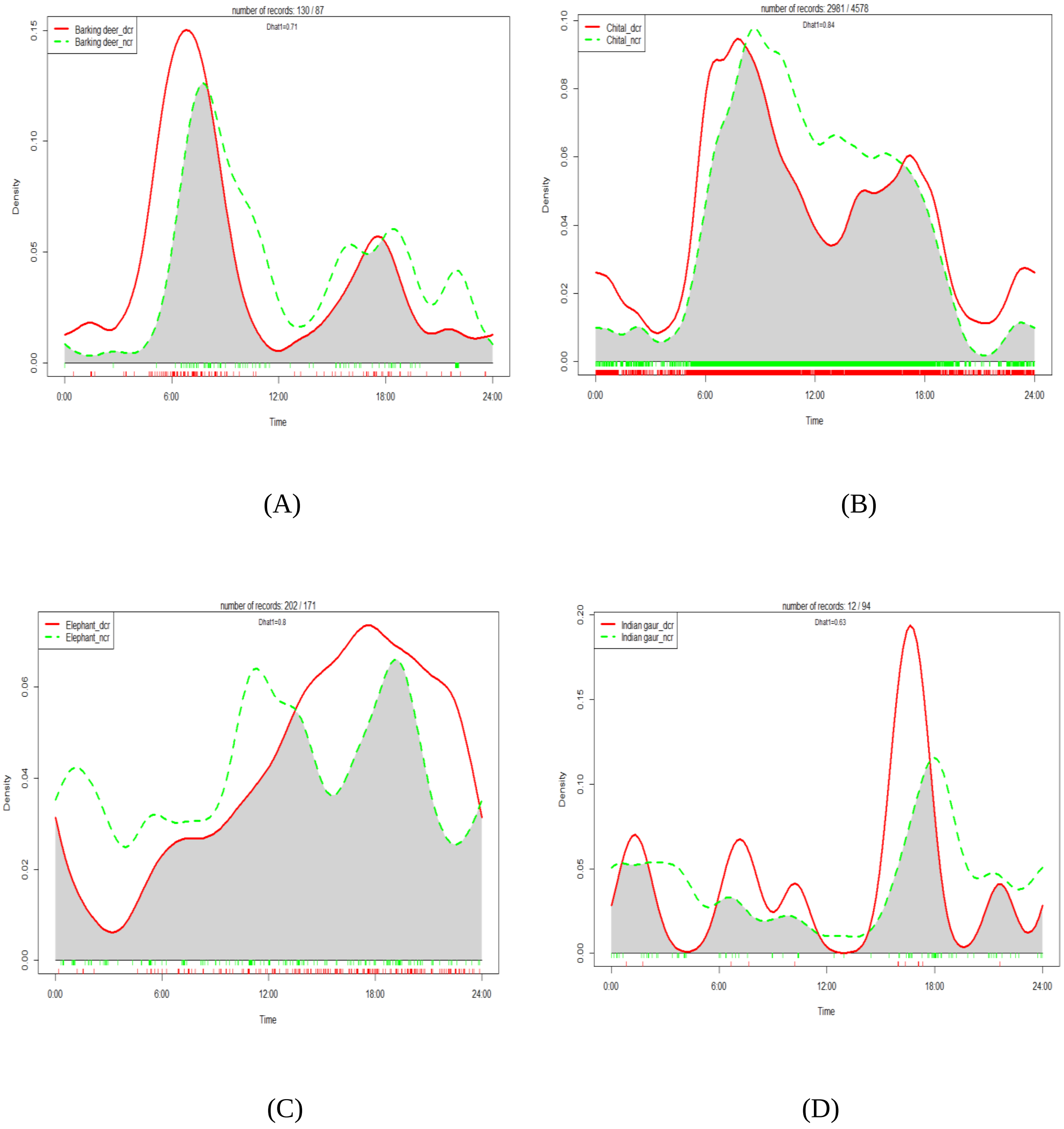
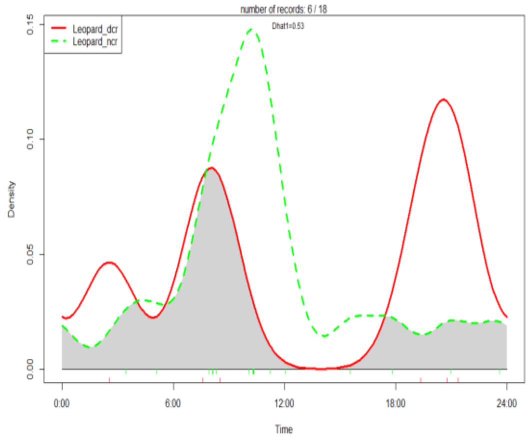
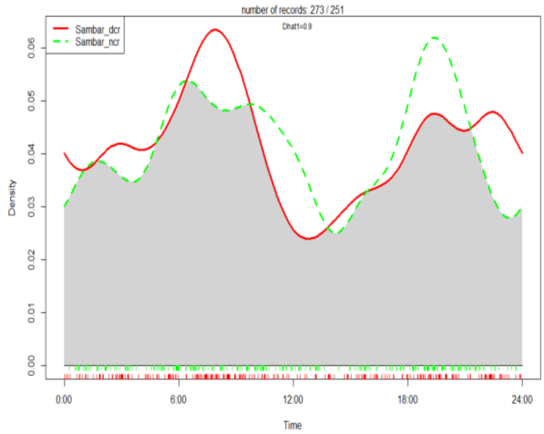


