Mitigation measures to reduce wildlife mortality due to roads in the Nagarahole-Bandipur corridor

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Introduction

Linear intrusions such as roads and railways lines are becoming an increasing threat to wildlife in India's already fragmented forest landscape. Rapid economic growth especially in the last decade has accelerated such human-induced modification of wildlife ecosystems. In India the ecological impacts of highways have received very little research attention and there are very limited efforts at comprehensive conservation planning. Policies restricting highways in ecologically critical areas have not been implemented which is a matter of considerable concern. This is an issue across the entire tropical region where economic development has led to increase in infrastructure projects.

These human-induced modifications are a concern across the entire tropical region where economic development has led to an increase in infrastructure projects. From a socioeconomic perspective up gradation of the surface transport network is seen as a key element for economic development. Construction and up gradation of road networks have been given emphasis in India's rapid economic growth (9% per annum). Several international donor and lending agencies are providing economic impetus for the expansion of the road networks. The World Bank and the Indian federal and state Governments through their own funding have emphasized on road up gradation and construction of new roads. This includes highways as well as rural roads providing connectivity to remote locations. The federal Government of India allocated a budget of U$13.67 billiong for road development in recent years (2008-11) in the country. The number of vehicles in India is growing at a rate of 10% per annum (GoI 2008) which is an important driver of the demand for roads.

This road development is having its impact on wildlife habitats as several new rural roads are being built and existing minor roads are upgraded as high speed roads in biologically sensitive areas. One of the important threats to endangered wildlife such as the tiger (*Panthera tigris*) is habitat fragmentation caused through this road building activity in tiger habitats. For example the State of Karnataka, which is home to one of the biggest tiger populations in the world, has planned up gradation and development of several new roads. Some of these roads cut through critical tiger habitats (Table 1) and could have a long-term impact on the connectivity of tiger habitats. Of the 15 National Highways in Karnataka nine pass through important wildlife habitats in the Western Ghats while parts of the 28 State Highways, of the total of 151, pass through the Western Ghats.

In India there have been only very limited efforts to understand the impacts of roads, especially on large mammals. Studies that provide comprehensive suggestions on mitigation measures are very few. Despite the fact that these projects will have a serious impact on tiger, elephant (*Elephas maximus*), liontailed macaque (*Macaque silenus*) and numerous other endangered wildlife species. Even mitigation measures such as speed calming measures (adding structures that reduce speed) are only installed in an ad-hoc manner with no biological considerations.

Table 1: Roads planned to be upgraded passing through critical wildlife habitats in Karnataka state, southern India.

S. No.	Name of the highway	Highway No.	Passing through
1.	Londa-Karwar road	SH 95	Dandeli-Anshi Tiger Reserve
2.	Karkala-Sringeri	NH 13	Kudremukh National Park
3.	SK Border-Kudremukh	SH 66	Kudremukh National Park
4.	Agumbe Ghat road	SH 1	Someshwara Wildlife Sanctuary
5.	Kollur-Nagodi		Mookambika Wildlife Sanctuary
6.	Mysore-Bantwal	SH 88	Kadamkal Reserved Forest
7.	Subramanya-Bisale	SH 85	Bisale Ghat and Bisale Reserved Forests
8.	Gundlupet-Ooty	NH 212	Bandipur Tiger Reserve
9.	Gundlupet-Sultan Bathery	NH 67	Bandipur Tiger Reserve

SH = State Highway, NH = National Highway

Impacts of roads on wildlife

Roads affect ecosystems, biological communities and species in numerous ways. Roads, especially highways, can have significant impacts on wildlife behaviour, survival and movement of animals by acting as physical barriers (Trombulak and Frissell 2000). They also fragment habitats, alter habitat quality and isolate wildlife populations resulting in genetic isolation of a population (Forman et al. 2003). Wider roads and highways impact movement of animals. This is especially true for wide-ranging large mammals as they come in contact with roads more frequently than some other species (Rytwinski and Fahring 2010).

Systematic studies have documented that roads decrease the survivorship and reproductive success of endangered species like tigers (Kerley et al. 2002) seriously impacting the source populations. Grizzly bears (*Ursus horribilis*) in Rocky Mountains shift their home ranges away from areas with high road densities (McLellan and Shackelton 1988). Wolves do not establish territories if road densities went past a critical threshold level (Jensen et al. 1986; Thurber et al. 1994). Laurance et al. (2005) document that elephants (*Loxodanta africana*) in Gabon preferentially located themselves in forests away from roads. Vehicular collision is one of the primary causes of death of endangered species like the Florida Panther (*Felis concolor*).

Altering physical environment, aiding the spread of exotic species, spread of pathogens, and an increase in passive harassment of animals due to an increase in human accessibility, are some of the other negative ecological impacts of roads (Trombulak and Frissell 2000). Roads also facilitate increased use of forest areas by humans for illegal activities such as timber smuggling, wildlife poaching that are subtle and more difficult to document.

In some wildlife species combination of poor eyesight, slow movement and over speeding of vehicles leads to mortality both in the lower taxa and larger animals (Laurance et al. 2009). Such unnatural mortalities due to roadkills can have deleterious effects on a population through loss of breeding individuals especially in apex, wide-ranging, large-bodied carnivores such as tigers.

Some of these impacts may be mitigated if speed calming and other mitigation measures are implemented intelligently to reduce the harmful effects of roads on wildlife. This can, to an extent be helpful in maintaining the integrity of genetic connectivity of wildlife populations. . Speed calming measures can reduce wildlife mortality and strategically placed structures would offer safe passage to wildlife thereby further reducing mortality, fragmentation effects, assist dispersal of animals, and reduce other impacts on wildlife. Wildlife crossing structures can increase permeability and habitat connectivity across roads. These mitigation measures have been extensively used in USA, Canada, and Spain and have proved to be successful (Land and Lotz 1996; Rodriguez et al. 1997; Clevenger and Waltho 2000; Jackson and Griffin 2000; Cain et al. 2003; Dodd et al. 2004).

Need for this study

Karnataka hosts some of the best protected areas for tiger and Asian elephant conservation. Within these protected areas, Nagarahole and Bandipur Tiger Reserves hold some of the highest densities of tigers and Asian elephants (Karanth et al. 2004; Goswami et al. 2007) acting as important source population sites for the larger landscape.

