

# Ecological effects of road through sensitive habitats

*Implications for wildlife conservation*



**Wildlife Institute of India  
2013**

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### **Funding Agency**

Wildlife Institute of India

### **Duration**

April 2008 to October 2012

### **Budget Outlay**

Rs. 20, 77,100



भारतीय वन्यजीव संस्थान  
Wildlife Institute of India

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# ACKNOWLEDGMENTS

## Wildlife Institute of India

**Director:** Shri P.R. Sinha

**Dean, Faculty of Wildlife Science:** Dr. V.B. Mathur

**WII Faculty:** Dr. S.P. Goyal, Dr. Y.V. Jhala, Dr. K. Sankar, Dr. Dhananjai Mohan, Shri Qamar Qureshi, Dr. Karthikeyan Vasudevan, Dr. K. Ramesh, Shri R. Suresh Kumar

**IT and Remote Sensing & GIS Cell:** Shri Rajesh Thapa, Ms. Nilanjana Roy

**EIA Cell:** Ms. Roshni Arora, Ms. Akanksha Saxena, Shri Narinder Singh Bist

## Madhya Pradesh Forest Department

Dr. H.S Pabla, Former Chief Wildlife Warden, Dr. H.S. Negi, Field Director, Pench Tiger Reserve (PTR), Dr. Nayak, Field Director, Pench Tiger Reserve, PTR  
Shri O.P. Tiwari, Deputy Field Director, PTR

## Assam State Forest Department

Shri S. Dutta, Field Director, Kaziranga National Park (KNP),  
Shri D. D. Gogoi, Deputy Field Director KNP, Shri R.N. Sharma, Research Officer, KNP

## Maharashtra State Road Development Corporation

Shri V D Sardeshmukh, Executive Engineer,  
Shri R.K. Das, Vice President (Environment)

## Envirosearch, Pune

Shri Jayant Kulkarni  
Dr. Prachi Mehta

## Bharati Vidyapeeth University, Pune

Dr. Erach Barucha, Director, Institute of Environment Education and Research (IEER);  
Dr. Shamita Kumar, Professor and Vice Principal, (IEER)

# EXECUTIVE SUMMARY

The road network is a spatial feature that is common in landscapes across the globe. There are an estimated one billion vehicles travelling on approximately 50 million km of public roads and the road network and traffic volumes are still increasing, particularly in Eastern Europe, China, India, and Latin America. The United States of America has the largest road network with over 6 million km public roads followed by China with ca 4.2 million km. India represents the third largest road system in the world with ca 4 million km.

While the reasons for promoting connectivity for human development and economic progress are well recognised in every new initiative in the transportation sector, the ecological concerns are not adequately mainstreamed in the finally implemented road schemes. This becomes evident from numerous examples of roads fragmenting and degrading habitats, endangering animal populations and destroying many plant populations throughout the world.

The need to combine conservation science and practical experience of building roads for securing and enhancing connectivity between natural areas with an overarching goal of conserving biodiversity is real and instant. Steady growth in the current knowledge would assist in meeting transportation planning challenges as they relate to conservation needs. The current research was a step in this direction. The following were the objectives of this study:

- To assess the nature of ecological effects associated with roads based on the study of existing road sections aligned through or along an ecologically sensitive area.
- To predict the nature of ecological effects of a proposed road upgradation (four lanes from two lanes) project with and without mitigation measures.
- Evaluate the compliance and effectiveness of mitigation measures in the earlier implemented road project.
- Suggest effective measures for preventing road induced impacts for harmonising conservation and development.

The following three different road sections were identified for conducting this study:

- i. **National Highway NH-7** (9 km stretch) between Kurai and Gandatola villages in the State of Madhya Pradesh that is aligned along on Pench Mowgli Sanctuary and forms the eastern boundary of Pench Tiger Reserve.
- ii. **National Highway -37**(61 km stretch) running along the southern boundary of Kaziranga National Park, between Bokakhat and Ghorakati range.
- iii. **Mumbai - Pune Expressway** (83 km) traversing the Western Ghats in Maharashtra State.

The study was undertaken during April 2008 - October 2012.