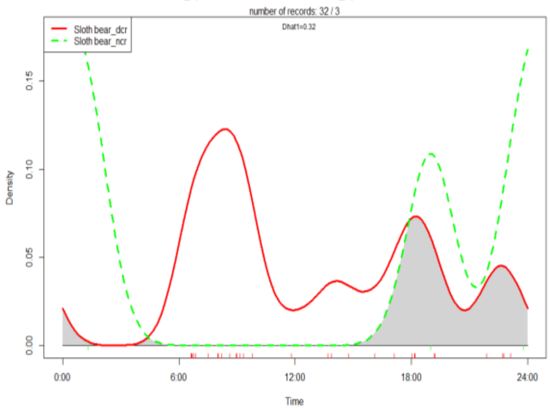
Figure 6 Activity pattern of Barking deer (A), Chital (B), Elephant (C) and Indian gaur (D) between the decommissioned road (dcr) and night traffic closed road (ncr)



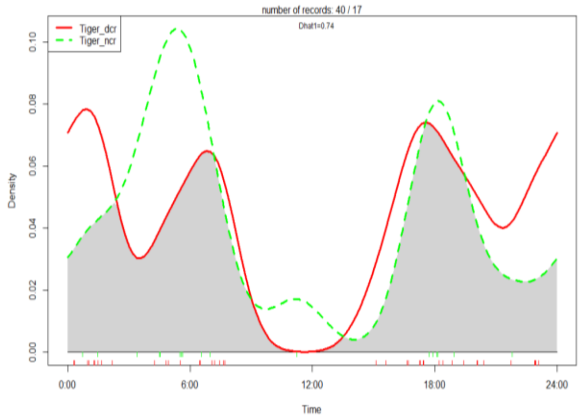
(E)



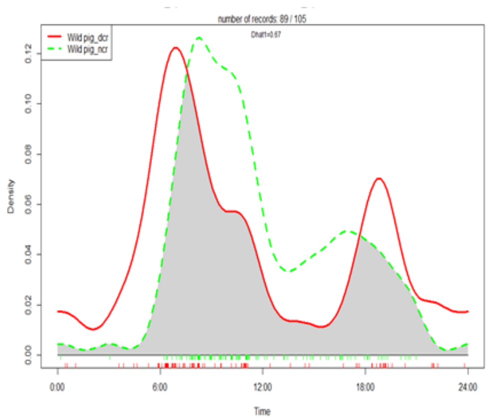
(F)



(G)



(H)



(I)

Figure 5 Activity pattern of Leopard (E), Sambar (F), Sloth bear (G), Tiger (H) and Wild pig (I)between the decommissioned road (dcr) and night traffic closed road (ncr)

4.3. Vegetation characterization to understand the vegetation composition across various distances from the roads and both in the decommissioned road and night traffic closed road:

A total of 2308 individual trees, belonging to 69 species were recorded in the two areas of the road. A total of 8267 individuals of shrubs and saplings belonging to 88 species were recorded in the two areas of the road. A total of 1614 individuals of herb species belonging to 42 species were recorded from the two areas of the road. A total of 19 grass species were found in this study from the two areas of the road.

Among these, 1066 individual trees belonging to 54 species were recorded from the decommissioned road. A total of 1553 individuals of shrubs and saplings belonging to 57 species were recorded in the decommissioned road. A total of 180 individuals of herb species belonging to 15 species were recorded in the decommissioned road. A total of 18 grass species were found in this study from the decommissioned road.

A total of 1242 individual trees belonging to 50 species were recorded from the night traffic closed road. A total of 6714 individuals of shrubs and saplings belonging to 66 species were recorded in the night traffic closed road. A total of 1434 individuals of herb species belonging to 37 species were recorded in the night traffic closed road. A total of 12 grass species were found in this study from the night traffic closed road.