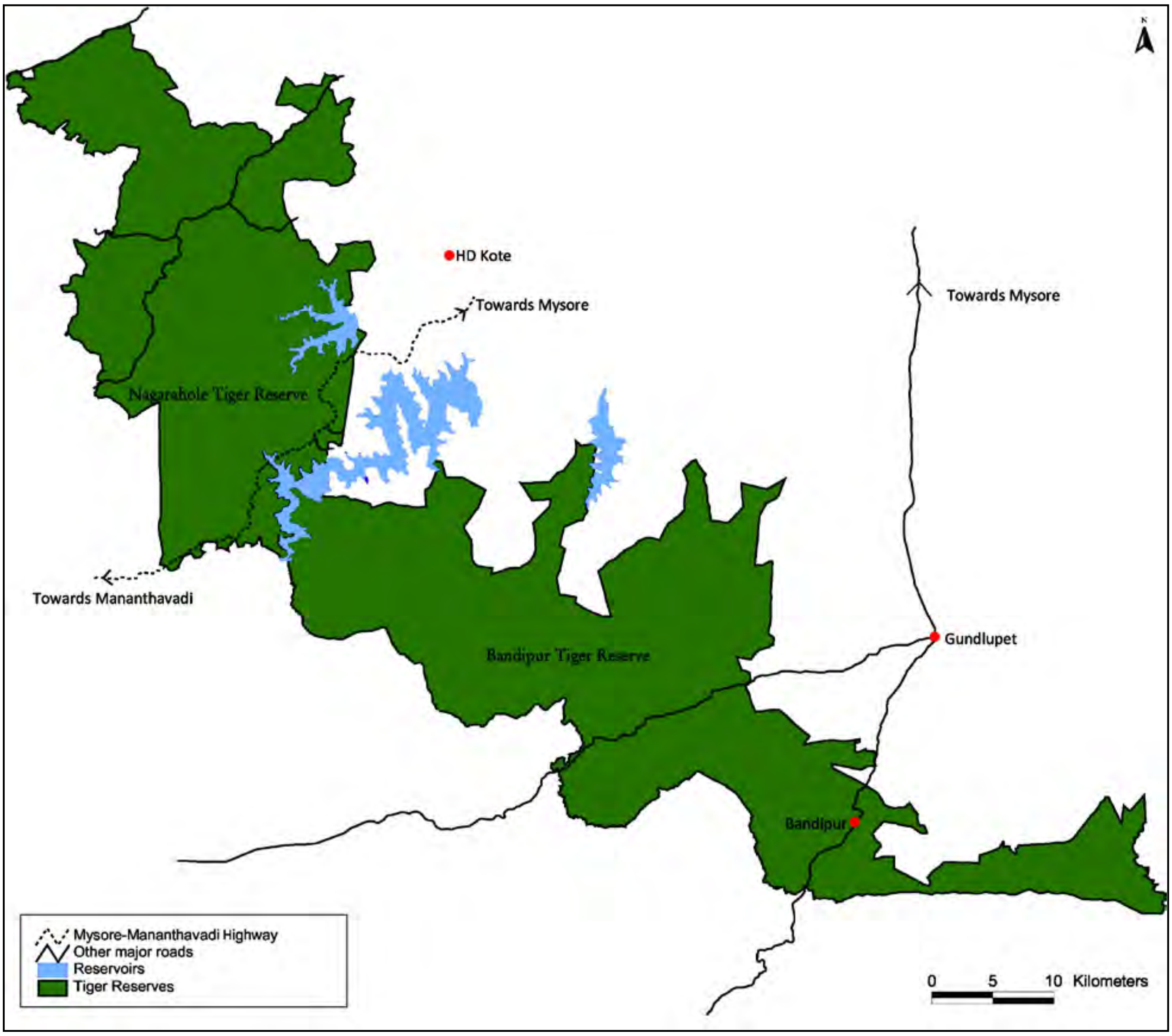
Amongst the anthropogenic threats are three major highways and three other major public access roads passing through Nagarahole and Bandipur Tiger Reserves (Map 1). These highways seriously impact wildlife populations due to accidental deaths, restricting the movement of wildlife resulting in fragmentation of wildlife populations and possibly even affecting seasonal migration and genetic dispersal. However there are no studies on the impacts of road on endangered wildlife species like tigers in India.

The Mysore-Mananthavadi Highway (State Highway 17D) passing through the southern part of Nagarahole is in a very crucial wildlife corridor and was upgraded as a high speed road in the year 2009. Since this road is also crucial for connecting two states the road up gradation could not be fully prevented.

The road construction agency proposed to build some mitigation measures to help alleviate impacts on wildlife including rumble strips, humps, chicanes and repairs of existing culverts to act as wildlife underpasses on the lines advised by Scott Wilson Kirkpatrick (2003). However the location and design of these mitigation measures were not based on scientific studies but on ad-hoc assessments carried out by road engineers and Environmental Impact Assessment consultants.

Hence a scientific study on the impact of this highway on large mammals, including tigers, would give insights into proposing mitigation measures for such highway construction within tiger habitats. More importantly it would clearly document the impacts of highways with high traffic density on large mammals. Hence this study proposed to provide an understanding of impacts of roads on wildlife and provide possible solutions to minimize these threats.

Map 1: Major roads through Nagarahole and Bandipur Tiger Reserves



Objectives

The objectives of this study were:

1. Understand the impact of the Mysore-Mananthavadi Highway on large mammals including tigers;

2. Assess the impact of traffic density on wildlife movement;

3. Suggest suitable locations for mitigation measures to reduce the impacts of vehicular traffic on wildlife;

4. Determine the efficiency of existing culverts as wildlife underpasses;

5. Based on the results to develop a framework for addressing the effects of roads through conservation planning aimed at reducing impacts of highways on wildlife specifically for endangered species such as tigers;

6. Educate Government departments involved in road up gradation/development about the impacts on wildlife and the mitigation measures to be implemented to reduce the ecological consequences of road building in critical tiger and other wildlife habitats.

Methods

We selected a 27.3 km stretch of the Mysore-Mananthavadi Highway passing through a homogeneous stretch of moist deciduous forests of Nagarahole Tiger Reserve in southern India. We divided this highway into three segments based on levels of vehicular and human activity in them. In the first segment of 7.4 km, vehicular traffic had been prohibited for 21 months (except for emergency and forest department vehicles on patrol) after a diversion had been created (see Map 2). The second segment of 11.7 km was ecologically very similar to the first, but there was a stretch on which vehicular traffic during day time had continued. The third segment of highway (8.2 km) formed the boundary between the Tiger Reserve and farmland, and was hence exposed to greater levels of human activity (mainly livestock grazing, collection of fuel wood, and presence of people), the levels of traffic were similar to the second segment. Segment 2 and 3 were used by vehicles only during the day, and the entire stretch of road was closed to vehicular traffic between 6 pm and 6 am.

In each of these segments, we estimated vehicular density along the road and also assessed use of the road edges by large mammals. To estimate vehicular density, the number of vehicles passing through segments 1, 2, and 3 (Map 2) were monitored for a 12-hour period between 6 am and 6 pm for 10 days. The time, number and type of vehicle were recorded.

To assess the use of road edges by large mammals, we first surveyed the entire stretch of the road across all three segments and counted the number of animal trails that intersected the highway every 100m. We recorded the topography of the road (slope, flat terrain, ridge and basin) in each of these 100m segments to assess if animals preferred any particular terrain for movement across the highway.

We then set up camera trap units across animal trails in 10 different locations within each segment for a period of 15 days. However, owing to technical malfunction and theft, effective sampling intensity varied in each segment (see Table 2). We tallied the frequency of captures at each trap location by species. Pictures of the same species taken at the same location at intervals of <20 minutes were conservatively treated as multiple pictures of the same group, and not tallied. However if it was conspicuous that the pictures were of different individuals/groups of animals (different tigers/herd of elephants or a tusker) within that time lag, they were treated as multiple captures.

