Impact of vehicular traffic on the use of highway edges by large mammals in a South Indian wildlife reserve

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India's phenomenal economic growth over the last decade has been accompanied by a much-needed expansion and improvement in transport and other infrastructure networks. While there are legally mandated assessments of the *potential* ecological impacts of such infrastructure projects prior to implementation, rarely are there post-implementation assessments of their *real* ecological impacts. In this communication, we present results of a preliminary study examining the impact of vehicular traffic on the usage of road edges by large mammals along a highway passing through Nagarahole Tiger Reserve, southern India. We estimated large mammal encounter rates at remotely triggered camera traps on two consecutive sections of the same highway – one closed to vehicular traffic and the other open to vehicles only during daytime. We observed lower encounter rates of chital, gaur and elephants at camera traps in the highway segment with higher vehicular traffic density, suggesting that these species avoided busy highways. Based on our findings, we emphasize the importance of continued ecological impact assessments of development projects to identify and mitigate unforeseen impacts. Further, an approach to development planning that integrates conservation concerns, especially where development projects coincide with ecologically critical areas, is urgently needed in India.

Keywords: Highway edges, impact assessment, large mammals, vehicular traffic, wildlife reserve.

THE story of India's dramatic economic growth over the last decade has been accompanied by growing hunger for natural resources and rapid expansion of its development infrastructure. From being an aid-dependent developing nation not so long ago, India now stands fourth among the world's nations in purchasing power parity GDP[1]. However, the welcome benefits of economic development have gone hand-in-hand with serious costs both to the people and the environment. These include the displacement of people, overexploitation of natural resources, disruption of ecological services and fragmentation of wildlife habitats.

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One of India's biggest challenges today is how it reconciles the pursuit of economic growth with the protection of its ecological integrity. To make economic growth and human development sustainable requires the identification, understanding and alleviation of the ecological costs of growth and development without forsaking their benefits.

The spike in India's growth over the last decade has involved a considerable expansion of infrastructural development projects. Among these, road and highway projects, which provide the vital foundation on which other sectors of the economy can be built, have received a huge boost. Several international donor and lending agencies have provided the economic impetus for the expansion of the road networks[2]. During 2008–2011, the Indian Government itself allocated a budget of US$ 13.67 billion for the development of roads[3]. This, in turn, has triggered a rapid growth of motor vehicles in India at 12% per year[4] and further intensified the demand for better roads.

Unlike in many forested tracts of Africa, South America or South East Asia, where road projects have opened up frontier areas to markets[5–7], road and highway projects in India have primarily involved an enhancement in the quality of existing roads, setting off proximate increases in vehicular activity, rather than fundamentally altering connectivity patterns, although important exceptions exist.

Road improvement and highway development projects are now increasingly being proposed within India's protected area (PA) network, which forms a mere 4% of the country's landscape. Although these roads enhance connectivity between key economic centres, the upgrading of minor roads to high-speed highways also poses a serious threat to wildlife in and around the PAs.

In India, the impact of roads or vehicular traffic on wildlife has received little research attention, except for a handful of studies that focus on road-kills of lower taxa[8–11], and one study on animal behavioural response to vehicular traffic[12]. Despite the fact that roads could affect numerous endangered wildlife species, there have been virtually no studies assessing their impacts, especially on large-bodied animals. As a result, the impact of roads and vehicular traffic on larger endangered species remains poorly understood in India.

The Western Ghats, a global biodiversity hotspot, hosts some of the world's best protected areas for tiger (*Panthera tigris*) and Asian elephant (*Elephas maximus*) conservation. In this study, we focused on Nagarahole Tiger Reserve in southern India (Figure 1), which forms the core of the largest global population of tigers[13] and Asian elephants[14]. Among the anthropogenic threats to Nagarahole are five major public access roads passing through the tiger reserve (Figure 1). Although vehicles on these highways have often caused accidental deaths of wildlife, no formal assessments of their impact on animal habitat