## **I. ECOLOGICAL IMPACTS OF NATIONAL HIGHWAY -7 ALONG PENCH TIGER RESERVE, MADHYA PRADESH**

The objective of the study was to assess the nature of ecological effects associated with National Highway-7. These effects ranged from changes in animal distribution especially of mammalian species and habitat use in response to modification and fragmentation of forests, threats of declining road permeability and increasing mortality of animals in all major animal groups. The study finally suggested measures to avoid and reduce road induced impacts on wildlife species and habitats for mainstreaming conservation concerns in road development.

### **Distribution of mammals in the fractured habitats along the road**

Impact of road on habitat use by mammals was assessed by using line transect method. This involved covering total distance of 748 km on foot. Data on transects was collected for two years.

The use of wildlife habitat in the forest fragments along road was relatively high ( $8.47 \pm 0.50$  individuals/km) in summer when compared to the use of these habitats during monsoon ( $5.03 \pm 0.53$  individuals/km), and winter ( $1.65 \pm 0.20$  individuals/km) seasons.

Animal encounters during summer were more in areas between 300 and 500 meter from the road and gradually decreased in the forest interior ( $R^2=0.528$ ,  $F= 20.136$ ,  $P=0.001$ ,  $df=19$ ). The artificial water sources (created by the State Forest Department) in most locations that were close to the road, attracted animal to use the road verges during summers when the water availability became limited in the forest interiors.

During winters, encounter rates were higher beyond 800 m and increased progressively in forest interiors. During monsoon, the encounter rate of mammals was randomly distributed.

### **Use of road verges by mammals**

Use of road verges by wild mammals was assessed based on road side counts and indirect evidences. Road side counts were made using a four-wheel vehicle driven at a speed of  $<20$  km/h. Continuous monitoring was done for 24 hrs on 3 days in each season: monsoon (July to October), winter (November to February) and summer (March to June). During the day time, direct observations were made of the animals present within 20 meter from the road.

The key findings were:

- 13 species of mammals used the road verge habitats but the use was spatially clustered.
- Maximum number of animal encounters based on direct and indirect evidences was clustered near water holes.
- The animal sighting in the road side habitat was positively related to the canopy cover - NDVI ( $p=0.001$ ) and negatively related to proximity to village ( $p=0.001$ ) and altitude (DEM) of the road ( $p=0.001$ ).
- Average encounter rate of mammals recorded in the road verge habitat was  $8.24\pm 0.12$  individuals/day.
- The use of road verge indicated diurnal variations as reflected in 84% of mammals being encountered during night time.
- The use of habitats in the road verge varied in different seasons with the highest use ( $6.79\pm 0.11$  individuals/10km/day) observed during summer when compared to use of these habitats ( $0.90\pm 0.01$  individuals/10km/day) during winter and monsoon ( $0.56\pm 0.005$  individuals/10km/day.)
- Encounter rates of animals both, diurnally and seasonally were also influenced by traffic volumes.
- The use of the road verges was relatively more ( $61\pm 19$  individuals/10km/day) by primates like rhesus macaques and hanuman langur ( $23\pm 14$  individuals/10km/day) based on their encounter rates.

This study suggests that the use of roadside habitat by animals was highly influenced by the water availability during dry season. The artificial water holes, created by the Forest Department along the road attract animals to use the road side habitat during the dry season (summer). This study recommends promoting better water source planning to reduce/minimize animal use of the roadside habitat by removing the water holes (hand pump) present close to the road side and creating more water holes in the interior areas along the road.

### **Road related mortality of mammals**

The road was monitored using standard road cruising methods for a total of 430 road cruising days spread across three seasons monsoon ( $n=147$ ), winter ( $n=143$ ) and summer ( $n=140$ ) between August 2008 to July 2010. Based on total effort of surveying 3870 km, total of 272 road induced kills of mammals were recorded in 430 days and included 15 species. On an average, 0.70 mammals/10km/day road kills were observed. The most vulnerable animal group was rodent accounting for 51% of the total kills of mammals.

The number of mammal kills varied across seasons and was positively correlated with seasonal variations in traffic volumes and other resources. The percentage kill of adult mammals was significantly higher (90%) than other age classes (Chi-square test,  $X^2=26.0$ , d.f.=14,  $P<0.026$ ). The number of kills of males (41 %) was also significantly higher than the percentage (32%) of females killed (Chi-square test,  $X^2=26.0$ , d.f.=18,  $P<0.009$ ).