Data on vehicular activity (vehicle density per hour) and surrogates of anthropogenic activity (camera trap encounter rate for domestic cattle and dogs) were summarized by segment. Against these measures of vehicular and anthropogenic activity, we compared species-wise encounter rates from camera traps to draw inferences on how vehicular activity affected large mammals.

Using GPS, existing culverts (that were built for hydrological purposes) that could possibly act as wildlife underpasses, as claimed by the road construction authority/Environmental Impact Assessment consultants, were mapped.

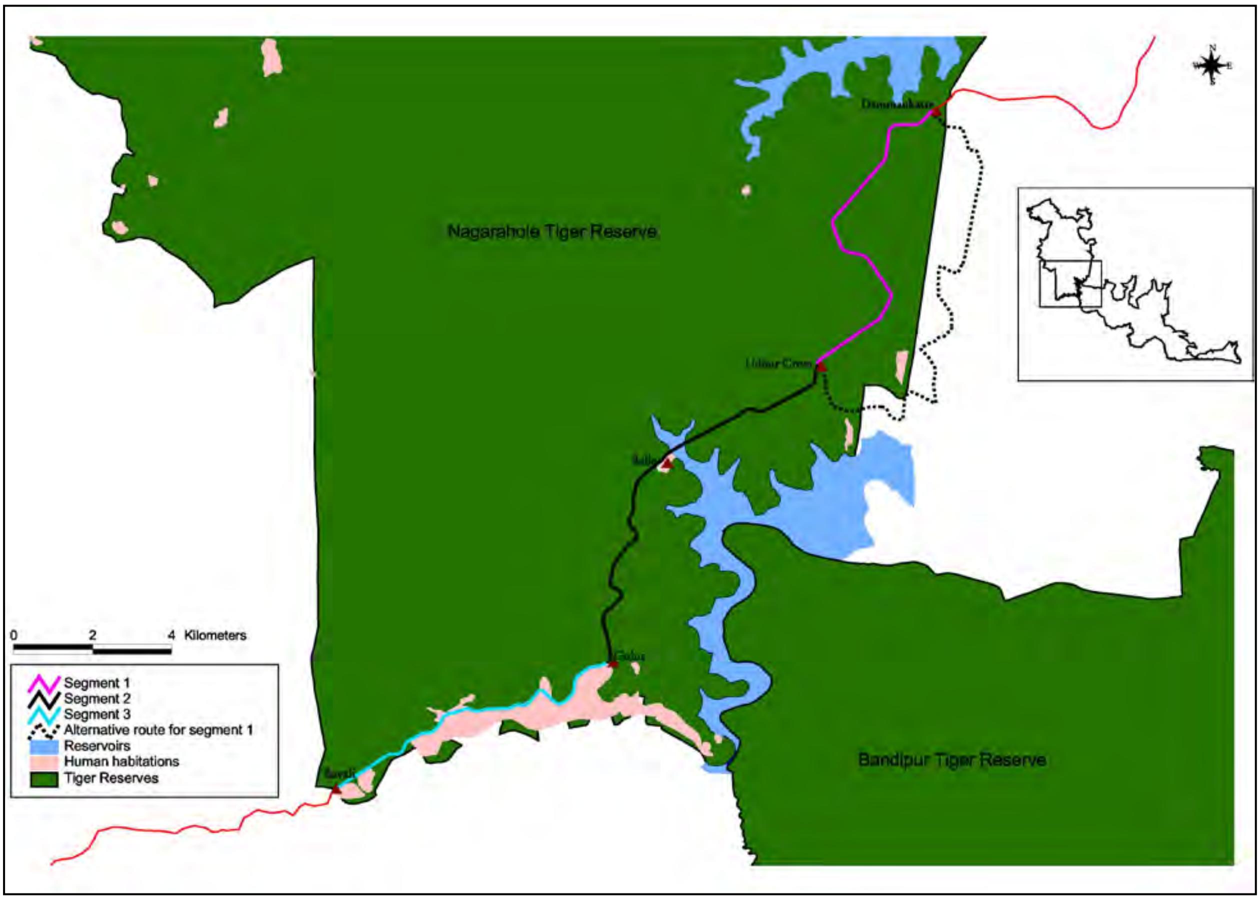
Structural measurements (height, depth and width) of all culverts and bridges on the Mysore-Mananthavadi Highway were measured to calculate their openness ratio (width*height/depth). Apart from openness ratio, evidence of flowing water, percentage of vegetation within the culvert, line of sight from the edge of the culvert (up to 50 m) were recorded to assess any possible relationship of these variables on the usage of culverts by wildlife.

Since segment 3 of the highway is at the edge of human habitations and farmlands, six culverts only within segments 1 and 2 were monitored to assess the use of these structures by wildlife for crossing the highway. Using camera traps we monitored the selected culverts over a period of 176 trap days (24 hr period) to assess the usage by different wildlife species including tiger and their prey.

Based on topographic features such as dips, curves, slopes and ridges we identified locations for implementation of speed calming measures that included road humps, rumble strips and chicanes.

Meetings and presentations were held with key Government officials who were involved in road development/up gradation work and officials of the Forest Department who are responsible for the management and conservation of this area.

Map 2: Different segments of the Mysore-Mananthavadi Highway



Results

A total of 736 animal trails that intersected the highway were counted on the Mysore-Mananthavadi Highway. The number of animal trails in segment 1, 2 and 3 were 323, 358 and 55 respectively. The number of animal trails/km was 43.6, 30.6 and 6.7for segment 1, 2 and 3 respectively (Table 2). Topography did not seem to affect the number of trails which seems to indicate that topographic features along this road is not influencing habitat use by wildlife animals.

Capture frequency

A total of eleven species of wildlife and domestic cattle and dogs were recorded in the camera traps. However due to very low capture rates the data for langur and peafowl was discarded.

The vehicular activity (vehicular traffic density/hr + s.e.) for segment 1 was 1.880 (±0.16), 44.00 (±1.47) for segment 2 and 40.73(±1.70) for segment 3. (see Figure 1a). The proportion of the highway adjoining human settlements and human interface between the different segments of the Mysore-Mananthavadi Highway passing through Nagarahole Tiger Reserve was 0.0, 0.09 and 1.0 km for segments 1, 2 and 3 respectively (Figure 1.b) . The encounter rates at camera traps of domestic cattle were 0 in segment 1, 0 in segment 2 and 0.133 (±0.051) in segment 3 and similarly for domestic dogs it was 0, 0 and 0.030 (±0.016) in segments 1, 2 and 3 respectively. These act as surrogates of anthropogenic activity.

Number of animal trails/km found intersecting with three segments of the Mysore-Mananthavadi Highway was 43.6, 30.6 and 6.7 for segment 1, 2 and 3 respectively (see Figure 2).