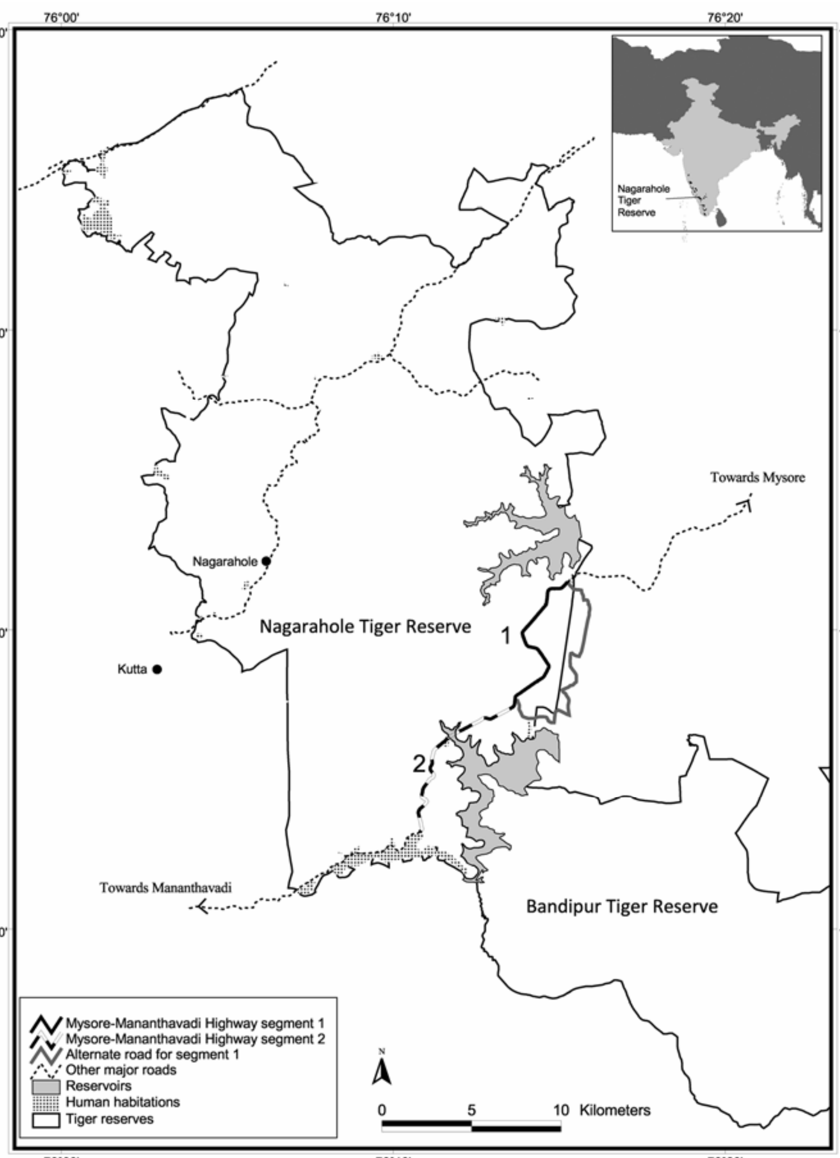

Figure 1. The Mysore–Mananthavadi Highway in Nagarahole Tiger Reserve and the two study segments.

use have been carried out. Amongst these roads is the Mysore–Mananthavadi Highway (MMH), passing through a crucial wildlife corridor in the southern part of Nagarahole. This highway was upgraded to a high-speed road in 2009. In this study, we document the impact of vehicular traffic on use of highway-edge habitats by large mammals.

Although it would have been ideal to assess the impact of highway vehicular traffic on wildlife by measuring animal usage of road edges before and after a highway was opened to vehicular traffic[15], we were unable to do so because the entire stretch of the road was open to vehicular traffic till recently. After an alternate road outside the national park became available, a stretch of the highway through it was closed to vehicular traffic. We therefore used a space-for-time substitution design[16], comparing a 'treatment' stretch of road exposed to vehicular traffic with the adjoining 'control' stretch of road that was recently closed to vehicular traffic.