The road kills were spatially clustered. Factors such as road topography; nearness to water sources and agriculture; volume of traffic and forest type in the road corridor influenced the mammal road kills.

The present study clearly illustrates that road related direct and indirect mortality on NH-7 can be a major source of impacts on a wide variety of mammalian species even in its present state of a two- lane road. The study recommended two different approaches to reduce road induced mortality of animals on NH-7 (i) adopt measures to alter human behavior through regulatory controls and (ii) measures for on-site habitat management that are likely to influence animal adaptations (Fig.1).

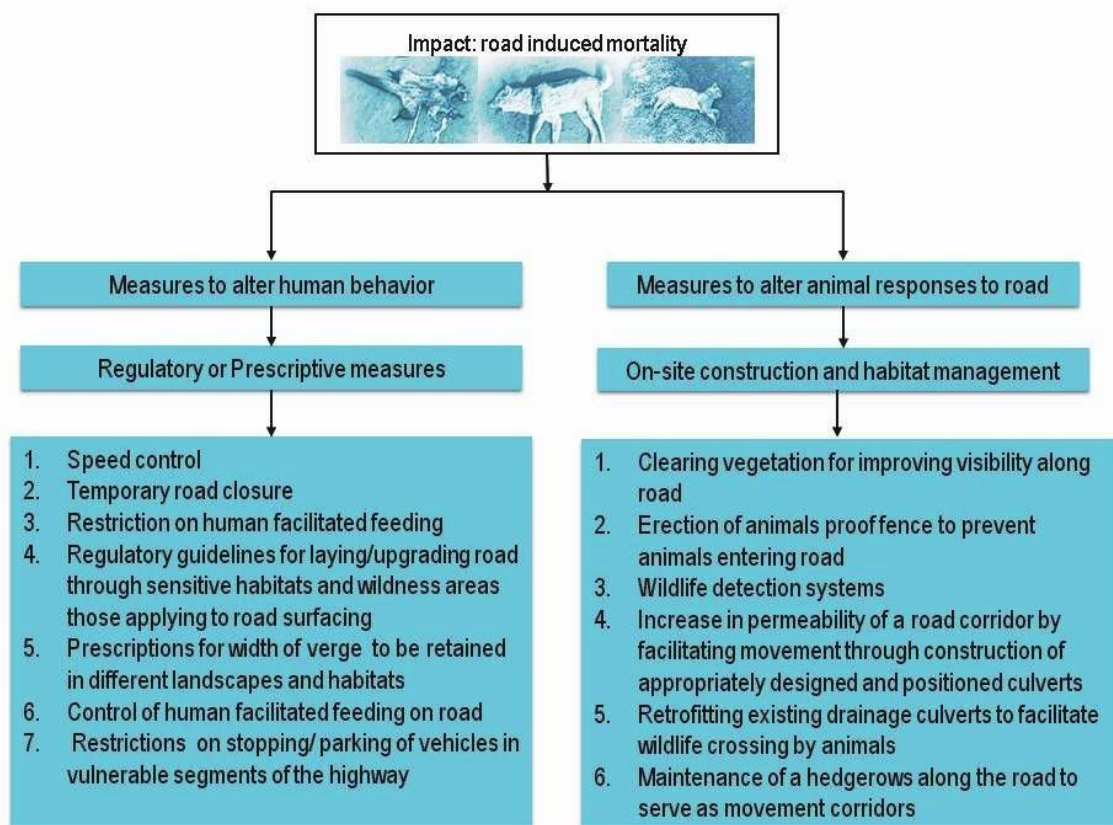


Fig.1 Mitigation approaches recommended for addressing road related mortality of animals.

## **Evaluation of the effectiveness of existing culverts for movement of mammals**

Thirty six culverts were monitored within a 9 km road corridor. Pugmark Impression Pads (PIPs) and camera trap methods were used for monitoring the effectiveness of existing culverts for movement of mammals. Observations were made for 540 days during three seasons (winter, summer and monsoon) during 2008-2010.