4.3.1. Shannon-Wiener diversity index comparison between the decommissioned road and night traffic closed road:

There are significant differences in herb, shrub and tree diversity between the decommissioned road and night traffic closed road. Herb and shrub diversity are more in the night traffic closed road. Tree diversity is higher in the decommissioned road. The comparison of diversity indices is given in Figure 8.

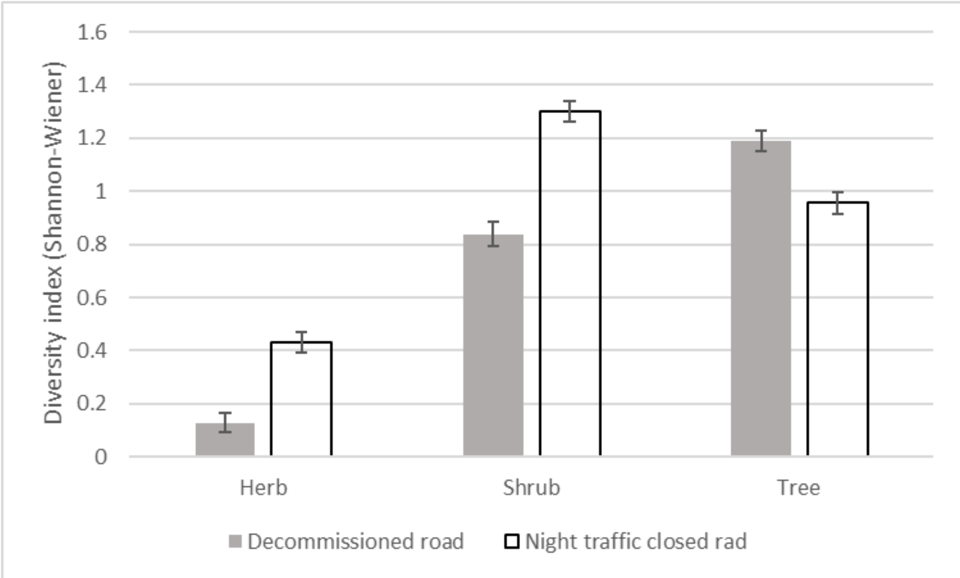


Figure 8 Diversity index (Shannon-Wiener) of herbs, shrubs and trees between the decommissioned road and night traffic closed road

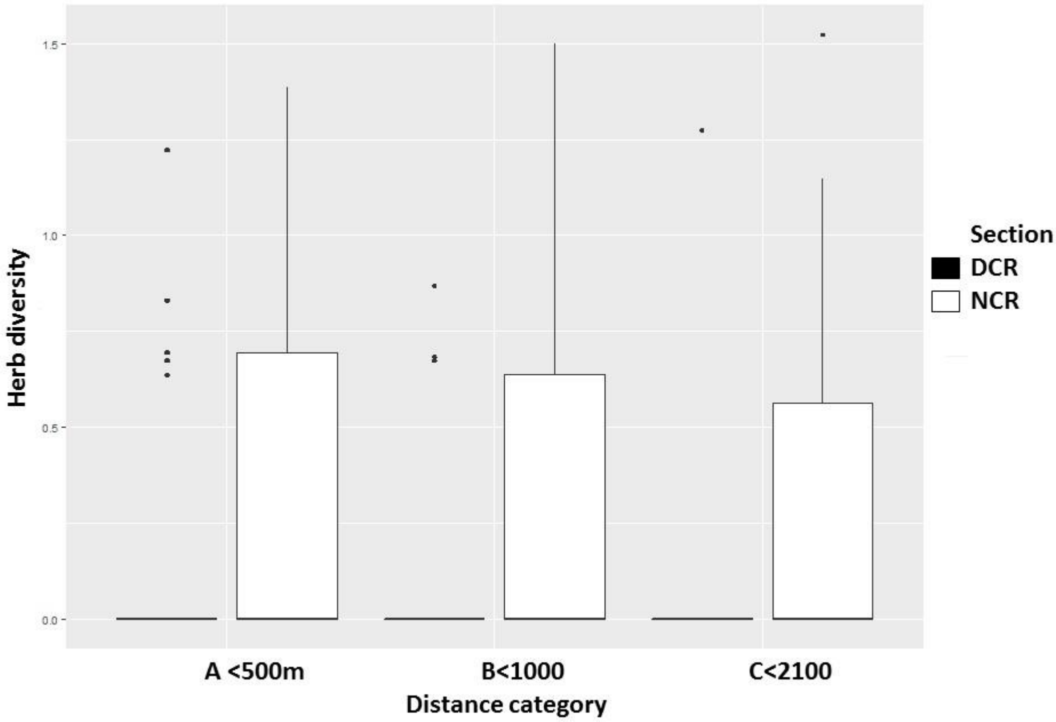


Figure 9 Herb diversity index (Shannon-Wiener) across various distances from both decommissioned road (DCR) and night traffic closed road (NCR)

Herb diversity differed between the two roads, it was higher in the night traffic closed road compared with the decommissioned road(ANOVA, $p<0.05$). The herb diversity didn't change with distance from the road for the decommissioned road (ANOVA, $p=0.916$)as well as for the night traffic closed road (ANOVA, $p=0.568$). This is given in figure 8.