We selected a 19.1 km stretch of MMH passing through a homogeneous area of forests in Nagarahole. We chose two segments of this highway based on the level of vehicular traffic in them. The two segments fell in the same forest type[17], had the same rainfall regime[18] and were managed as part of the National Park under the same management objectives. Therefore, we considered that the ecology and management regimes across the two highway segments were comparable, leaving highway traffic as the most important way in which they differed. In segment 1 (7.4 km in length), vehicular traffic had

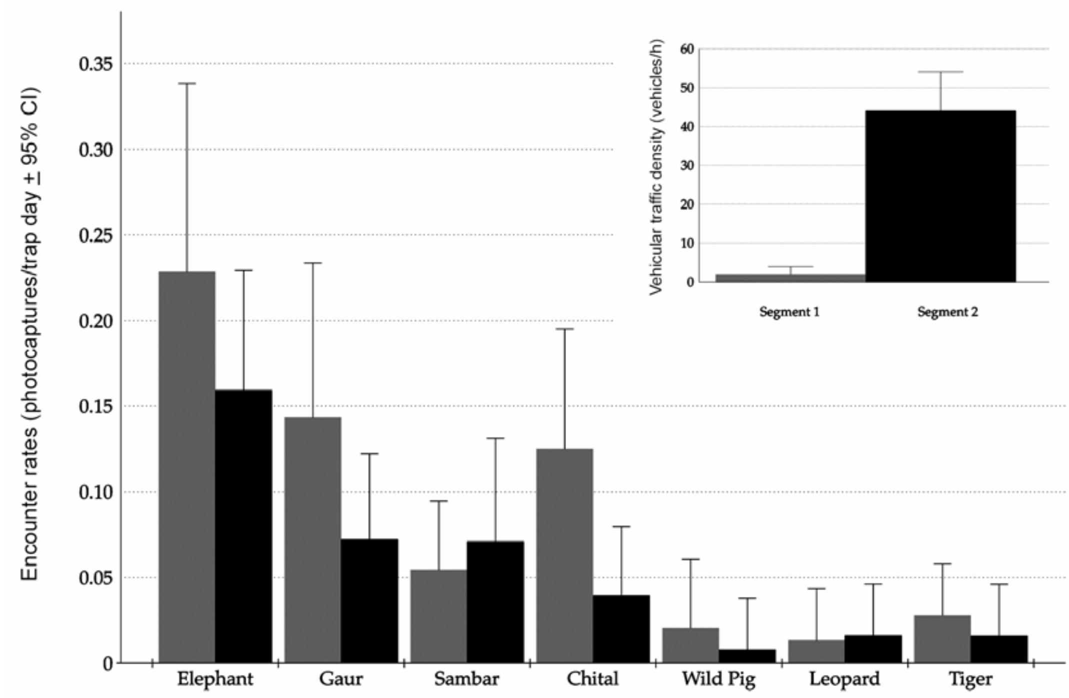

Figure 2. Encounter rates (number of photo-captures per trap day + 95% bootstrapped CI) for seven species of large mammals in the two segments (segment 1 – light grey, segment 2 – black), of the Mysore–Mananthavadi Highway. (Inset) Difference in vehicular traffic density between the two segments.

been prohibited for 34 months (with exceptions for park vehicles on patrol and public emergencies) after a diversion had been created (Figure 1). On the other hand, vehicles continued to use segment 2 (11.7 km in length) through the day, while both segments of MMH through the park remained closed for vehicles between 6 pm and 6 am.

In both segments, between November 2009 and June 2010, we estimated vehicular density along the road and also assessed the use of road edges by large mammals. To estimate vehicular density, the number of vehicles passing through segments 1 and 2 was monitored for a 12-h period between 6 am and 6 pm over 10 days. The time, number and type of vehicle were recorded. To assess the use of road edges by large mammals, we first surveyed 100 m stretches of the entire highway in both segments and counted the number of animal trails intersecting the highway. We then set up camera trap units across animal trails in 10 different locations within each segment for 15 days between November 2009 and June 2010. Owing to unit malfunctioning and theft, we were unable to achieve equal sampling effort in each segment and managed 148 and 126 trap-days in segment 1 and 2 respectively. We tallied the frequency of captures at each trap location by species and date. Pictures of the same species taken at the same location at intervals of < 20 min were conservatively treated as multiple pictures of the same group, and not tallied. However, if it was obvious that the pictures were of different individuals/groups of animals (different tigers identified by their stripe patterns/herd of elephants or a tusker) within that time lag, they were treated as multiple captures.