This study observed that all existing culvert structures have low permeability for mammals especially for large mammals present in the area. Based on road kills/hits, indirect evidences of animal presence during all three seasons (summer, winter and monsoon) over two years and the monitoring of the culverts, it was observed that animals used the road more often than the crossing structures. Out of 13 species using the habitat in the road corridor, only 7 species used the culverts. Species use of individual culverts varied from 1 to 7 species per culvert. The use of culverts by the mammalian species was very limited. An average of 0.36 animal crossing/culvert/days was recorded based on the total monitoring (540 days) effort under this study.

Use of culverts was strongly influenced by openness ratio, dimension and design features and not by location in the present context. Use of the culverts by animals was positively correlated ( $r = .602$ ,  $P < 0.01$ ) to the openness of culvert and negatively correlated ( $r = -.583$ ,  $P < 0.01$  and  $r = .438$ ,  $P < 0.01$ ) to the noise level in the culvert and proximity to the forest.

Keeping in view that it is vital to maintain connectivity of the habitats across the roads in these zones for ensuring long term conservation of carnivore and herbivore species, general guidance is provided for enhancing the suitability of different crossing structures for wild animals using the habitats along the National Highway. Specific recommendations include retrofitting some of the existing crossing structures and construction of 5 additional large passages.

*General guidance on planning suitable passages for animals using the habitats along NH-7*

Species	Large underpass			Culverts			Canopy crossing
	Open span bridge / flyover > 90 m wide X 7 m high	60m wide X 7 m high	30m wide X 7 m high	Slab culvert 3 to 5m wide X 4m high	Box culvert <3 m wide X 2 m high	Pipe culvert 1 to 2m diameter	
Tiger	R	P	NR	NR	NA	NA	NA
Leopard	R	R	P	NR	NA	NA	NA
Sloth bear	R	R	P	NR	NA	NA	NA
Wild dog	R	R	P	NR	NA	NA	NA
Jackal	R	R	R	P	NR	NA	NA
Hyena	R	R	R	P	NR	NA	NA
Wolf	R	R	R	P	NR	NA	NA
Fox	R	R	R	P	NR	NA	NA
Jungle cat	R	R	R	P	NR	NA	NA
Rusty spotted cat	R	R	R	P	NR	NA	NA
Civet	R	R	R	R	NR	NA	NA
Mongoose	R	R	R	R	P	P	NA
Gaur	R	P	NR	NR	NA	NA	NA
Sambar	R	R	P	NR	NA	NA	NA
Nilgai	R	R	P	NR	NA	NA	NA
Chital	R	R	R	P	NA	NA	NA
Blackbuck	R	R	R	P	NR	NA	NA
Indian Muntjac	R	R	R	P	NR	NA	NA
Mouse deer	R	R	R	P	NR	NA	NA
Four horned antelope	R	R	R	P	NR	NA	NA
Indian gazelle	R	R	R	P	NR	NA	NA
Wild pig	R	R	R	R	NR	NA	NA
Porcupine	R	R	R	R	NR	NR	NA
Hare	R	R	R	R	P	NR	NA
Squirrels	R	R	R	R	R	P	R
Primates	R	R	R	R	NR	NA	R
Rodents	R	R	R	R	R	R	NA
Monitor lizard	R	R	R	R	R	R	NA
Snakes	R	R	R	R	R	R	NA
Turtles	R	R	R	R	R	R	NA
Frog and toad	R	R	R	R	R	R	NA
Lizards	R	R	R	R	R	R	NA
Invertebrates (creeping animals)	R	R	R	R	R	R	NA

R- Recommended, P-Possible if adapted to local condition, NR- Not recommended, NA- Not applicable

## Impact of road on birds

The 9 km length road was surveyed for a total of 430 road cruising days spread across three seasons monsoon (n=147), winter (n=143) and summer (n=140) between August 2008 and July 2010 following the standard road cruising methods adopted for vertebrates.

A total of 143 bird kills belonging to 16 different species were recorded in 430 days. The average bird mortality rate was 0.36 birds/10km/day. Maximum numbers of bird hits were recorded in miscellaneous forest followed by teak dominant forest. The insectivore birds were found to be most vulnerable to hits (35%) during their attempt to feed on insects on the road followed by omnivore birds (30%). Highest mortality of bird hits was recorded during summer (52%) followed by 35% kills during monsoon. The bird hits were spatially clustered and were negatively related to the distance at which the birds were visible to the driver on the road ( $p=0.001$ ) and to elevation.