Capture rates for different wildlife species are 0.23 (±0.044), 0.157 (±0.028) and 0.010 (±0.010) for elephants, 0.143 (±0.034), 0.071 (±0.022) and 0 for gaur, 0.055 (±0.017), 0.071 (±0.025) and 0.050 (±0.019) for sambar, 0.124 (±0.028), 0.039 (±0.015), 0.09 (±0.019) for chital, 0.020(±0.014), 0.008(±0.008), 0.040(±0.018) for wild pig, and 0, 0.008(±0.008), 0.041 (±0.023) for black-naped hare in segments 1, 2 and 3 respectively. For carnivores it was 0.027(±0.012), 0.016(±0.011), 0 for tiger, 0.013(±0.013), 0.016(±0.011), 0 for leopard and 0, 0, 0.051 (±0.029) for jungle cat for segments 1, 2 and 3 respectively (see Figure 3).

Table 2: Different parameters measured on the Mysore-Mananthavadi Highway

Segment	**1**	**2**	**3**
Road Length (km)	7.4	11.7	8.2
Proportion of road intersecting human habitation (km)	0.0	0.09	1.0
Camera trapping effort (trap-days)	148	126	98
Animal trails / km	43.6	30.6	6.7

Figure 1: Differences in vehicular activity and human interface between the segments of the Mysore-Mananthavadi Highway passing through Nagarahole Tiger Reserve. Graphs below show variations across segment with respect to: (a) vehicular traffic density (vehicles/hr + s.e.); (b) proportion road-length adjoining human settlements and farmland; and (c) encounter rates (encounters/trap day + s.e.) of domestic cattle and dog at camera traps.

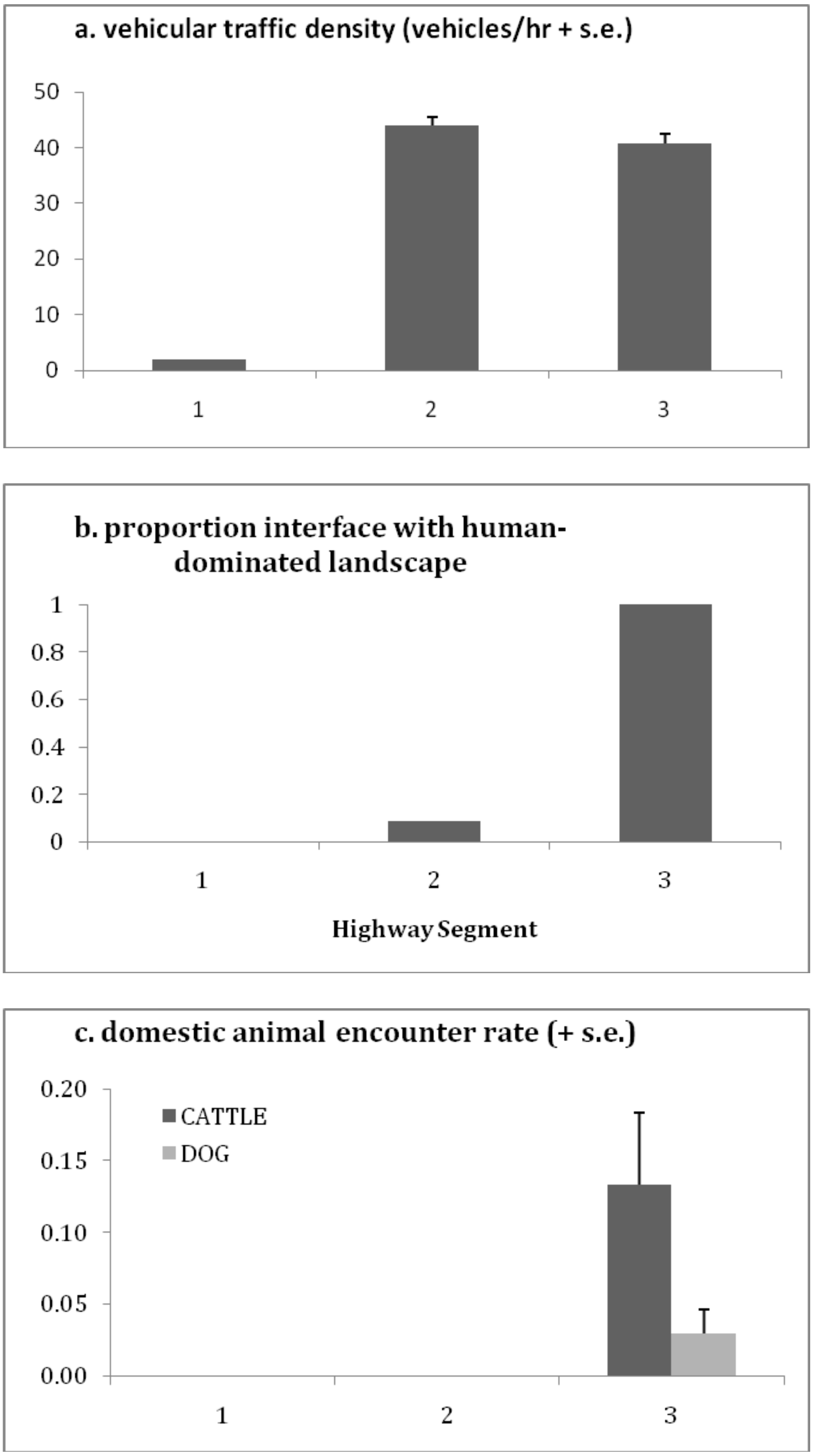


Figure 2: Number of animal tracks found intersecting with three segments (x-axis) of the Mysore-Mananthavadi Highway.