Data on vehicular activity (vehicle density/hour) were summarized by segment. Against these measures of vehicular activity, we compared species-wise encounter rates from camera traps to draw inferences on how vehicular activity affected large mammals. We did this by computing species-wise means of photo-capture rates from 10 trap days, randomly drawn with replacement from a pool of 15 and 14 trap nights in segments 1 and 2 respectively. We used Monte Carlo simulations to assess the significance level of differences observed in the mean photo-capture rates between segments 1 and 2.

The mean vehicular traffic density in segment 2 (44.0 ± 1.5 vehicles/h) was nearly 23 times greater than in segment 1 (1.9 ± 0.2 vehicles/h; Figure 2).

In all, a total of 681 animal trails intersected MMH (segment 1 – 323, segment 2 – 358). The mean density of animal trails along MMH in segment 1 (43.6/km; SE 0.22) was over 40% higher compared to segment 2 (30.6/km; SE 0.21), suggesting a greater use of road edges by animals in the nearly vehicle-free segment 1.

Although nine mammal species were encountered in the camera traps, species with very low capture rates were omitted from the analysis. The mean photo-capture rates of seven different wildlife species are given in Figure 2. Our data strongly suggest an avoidance of busy stretches of highway by certain large mammals. Segment 2, which had 23 times the vehicular traffic density compared to segment 1, had lower photo-capture rates for species such as chital (*Axis axis*; $P < 0.01$), gaur (*Bos gaurus*; $P = 0.04$) and elephant ($P = 0.08$). For species such as the wild pig (*Sus scrofa*), tiger and leopard (*Panthera pardus*), whose photo-capture rates were zero-inflated, the differences were not discernable. A more sustained monitoring over time may enable a better assessment of how these species respond to vehicular traffic along highways.

While vehicular traffic on roads may indeed repel some species, it must also be seen that clearing along road edges may create micro-habitats that attract animals[19]. Thus, the continued usage – as opposed to total avoidance – of segment 2 by herbivores may also be attributed to the abundance of grass along the highway edges, which is a consequence of efforts made by the Forest Department to clear vegetation on either side of the highway. However, this also makes herbivore species such as chital, gaur and sambar (*Cervus unicolor*) that graze along highway edges more susceptible to road kills. In the adjoining Bandipur Tiger Reserve high road-kill mortalities of chital, sambar and other species such as mouse deer (*Moschiola meminna*), black-naped hare (*Lepus nigricollis*) and small Indian civet (*Viverricula indica*) were observed, particularly when night-time vehicular movements were unrestricted (S.G., pers. obs.).

Even in 2003, the traffic density on MMH was estimated at 50 vehicles/day[20], whereas our current estimate shows that this has now increased to about 553 vehicles/day, despite the highway now being open to traffic only for a 12-h period. There has thus been a 22-fold increase in vehicular traffic density on this highway in over just seven years. Given the strong likelihood of similar changes to vehicular density in other PAs across the country, we argue that, wherever possible, alternate road alignments need to be developed so that high-speed traffic can be permanently kept out of the PAs. Similarly, the closure of vehicular traffic at night, when wildlife are most susceptible to road kills, may also be an advisable option in the PAs.

Vehicular speed and traffic volume are the important determinants of road kills[21]. A set of safeguards such as speed-calming measures (e.g. chicanes, rumble strips, or road humps) is important in reducing road kills. Similarly, as the roads are being improved to accommodate greater traffic volume, the rate of successful wildlife crossing will decrease[19]. Hence, scientifically designed wildlife crossing structures must be put in place while planning highways through wildlife reserves. The location of these speed-calming measures and crossing structures has to be suggested by experts with the requisite understanding of wildlife behaviour and ecology of the site.

Systematic monitoring of vehicular movement and wildlife mortalities due to vehicular collision, which is currently not being carried out in India, needs to be initiated. State Forest Departments do not take road kills seriously unless the animal killed is large. Hence systematic record-keeping of all mortalities due to road kills would provide the necessary data to assess and mitigate impacts of vehicular traffic on wildlife.