Shrub diversity differed between the two road categories (ANOVA, $p<0.05$), it being higher in the night traffic closed road compared with the decommissioned road. The shrub diversity didn't change with distance from the road for the decommissioned road (ANOVA, $p=0.898$) but differed for the night traffic closed road(ANOVA, $p<0.05$) (Figure 9).

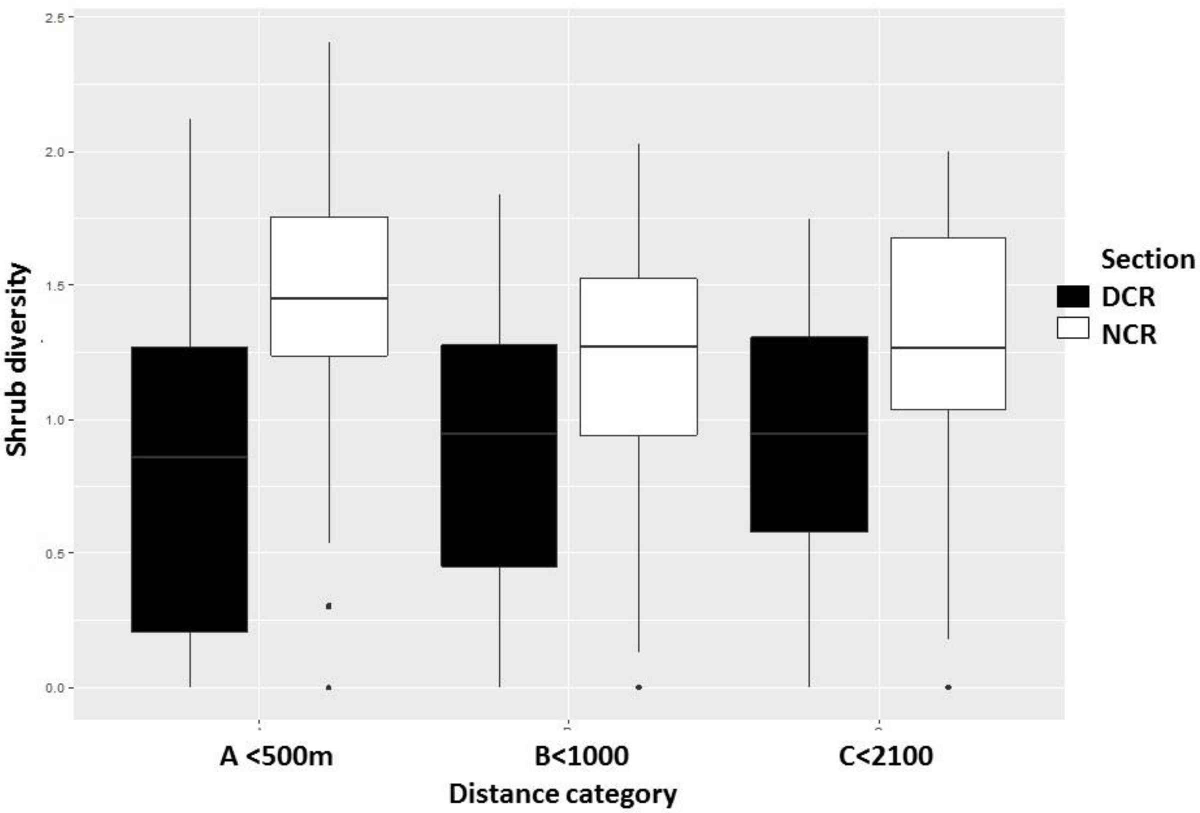


Figure 10 Shrub diversity index (Shannon-Wiener) across various distances from both decommissioned road (DCR) and night traffic closed road (NCR)

4.3.2. Tree basal area comparison across various distances from both decommissioned road and night traffic closed road:

Tree basal area did not differ between the two roads of night traffic closed road and decommissioned road (ANOVA, p=0.973). The tree basal area didn't change with distance from the road for the decommissioned road (ANOVA, p=0.163) as well as for the night traffic closed road (ANOVA, p=0.29) (Figure 11).