The study recommends that strategies for mitigating mortalities of birds along the highway should be focused on (i) managing road side habitat structure to reduce attractiveness for birds (ii) encouraging birds to fly higher above the roadway to reduce risk of collisions and (iii) maintaining a clear zone, devoid of trees and shrubs to prevent reptiles and rodents become easy prey for many bird species that get attracted to use road corridor for patrolling for food (Fig.2).

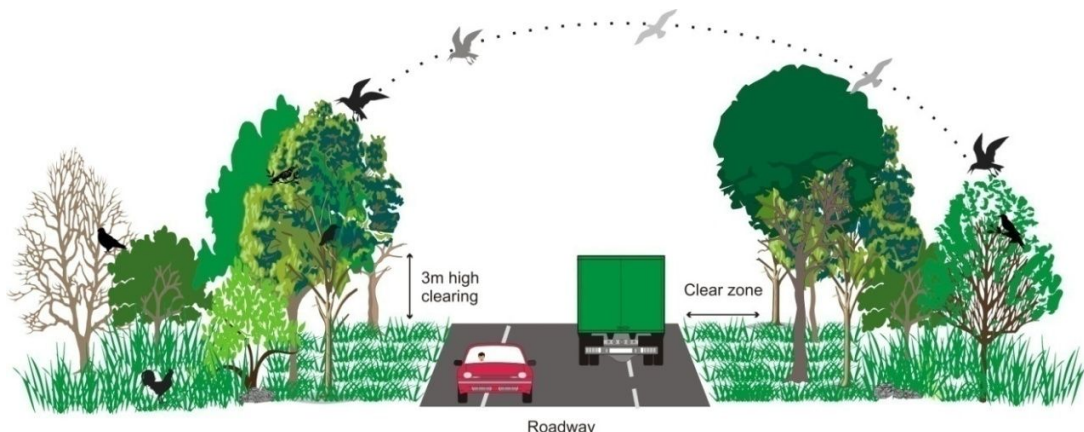


Fig. 2 Conceptual plan of the road and road side habitat management to reduce bird hits.

## Impact of road on snakes

Impact of road on snakes was assessed using road cruising methods. A total of 490 road kills of snakes were recorded in 430 days which belonged to 20 different species. Fatalities of snakes occurred throughout the length of the road. This observation renders support to the fact that snakes continue to attempt to use habitat that has been dissected by the road which poses a major barrier for their movement.

Road kills of snakes have a strong positive correlation with traffic on the road ( $r= 0.99$ ,  $p<0.001$ ). The average mortality rate (1.13 animal/10km/day) of snakes varied seasonally. Nearly 72% of the snakes that got killed were nocturnal. The highest mortality was recorded during monsoon (50%), followed by summer (37%) and winter (13%). The snake hits were

spatially clustered in locations nearer to villages that have agriculture fields. Linear regression showed that snake kill was positively correlated with elevation and negatively correlated with the distance to agricultural fields, water and the animal crossings. 12 kills of Indian rock python (Schedule-I) were recorded during the study period. Of these, 9 individuals were juvenile. The road induced loss of dispersing juveniles and consequent isolation is likely to have an impact on the gene flow across the landscape. The threat to snake species may vary with differential mortality of animals that cross slowly (e.g. Russell's viper) than with snakes that immobilize, or freeze in response to a passing vehicle.

The study recommends that developing ecologically sensitive approaches and innovative design that can be applied both at the planning stage and also subsequently as a retrofit would be most effective in controlling road kills. The authors recommend placing strips of individual surfaces that are attractive from a thermoregulatory perspective along the road in high mortality zones determined in this study (Fig.3). Such measures can be initially implemented on the experimental basis and once tested for their effectiveness, can be subsequently replicated in other road schemes.