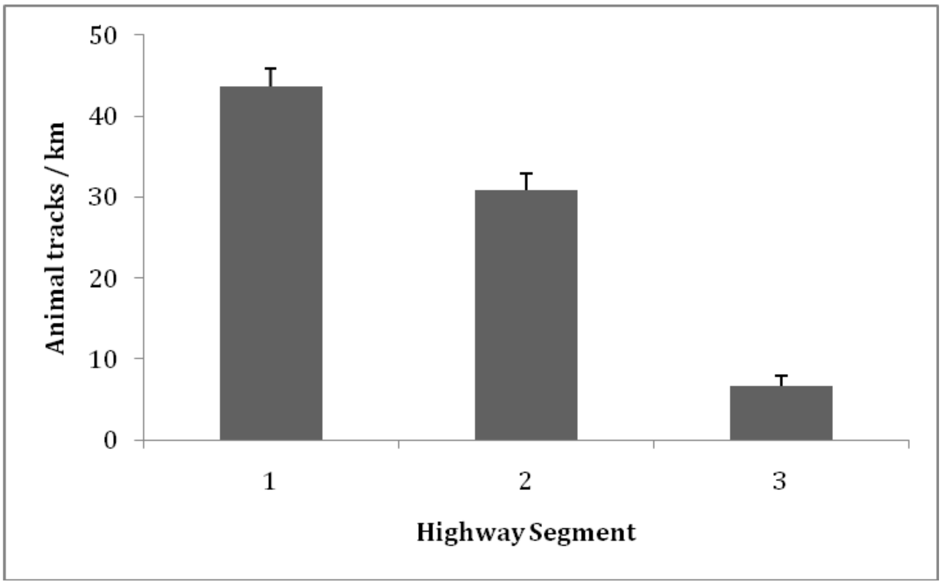
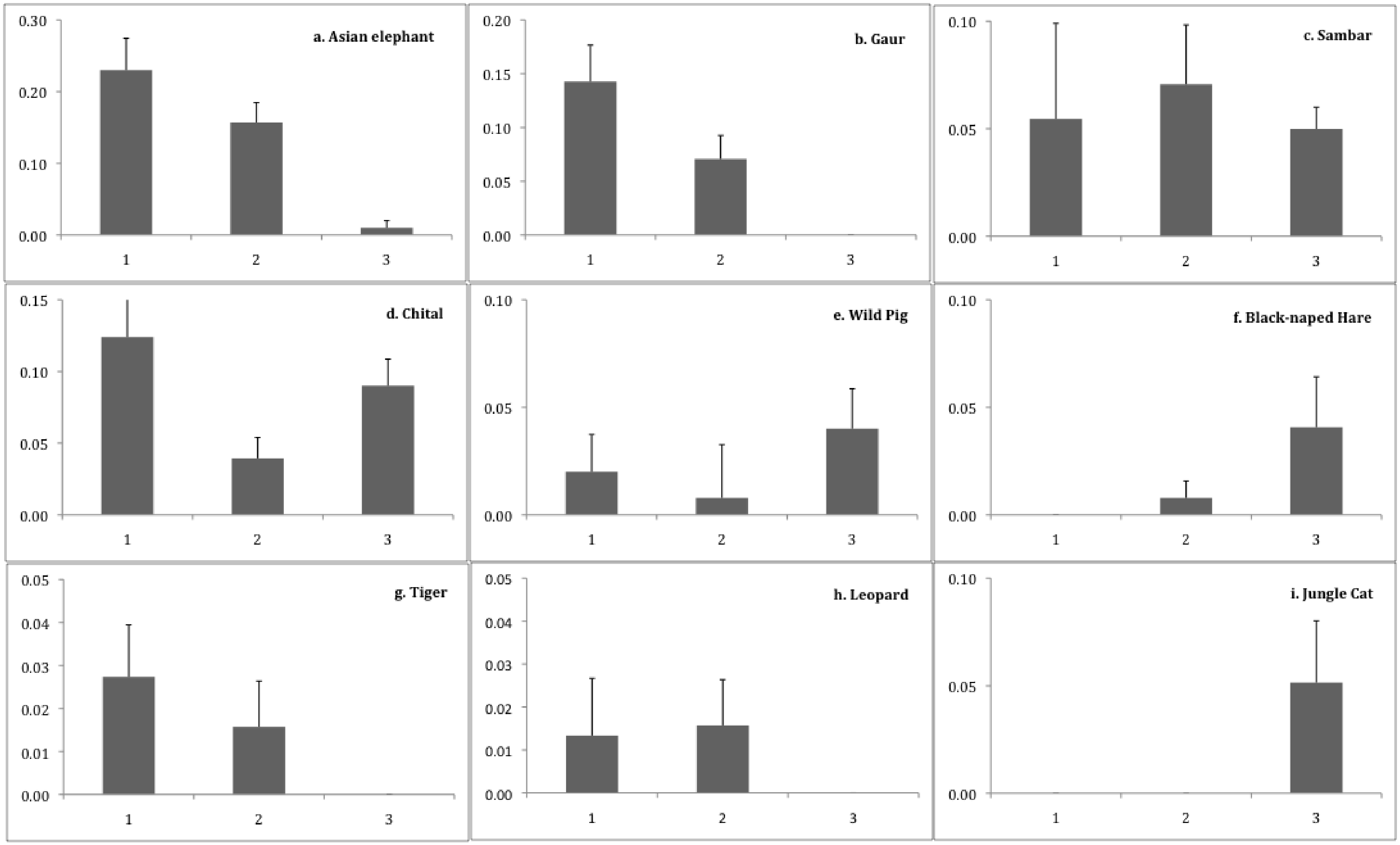


Figure 3. Camera trap capture rates (no. of captures per trap day + s.e.) for 9 species of large mammals in three segments of the Mysore-Mananthavadi Highway (x-axis) within Nagarahole Tiger Reserve.



Culverts as wildlife underpasses

A total of 20 culverts are present in the 27.3 km stretch of the Mysore-Mananthavadi Highway within Nagarahole Tiger Reserve which have been built for hydrological reasons. Of the 20 culverts only 10 of them lie within forest limits while the other 10 lie in human habitations (segment 3) (Map 3). The structural details of all the culverts are given in Table 3.

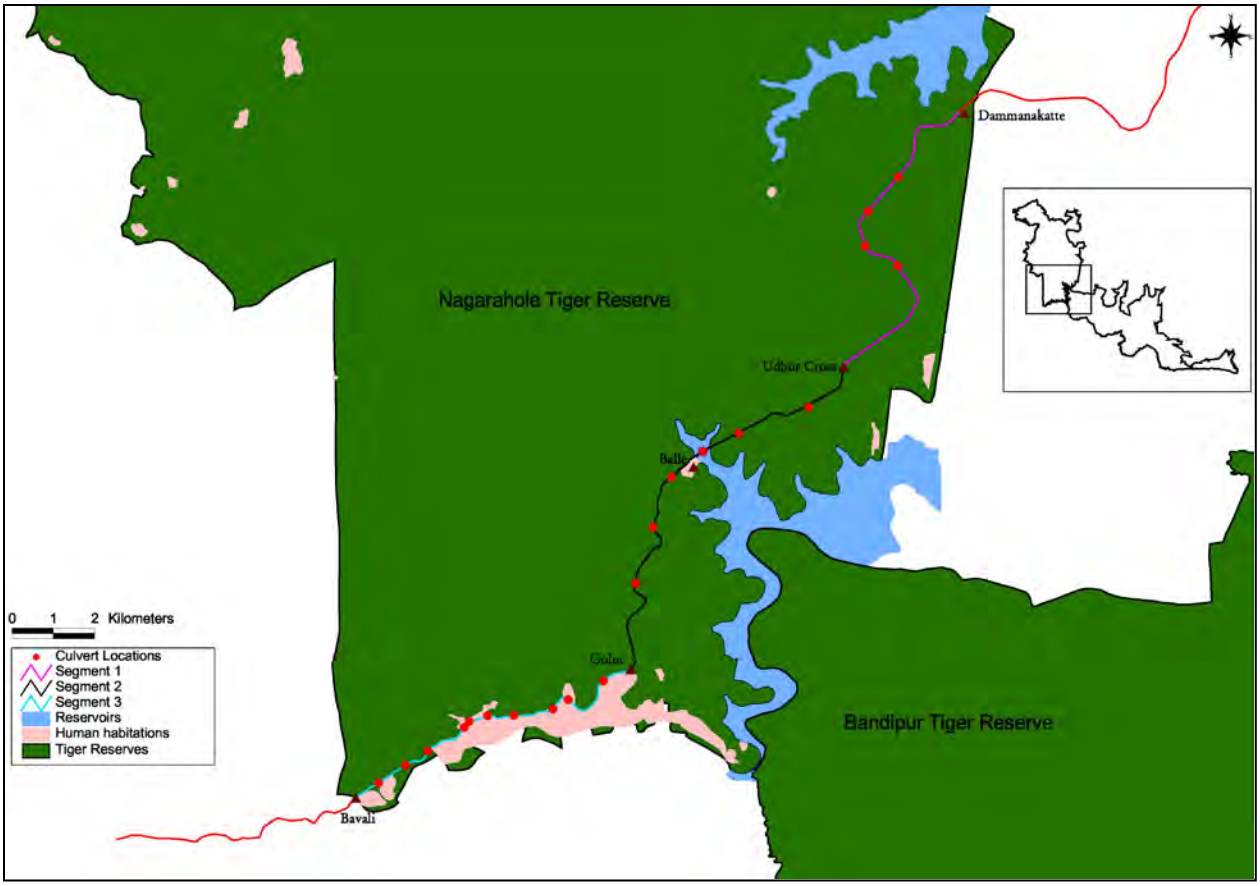
Table 3: Structural details* of culverts on Mysore-Mananthavadi Highway within Nagarahole Tiger Reserve.