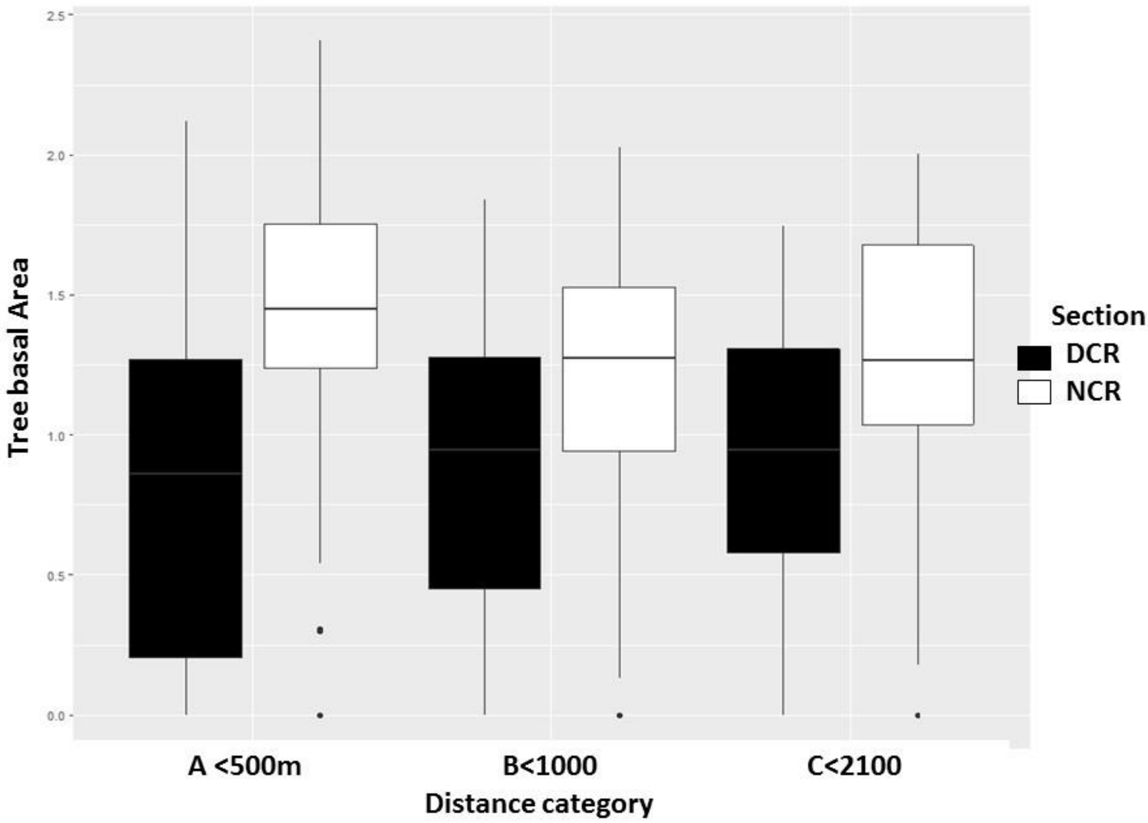


Figure 11 Tree basal area comparison across various distances from both decommissioned road (DCR) and night traffic closed road (NCR)

4.3.3. Canopy cover comparison across various distances from both decommissioned road and night traffic closed road:

Canopy cover differed between the two road categories (ANOVA, p<0.05), it being higher in the night traffic closed road compared with the decommissioned road (Figure 12). The Canopy cover didn't change with distance from the road for the decommissioned road (ANOVA, p=0.103) but differed for the night traffic closed road(ANOVA, p<0.05) (Figure 13).