Our study draws attention to the process of mandatory environment impact assessments (EIAs) that are today required in India before development projects such as highways are approved within wildlife habitats[22]. Although these EIAs are a step in the right direction, their implementation leaves a lot to be desired. First, the legally mandated process of assessing potential impacts is highly prone to misuse[23,24]. The prevailing system of rapid EIAs by untrained people, often hired by project proponents themselves, must make way for rigorous and peer-scrutinized assessments carried out by trained wildlife biologists. EIAs must also be required to assess the broader impacts of roads rather than focusing just on the physical aspects of their construction[7]. Second, it is essential that the EIA process be changed such that development projects that are already approved in PAs are assessed on a continuing basis for unforeseen impacts, and post-hoc mitigation measures are legally mandated where necessary to reduce such impacts.

Although roads and other infrastructure are important for economic development, poor planning, disregard for the ecological aspects and excessive road expansion into wildlife habitats will further fragment and destroy wildlife populations and their habitats in the long term.

Sustaining India's growth story is possible only if ecological safeguards such as EIAs are not forsaken in the pursuit of economic growth and human development. If India is serious about achieving this balance, there is no escape but to invest in a more holistic process of development planning that includes – rather than ignores – the conservation of its priceless natural heritage.

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ACKNOWLEDGEMENTS. We are grateful to 21st Century Tiger for funding this project. Support and permission provided by the Karnataka State Forest Department is appreciated. We thank Meera Saxena, B. K. Singh, B. J. Hosmath, Vijayranjan Singh, D. Yatish Kumar, Satish, Hiremath and all staff of Nagarahole National Park for their help. S.G. and H.C.P. were supported by Wildlife Conservation Society and Centre for Wildlife Studies, Bangalore while M.D.M. was supported by Nature Conservation Foundation, Mysore. Resource support was provided by Centre for Wildlife Studies. We also thank Madhukeshwar and all volunteers who were involved in data collection.

Received 2 September 2011; revised accepted 21 February 2012

Biopesticide formulation to control tomato lepidopteran pest menace

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In the present study an indigenous biopesticide formulation (BPF) comprising easily accessible botanicals along with cow urine, was evaluated for its efficacy against insect pests of tomato crop under field. BPF gave promising results in controlling tomato fruit borers and afforded substantial yield of the produce. The BPF treatment could control 70–80% of fruit borers compared to check plots, resulting in enhanced fruit yield of 35 tonnes/ha as compared to 15 tonnes/ha in the check plots. The main aim of this study was to reduce the load of synthetic chemical pesticides and evaluate indigenous knowledge as an alternate component of pest management to have pesticide residue-free tomato.

Keywords: Biopesticide, cow urine, pest control, tomato.

TOMATO (*Lycopersicon esculentum*) is the world's second important vegetable crop known for its protective food because of its special nutritive value and its widespread production. In India nearly 7.1 million tonnes of tomato is produced annually, ranking it fifth in the world, from an area of 5.4 lakh ha, placing the country at the second position globally based on its area of production. On an average about 10,800 tonnes of tomato is exported annually from India. The major importers of Indian tomatoes are Bangladesh, Nepal, Pakistan and the UAE[1].

Because of its fleshy nature, tomato fruit is attacked by a number of insect pests and diseases[2,3], resulting in the consumption of large amounts of pesticides which leave their toxic residues[4]. As it is a short-duration crop and gives high yield, it is important from an economic point of view. Spider mites, *Tetranychus urticae* Koch; whitefly, *Bemisia tabaci* Genn; leaf miner, *Liriomyza trifolii* and borers, *Helicoverpa armigera* Hubner are serious pests on tomato causing considerable yield loss under open field conditions in India[3]. The yield loss in tomato crop due to fruit borer (*H. armigera*) alone amounts to 22–38% (ref. 5) or one thousand crores rupees per annum[6]. *H. armigera* is a polyphagous pest and has been reported to infest 181 cultivated and uncultivated plant species in India[7]; it accounts for 90–95% of the total damage to the fruit commodity[8,9]. Synthetic chemicals may be used in plant protection programmes to limit crop damage by

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