Culvert no.	*Latitude*	*Longitude*	*Width (w)*	*Height (h)*	*Depth (d)*	*Openness ratio (w*h/d)*
CL01	11.9962	76.24029	4.24	3.46	9.77	1.501
CL02	11.9885	76.2335	5.4	4.9	9.83	2.692
CL03	11.98069	76.23283	3.64	4.76	9.82	1.764
CL04	11.97625	76.24016	11.91	6.65	8.27	9.577
CL05	11.94436	76.22012	4.28	3.77	9.82	1.641
CL06	11.93846	76.2044	3.6	3.32	9.81	1.218
CL07	11.93439	76.19635	26	6.57	8.49	20.120
CL08	11.9286	76.18922	7.8	5.1	8.41	4.730
CL09	11.91733	76.1851	2.82	3.9	9.81	1.121
CL10	11.90461	76.18117	11.78	5.4	8.26	7.701
CL11	11.88267	76.17392	4.25	3.7	9.79	1.606
CL12	11.87846	76.16595	5.49	3.73	9.96	2.056
CL13	11.87633	76.16252	2.3	2.98	9.84	0.696
CL14	11.87492	76.15376	3.67	3.32	9.8	1.243
CL15	11.87479	76.14782	5.45	3.15	9.82	1.748
CL16	11.87358	76.14368	5.5	3.21	9.8	1.801

CL17	11.87224	76.14252	5.48	4.38	9.8	2.449
CL18	11.86686	76.13436	4.25	3.81	9.79	1.654
CL19	11.86363	76.12928	3.6	2.66	9.82	0.975
CL20	11.85965	76.12325	5.45	4.85	9.85	2.683

* all dimensions are given in meters

Map 3: Locations of major culverts on the Mysore-Mananthavadi Highway in Nagarahole Tiger Reserve



A total of 16 photographic captures of animals using culverts to cross the highway was recorded (Table 4). Of these 16 captures, only six photographic captures were of large mammals using the culverts.

Table 4: Number of photo captures of wildlife observed using culverts to cross the Mysore-Mananthavadi Highway

Species	*No of photographs recorded*
Langur	6
Wild pig	3
Bonnet macaque	2
Leopard	1
Sambar	1
Chital	1
Blacknaped hare	1
Peafowl	1

Locations for speed calming measures

Based on topographical features, locations for installing speed calming measures were suggested to the Forest Department (Map 4) and the road construction agency. The number of mitigation structures (road humps, rumble strips and chicanes) to be constructed is as per the orders of the Honourable Supreme Court of India (CEC 2008).

A total of 47 locations for installing road humps, 17 locations for rumble strips and 5 locations for chicanes have been identified. Details of speed calming measures, GPS locations and type of speed calming measures to be installed are given in Table 5.

Map 4: Locations of speed calming measures suggested to be implemented on the Mysore-Mananthavadi Highway

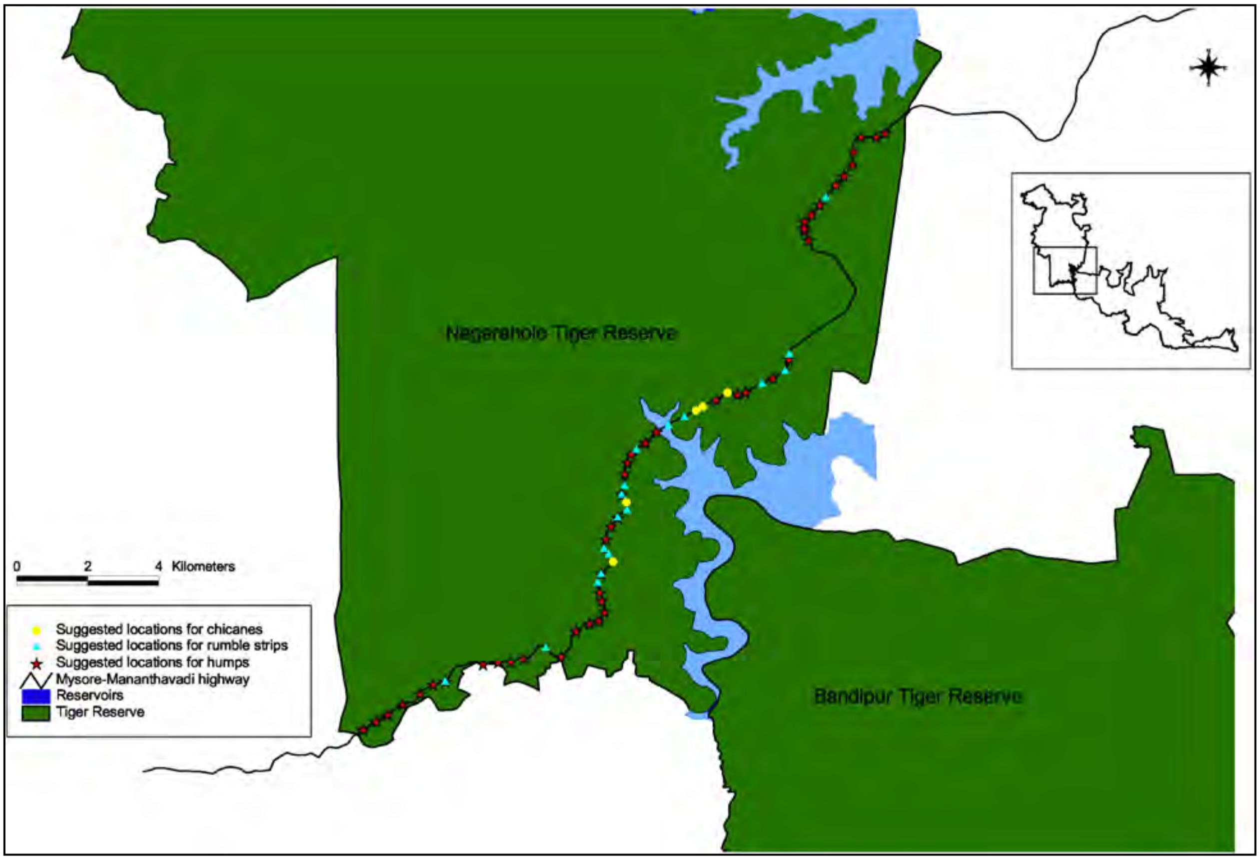


Table 5: Suggested locations for installing speed calming measures on the Mysore-Mananthavadi Highway