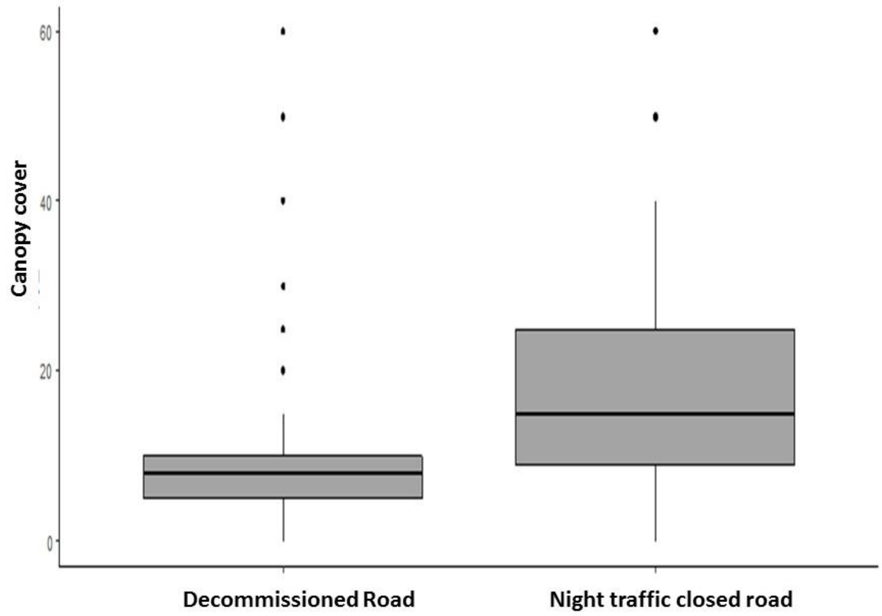


Figure 12 Canopy cover comparison between the decommissioned road and the night traffic closed road

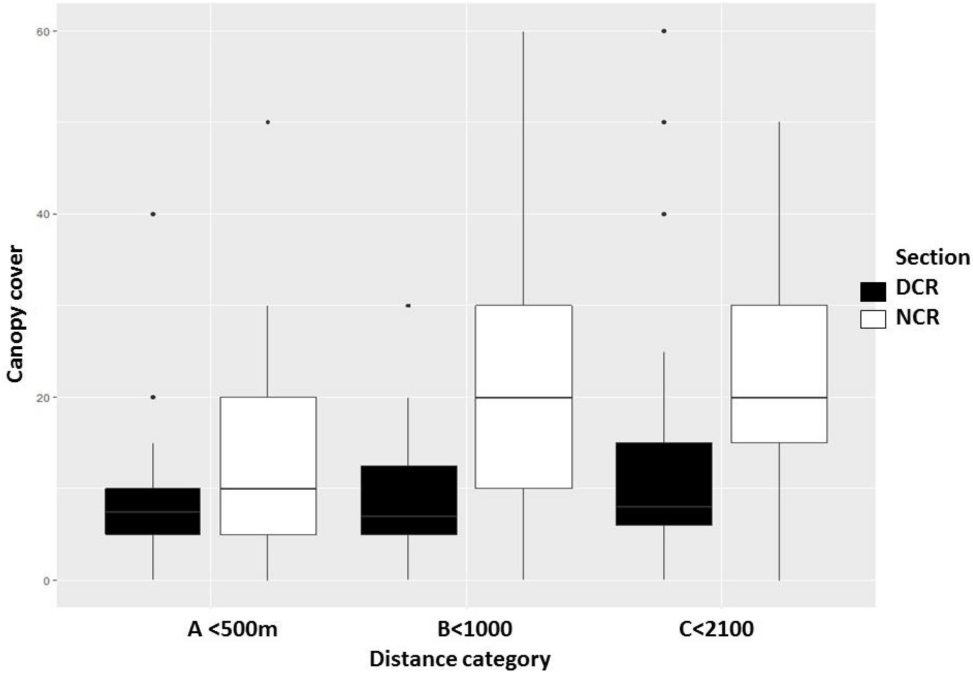


Figure 13 Canopy cover comparison across various distances from both decommissioned road (DCR) and night traffic closed road (NCR)

4.3.4. Invasive species cover comparisons across various distances from the roads and in both decommissioned road and night traffic closed road*:*

Invasive cover differed between the two road segments (ANOVA, p<0.05), it being higher in the decommissioned road compared with the night traffic closed road (Figure 14). The Invasive cover didn't change with distance from the road for the decommissioned road (ANOVA, p= 0.255) but differed for the night traffic closed road(ANOVA, p<0.05) (Figure 15).

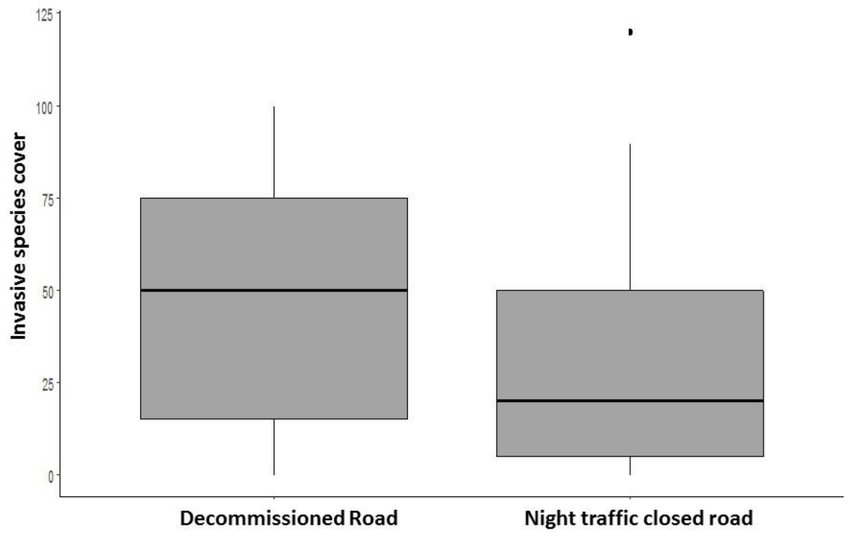


Figure 14 Invasive species cover comparison between the decommissioned road and the night traffic closed road