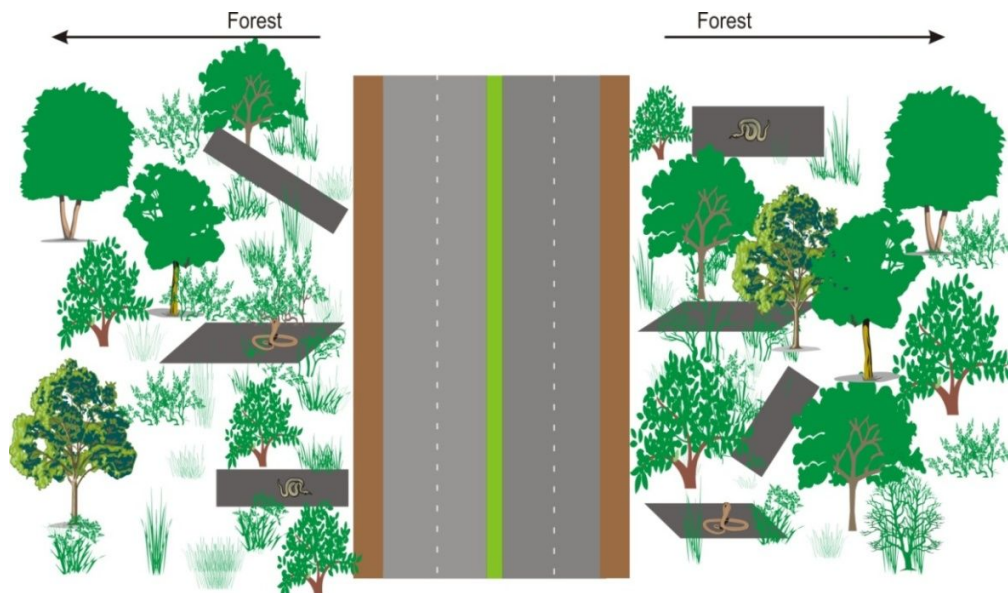


Fig. 3 Creation of alternative sites for thermoregulation of snakes

### Impact of road on amphibians

The stretch of NH-7 was surveyed using standard road cruising methods for a total of 430 cruising days spread across three seasons monsoon (n = 147), winter (n = 143) and summer (n = 140) between August 2008 and July 2010.

In the survey involving a total effort of 3870 km, 183 road kills belonging to 3 different species of anurans were recorded. Another 48 individuals could not be identified because of the macerated state of the carcasses that were repeatedly run over by vehicles.

Overall, an average 0.47 amphibian kills/10km/day was observed. Maximum number of anuran kills was recorded during monsoon (87%) with 80% kills observed just after the first shower. Overall, 90% of amphibians were killed during night.

The number of anuran road kills varied across seasons and was negatively related to the number of vehicle plying on the road. Road kills occurred randomly, but high mortality hotspots were spatially clustered on the road. Linear regression showed that the anuran mortality was negatively related to the proximity to water resources.

## **II. NATIONAL HIGHWAY 37 ALONG KAZIRANGA NATIONAL PARK, ASSAM**

The focus of this study was to evaluate the permeability of these corridors and to identify factors that constrain the use of corridors by animals.

National Highway-37 receives  $4716 \pm 631$  vehicle/day average annual daily traffic. Average daily traffic flow on this road varied for summer (5236 vehicle/day), winter (4898 vehicle/day) and monsoon (4013 vehicle/day).

The section of the National Highway-37 along the Kaziranga National Park (KNP) cuts through four animal movement corridors: Panbari, Haldibari, Kanchanjuri and Ghorakati. The use of these corridors by wild animals was evaluated based on track plots/pugmark impression pads (PIP) that were laid in the existing trails/corridor. A total 104 such trails were identified. Of these, 33 trails/paths were identified in Ghurakati corridor; 31 trails/paths in Kanchanjuri corridor; 28 trails/paths in Haldibari corridor and 12 trails/paths in Panbari corridor.

The highway which traverses all the corridors for variable lengths influences the relative magnitude of biotic pressures operating within and around the KNP. The relative intensity of biotic pressures becomes the key factor regulating the permeability of corridors for movement of different groups of animals.

The Haldibari corridor, located between Bagori range and Kohora range of Kaziranga NP represents the area included under the 5th and 2nd addition of Kaziranga National Park. This connects the Kaziranga National Park, in the north with Karbi Anglong WLS. The corridor is mostly used by the large herbivores such as elephants ( $1.95 \pm 5.47$  encounter/day) and large carnivores  $0.38 \pm 1.28$  (encounter/day) such as tiger especially during the flood season.