Sl. No.	*Latitude*	*Longitude*	*Mitigation measure*
01.	11.9529	76.227964	Rumble strips
02.	11.95152	76.227788	Hump
03.	11.94864	76.226864	Rumble strips
04.	11.94675	76.223656	Hump
05.	11.94543	76.22098	Rumble strips
06.	11.94323	76.216809	Hump
07.	11.9427	76.214641	Hump
08.	11.9431	76.21223	Chicane
09.	11.94123	76.209348	Hump
10.	11.93952	76.205988	Chicane
11.	11.93855	76.204252	Chicane
12.	11.93701	76.201306	Rumble strips
13.	11.93493	76.197257	Rumble strips
14.	11.93318	76.194236	Hump
15.	11.93049	76.191389	Hump
16.	11.92871	76.18917	Rumble strips
17.	11.92754	76.187844	Hump
18.	11.92537	76.186832	Hump
19.	11.9226	76.186227	Hump
20.	11.91956	76.186159	Rumble strips
21.	11.9173	76.185425	Rumble strips
22.	11.9173	76.18542	Hump
23.	11.91529	76.186604	Chicane
24.	11.91338	76.186855	Rumble strips
25.	11.91146	76.18447	Rumble strips
26.	11.91146	76.18447	Hump
27.	11.90922	76.182693	Hump
28.	11.90597	76.181379	Hump
29.	11.90358	76.180933	Rumble strips
30.	11.90218	76.182121	Rumble strips
31.	11.9002	76.183239	Chicane
32.	11.89721	76.180211	Rumble strips
33.	11.89721	76.18021	Hump
34.	11.89509	76.179365	Rumble strips
35.	11.89251	76.1799	Hump
36.	11.89034	76.180381	Hump
37.	11.88748	76.181124	Hump

38.	11.88518	76.179523	Hump
39.	11.88455	76.177308	Hump
40.	11.88267	76.173818	Hump
41.	11.87623	76.170178	Hump
42.	11.87841	76.166185	Rumble strips
43.	11.87623	76.17018	Hump
44.	11.87576	76.160651	Hump
45.	11.87498	76.157375	Hump
46.	11.87481	76.1542	Hump
47.	11.87433	76.150309	Hump
48.	11.86992	76.140745	Rumble strips
49.	11.86992	76.14075	Hump
50.	11.86913	76.137683	Hump
51.	11.86674	76.134241	Hump
52.	11.86413	76.129959	Hump
53.	11.86156	76.12615	Hump
54.	11.85983	76.123253	Hump
55.	11.85771	76.119941	Hump
56.	11.98174	76.23273	Hump
57.	11.98407	76.23186	Hump
58.	11.98489	76.23163	Hump
59.	11.98651	76.23180	Hump
60.	11.98826	76.23342	Hump
61.	11.99076	76.23563	Hump
62.	11.99260	76.23716	Rumble strips
63.	11.99571	76.23972	Hump
64.	11.99797	76.24170	Hump
65.	12.00104	76.24377	Hump
66.	12.00419	76.24414	Hump
67.	12.00788	76.24613	Hump
68.	12.00792	76.24995	Hump
69.	12.00886	76.25210	Hump

Discussions

Two major factors affect road kill rates; traffic volume and speed. Vehicular density on the Mysore-Mananthavadi Highway has increased by 1100 per cent. In the year 2003 the traffic volume on the Mysore-Mananthavadi Highway was 50 vehicles per day (Scott Wilson Kirkpatrick 2003). Our current enumeration of vehicular data shows that it has increased to an average of 553 vehicles during the 12 hr period when the highway is open for vehicular traffic. This clearly indicates a high volume of traffic on this highway.

This study results clearly show that wildlife had no preferences for topographical features while crossing the highway. However based on biological properties of the animals such as poor eyesight and slow response of some species, and traffic volumes and speed on the Mysore-Mananthavadi Highway it is extremely important that speed calming measures are installed at curves, slopes and ridges.

The tally of frequency of captures of different wildlife species gives a clear indication of avoidance of the highway and human inhabited areas by certain species. The capture frequency of elephant, gaur, tiger and leopard indicate strong avoidance by these species of the highway segment that has high human interface (segment 3). While these species still used the segment with vehicular traffic (segment 2), their capture rate decreased compared to segment 1 which had no vehicular traffic. These captures were mostly during night time when there was no vehicular traffic in any of the highway segments. Though the number of captures for tiger and leopard are small we do have some indicative patterns.

Sambar and chital used segments that had both vehicular movement and human habitations. The usage of segment 2 by these species is perhaps due to the availability of grass at the forest-highway interface which the Forest Department manages by clearing vegetation to about 15m on either side of the highway. These habitat edges attract graziers such as chital and sambar. The usage of segment 3 by these two species was again at night time as they were perhaps attracted to the forest edges for grazing.

Though effects of roads are negative, some species respond positively to micro-habitats created near roads (Forman et al. 2003). Similar results are obtained in this study for chital and sambar. These are the species that are most susceptible to road kills. In the adjoining Bandipur Tiger Reserve high road kill mortality of species such as chital, sambar, mouse deer, black-naped hare, civets and other species are observed. Some of these species are attracted to the highway edges by the food that people throw out while traveling on the highway or due to intentional feeding of wildlife.

Wild pig attained the highest frequency of capture at forest edges with agriculture interface, which was segment 3. Similarly jungle cat and black-naped hare also attained their highest capture frequencies in segment 3 as they are probably attracted to open areas. Black-naped hare would find increased grazing opportunities and jungle cat perhaps attracted by rodents that would be abundant in forest edges with agriculture interface. Similarly the capture frequencies of domestic cattle and dogs were observed only in segment 3. These act as surrogates of high anthropogenic activity in segment 3.

These observed variations in capture frequencies of wildlife can be used as a measure of impacts of vehicular traffic on the use of highway-edges by large mammals. The corridor where the study was carried out lies close to a large man-made reservoir to which large mammals are attracted during the dry season. Further sampling across different seasons (dry and wet seasons) would give us a better understanding of seasonal use of highway edges by wildlife. Similarly long-term studies on this aspect can give more robust results.

Camera trap results clearly indicate that the existing culverts do not function as underpasses for wildlife. These culverts were built solely for hydrology purposes and do not to facilitate wildlife crossings. Environmental Impact Assessments about highway construction need to consider this aspect. This study also highlights the point that impact assessment on wildlife by projects like these needs scientific and quantitative assessments carried out by trained wildlife biologists and not through rapid Environment Impact Assessments.