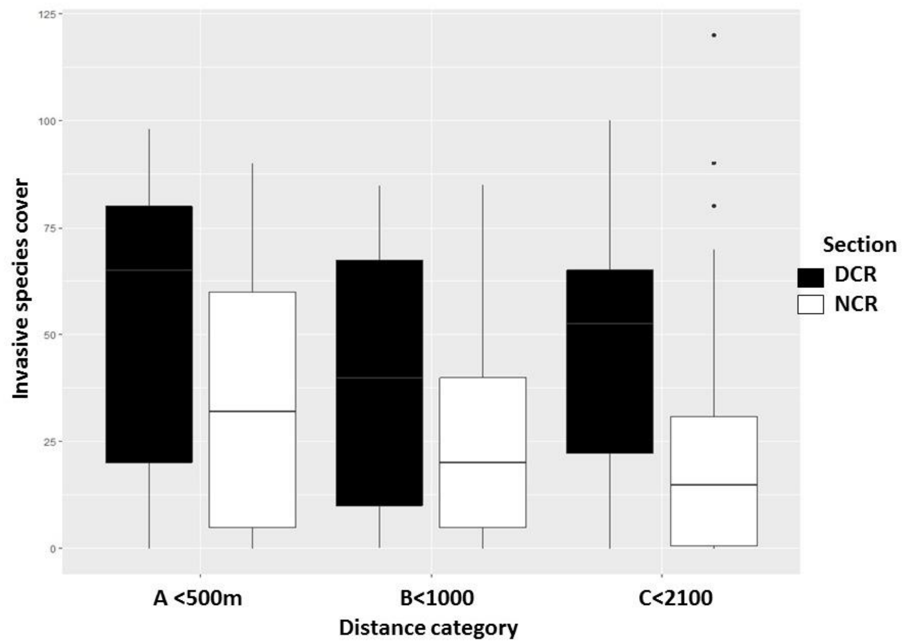


Figure 15 Invasive species cover comparison across various distances from both decommissioned road (DCR) and night traffic closed road (NCR)

5. DISCUSSION:

5.1. Estimation of Vehicular traffic in both decommissioned road and night traffic closed road segments:

The mean number of vehicles in the night traffic closed road (56.0 ± 2.0 /h) was 31 times higher than the decommissioned road (1.8 ± 0.1/h) (Figure 3).

During 2009, the mean number of vehicles in both decommissioned road and night traffic closed road was 1.9 ± 0.2 vehicles per hour and 44.0 ± 1.5 vehicles per hour respectively (Gubbi, Poornesha & Madhusudan, 2012). The number of vehicles increased by 10 vehicles per hour over a period of ten years in the night traffic closed road. This is very important to note that the night traffic closed road had higher vehicular disturbance and it was increasing every year. But, vehicular pressure was low and remained constant in the decommissioned road over a period of time.

The active hours of vehicular traffic similar in both the segments with few vehicles in the Decommissioned road.

5.2. Camera trapping to understand the encounter rate and activity pattern in both decommissioned road and night traffic closed road segments:

The encounter rates of Barking deer, Chital, Elephant, Indian gaur, Sambar, Tiger, Leopard and Wild pig were significantly different between the decommissioned road and night traffic closed road. In these, seven mammals out of nine mammals found to be high in the decommissioned road than in the night traffic closed road (Figure 5). Among this Leopard and Sloth bear had very low capture rates. Discarding those animals, remaining five animals were showing high encounter rates in the Decommissioned road. It shows that these animals are avoiding the vehicular traffic road. The encounter rates for Chital, Elephant and Wild pig are similar to results observed by Gubbi, Poornesha & Madhusudan (2012). But, Sambar was found to be avoiding the vehicular traffic road in contrary to that study (Gubbi, Poornesha & Madhusudan, 2012). Similarly, studies have documented the avoidance of high traffic roads by large mammals such as Grizzly bear (Northrup et.al, 2012) and other Carnivores (Alexander, Waters & Paquet, 2005).