The study observed that Panbari and Ghorakati corridors were relatively more disturbed and had reduced permeability for large mammals.

### III. MUMBAI - PUNE EXPRESSWAY (MAHARASHTRA)

The main objective of this study was to assess if the mitigation measures proposed as part of the EIA of Mumbai-Pune Expressway conducted earlier by WII in 1998 were complied with and if the suggested measures had been effective in reducing the ecological impacts on sensitive habitats and wildlife within the expressway corridor.

A number of measures to mitigate the impacts of MPE on biodiversity during construction and operation were suggested in the EIA (WII 1998). As an outcome of follow-up, the status of the implementation of mitigation measures and their effectiveness in addressing the conservation concerns is presented in Table.

Issues	Mitigation measures proposed	Status of implementation	Remarks
Lonavala lake, the largest water body <i>en route</i> the expressway alignment is a major source of drinking water for the human and livestock population in the area. Key threats associated with alignment of expressway along the periphery of Lonavala lake included water pollution and alteration of lake ecology during land clearing and earth movement.	Realignment of the expressway in this section was recommended to prevent pollution of Lonavala lake and impairment of the functioning of the ecosystem of the lake.	The expressway was realigned to merge with NH-4 in this section to avoid the lake completely.	The successful implementation of the EIA condition to realign the highway has averted the risks of pollution of lake.
Loss of top soil, degradation of valley habitats and alteration in drainage due to down slope disposal of excavated material during road construction.	Two specific locations (Pimpoli and Hanode) were identified for dumping excavated rock and earth and adherence to these sites was specified as a condition for approval of the project.	The excavated rock material from tunnelled areas form mounds near tunnel openings. Rock and rubble excavated during the laying of the road was disposed in valleys areas on pristine forest.	Non compliance of the condition has created impervious covers of rock pile on the topsoil. Disposal of debris and rock down slopes have destroyed valley floor habitats.
Threats of fragmentation of the only corridor that connects North - South forest habitat by the expressway alignment.	Construction of 9 tunnels was recommended in EIA to avoid fragmentation of pristine and integrated areas that are habitats of many rare and endangered species.	Only six tunnels were constructed. Of these only two correspond with earlier approved design and locations.	The severed connectivity between the Rajmachi valley and Amba valley has constrained genetic exchange and free movement of species across their ranges. Where animals are unable to cross successfully, incidences of collisions have been observed.

Fragmentation of intact forest canopy associated with cutting of trees for road widening could result in immediate effect on territories of Malabar giant squirrel within the affected area and a ripple effect on squirrels in adjacent territories	Construction of recommended tunnel in section from 7.6 km to 9.0 km between Rajmachi valley and Amba valley.	Proposed tunnel was not constructed in the section of expressway aligned through Malabar giant squirrel.	The habitat of giant squirrels has become highly fragmented.
Conservation concerns linked to opening of many of the pristine wildlife habitats.	Improve protection by roping in additional habitats under protected area network by upgrading an area of 150 km <sup>2</sup> within the existing Koyna WLS to a NP; creating a NP (150 km <sup>2</sup> ) at the centre of the existing 372 km <sup>2</sup> Radhanagari Wildlife Sanctuary and creation of a 50 km <sup>2</sup> Wildlife Sanctuary within the crest line forests of Mahabaleshwar.	While this was planned by the Forest Department in great detail using satellite imageries and Reserve Forest from topographic sheets, the proposal for mitigation agreed to, has never been implemented.	Conservation prospects of the existing gene pools for their intrinsic and intangible values have been grossly ignored.
Since species richness, endemism and rarity in plant species of Khandala region are mainly confined to the Amba Valley, destruction and degradation of the ecological values of the valley systems was feared due to the alignment of the expressway through this valley.	Setting up of Sanctuary in the name of Father Santapau was a specific recommendation to protect the rare and endemic species of Khandala region.	The Maharashtra State Wildlife Advisory Board endorsed this area but has still not been designated as a protected area.	The project has failed to secure long term prospects of conservation of important wilderness values of Amba valley and Khandala region.

The observations clearly established that most of mitigation measures had not been complied with. As a consequence, the connectivity between habitats that were crucial for conservation of many endangered species of animals and plants had been seriously compromised.