Roads are a conspicuous feature in the modern landscape. A framework for addressing their effects through conservation planning that would address the immediate impacts as well as provide long-term solutions for reducing impact of linear intrusions like highways on wildlife needs to be developed. This is specifically required with respect to endangered wildlife species like tiger.

Although roads are important for economic development, poor planning, disregard of ecological aspects and excessive road expansion into wildlife habitats will further fragment and destroy wildlife populations and their habitats in the long-term. Unfortunately except for air pollution, impacts of surface transportation on wildlife is largely ignored (Forman et al. 2003) especially in countries like India.

As roads are upgraded to accommodate greater traffic volume the rate of successful wildlife crossing decreases (Forman et al 2003). Vehicular speed is one of the important determinants of road kills. Hence implementing speed calming measures is an important measure for reducing road-kills. The location of these speed calming measures have to be suggested by wildlife biologists who have a comprehensive understanding of the site and behaviour of wildlife. These recommendations have to be strictly adhered to.

Road impacts are more serious when the species threatened are endangered or otherwise have high conservation value. Closure of night time traffic when wildlife is most susceptible for road kills is highly advised in ecologically important areas. However it may not be possible to halt night traffic on all highways passing through wildlife habitats. Wherever possible alternate roads needs to be developed so that these high speed roads can be permanently avoided through critical wildlife habitats.

European and North American countries have invested heavily on maintaining connectivity for wildlife through construction of mitigation measures (Forman et al. 2003). India needs to consider this option and serious scientific work needs to be carried out to develop multi-species mitigation measures. This can minimize some effects of day time traffic wherever alternate alignment is not available.

Systematic record keeping of wildlife mortalities due to vehicular collision is currently not practiced in India. State Forest Departments do not consider it a serious offence unless the animal killed is a large wildlife species. Hence systematic record keeping of all mortalities due to vehicles and implementing the Wild Life Protection Act (1972) where killing of wildlife due to road accidents is considered as poaching, should be strictly enforced.

The Western Ghats have seen an unprecedented increase in developmental activities in the last 15 years. Contradictory goals of different Government departments need to be minimized through integrated development planning. Or else the last few patches of wildlife habitats will be further fragmented.

The principal investigator of this project is a member of the Mysore-Mananthavadi Highway up gradation monitoring committee. The results of this study have been presented to the committee for implementation of mitigation measures. The Principal Investigator was instrumental in convincing the Government for the night closure of Mysore-Mananthavadi Highway which is now being successfully implemented since July 2008. Currently a proposal to upgrade the alternate road for segment 1 of this highway to outside the national park limits is being worked out with the Government to further reduce the impact of this highway.

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Appendix 1

Camera traps were installed on animal trials along the three different segments of the Mysore-Manathavadi Highway to assess use of highway edges by wildlife - © Sanjay Gubbi

The Mysore-Mananthavadi Highway was upgraded as a high speed road in the year 2009 – © P.M.Muthanna

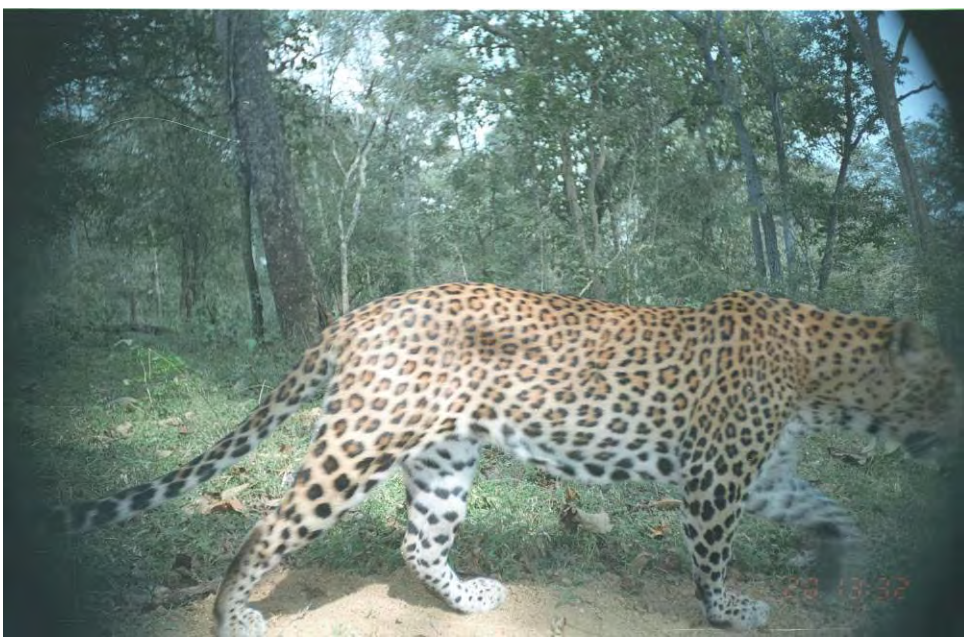
The Mysore-Mananthavadi Highway (seen on the extreme right of the picture) is built in an extremely important corridor between Nagarahole and Bandipur Tiger Reserves – © Sanjay Gubbi/WCS-India.

Camera traps were placed under culverts with varied structural dimensions to assess their usage by wildlife to cross the highway - © Sanjay Gubbi

Enumeration of vehicles in the three different segments of the Mysore-Mananthavadi Highway was undertaken with help of volunteers – ©H.C.Poornesha/WCS-India

Culverts under the highway were monitored to assess wildlife usage - ©Sanjay Gubbi/WCS-India.

Tigers used highway edges mostly when the traffic was non-existent during night time – ©Sanjay Gubbi/WCS-India.



Leopards showed similar patterns of highway edge avoidance as tigers - ©Sanjay Gubbi/WCS-India

Capture rates of elephants and gaurs decreased in the highway segment where traffic density and human interference was higher - ©Sanjay Gubbi/WCS-India

Sambar and chital were perhaps attracted to highway edges due to the higher availability of grass due to vegetation clearance carried out - ©Sanjay Gubbi/WCS-India

Highest capture rates of domestic dog and cattle were seen in highway edges with highway human habitation/farmland interface - ©Sanjay Gubbi/WCS-India

A tiger crosses Segment 1 of the Mysore-Mananthavadi Highway which is now closed to vehicular traffic due to the efforts of the Principal Investigator of this project - © Mahesh Mudaliyar

The closed part of the Mysore-Mananthavadi Highway (segment 1) has allowed large carnivores to use the highway edges even during day time - ©H.C.Poornesha/WCS-India

Camera trap results of the study showed higher usage of the Mysore-Mananthavadi Highway in closed part of the road (segment 1) by elephants during day time - ©Sanjay Gubbi/WCS-India

A sub-adult tusker crosses the closed part of the Mysore-Mananthavadi Highway during day time - ©Vikram Nanjappa

Young animals can be particularly susceptible to road kills due to speeding vehicles - ©Sanjay Gubbi/WCS-India

It is important to install speed calming measures in curves, slopes and ridges - ©Vikram Nanjappa