Indian gaur had maximum encounter rate in the vehicular traffic road because this large herbivore could be adapted to the vehicular traffic and also the grass level is high in the edges along the night traffic closed road. This kind of behaviour observed in Moose uses the high traffic road to overcome short-term limiting factors such as sodium deficiency (Laurian et. al, 2008). While other ungulates are using the less disturbed area, the gaur is using this high vehicular traffic road more than other mammals possibly to take advantage of higher grass biomass. Similarly, species such as White-tailed deer found to be using the habitat close to the roads to escape from the predators because predators avoid the road-edge areas (Forman & Deblinger, 2000). Larger ungulates have a high tolerance level to high traffic volume by habituating themselves to the disturbance (Alexander, Waters & Paquet, 2005).

5.2.1. To understand the activity pattern of mammals in two segments of the roads*:*

The activity pattern of the eight mammals out of nine mammals found to be similar across the two road sections (Figure 6 and 7). It could be because of the activity pattern of mammals shaped by other factors such as inherent characters, competition (Lucherini, Reppucci & Walker, 2009) and environmental factors (Bartness & Albers, 2000). Hence, there are no changes in the activity pattern of the mammals in these two road segments. Sloth bear had very few encounter rates from the night traffic closed road to explain the activity pattern.

5.3. Vegetation characterization to understand the vegetation composition and invasive species cover across various distances from the roads and both in the decommissioned road and night traffic closed road:

Herb and shrub diversity was high in the night traffic closed road than the decommissioned road (Figure 8). It could be because of the road with high vehicular traffic spread the seeds of herbs and shrubs through vehicles (Von Der Lippe & Kowarik, 2007; Zwaenepoel, 2006) and also because of edaphic factors. It might be also because of the dominance of invasive species on native shrub diversity (Stylinski & Allen,1999). The invasive species cover was more in the decommissioned road. Due to this, the regeneration of shrub and herb species were suppressed by the invasive species.

Shrub diversity was low in the decommissioned road because of herbivores are shaping the shrub and tree diversity by browsing on them (Kuijper et. al., 2010; Rooney & Waller, 2003). Tree diversity was higher in the decommissioned road than the night traffic closed road (Figure 8). The herb, shrub and tree diversity was different in these two sections of the road possibly due to the edaphic factors (Clark, Palmer & Clark, 1999) and also because of management activities such as view line maintenance and canopy opening close to the road.

Tree basal area was found to be similar between the decommissioned road and high in the night traffic closed road and various distances from the road also. Tree basal area was not much affected because of roads.

Canopy cover was low in the decommissioned road and high in the night traffic closed road. It might be due to the higher elephant activity into the decommissioned road (Fritz, 2017) and because of edaphic factors (Clark, Palmer & Clark, 1999). Elephants alter the habitat structure by breaking the twigs, branches and eating the barks (Joshi & Singh, 2008).

Canopy cover was similar between three different distance classes in the decommissioned road. It is due to canopy opening and tree cutting are forbidden along the road in the decommissioned section. But canopy cover is low nearby road and it increases with the distance from the night traffic closed road (Figure 13). Here, the road is maintained by opening the canopy along the road. Due to this reason the canopy cover was low near to the night traffic closed road.

The invasive species cover was high in the decommissioned road than the night traffic closed road. It might be because of the animals which are using low disturbed area are dispersing the seeds of invasive species (Day et. Al, 2003; Ramaswami et. al, 2016), Further invasion with a low level of canopy cover into decommissioned road owing to the presence of large herbivores such as elephants (Fritz, 2017; Joshi & Singh, 2008). The low level of the canopy provides more light to the invasive species for further invasion (Parendes & Jones, 2000).

The invasive cover was similar in the decommissioned road across three different distance classes but it follows a pattern in the invasive cover at the night traffic closed road. It was high close to the vehicular traffic road and it was low away from the vehicular traffic road (Figure 15). This could be because of vehicles are acting as dispersers of invasive species (Von der Lippe & Kowarik, 2007; Zwaenepoel, 2006) and other road-related disturbances (Gelbard & Belnap, 2003; Mortensen et. al, 2009; Parendes & Jones, 2000). The opening of canopy close to the road also another reason for high-level invasive cover in the night traffic closed road.

6. CONCLUSIONS:

This study shows a negative impact of the road on encounter rates of mammals but activity pattern seems to be unaffected by vehicular traffic. It also elucidates the impact of road related disturbances on the vegetation structure and how the roads facilitate for the invasive species spread inside the forests. Since roads are creating a lot of impacts on wildlife, it should be properly designed before making the roads inside the forest areas. Further research is required to know the diverse impacts of roads on animals and plants.

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