Promoting Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife: From best practice prescriptions to implementation

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Background and rationale

- Roads, railway lines and power lines traverse many of India's wilderness areas, fragment wild habitats and result in injury/ mortality of animals.

- Progressive and rapid growth trends in linear development sectors pose the greatest challenge in ensuring that development and conservation become complementing goals in the national interest

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Background and rationale

- Harmonising biodiversity conservation and linear developments requires **mainstreaming** biodiversity conservation in linear developments.

- All infrastructure development Ministries/ Departments/ Agencies both at the Central and State levels must harmonize their policies/ plan/ activities with environmental conservation standpoint.

- Granting Environmental Approvals must not become a '*fait accompli*' process requiring '*retrofitting*' but should be based on '*pro-active planning*'.

India's Linear Infrastructure Development Philosophy: *Mainstreaming*

Mainstreaming is best understood as an attempt of modifying larger development strategies by incorporating biodiversity goals for both development and conservation.

- *Development without Destruction*
- *Development with Design*

Mainstreaming Approaches

Linear infrastructure developments need to be made '*animal friendly*' to provide pathways for movement of species and be 'SMART' and 'Green' to effectively mitigate the ecological impacts of roads, railway line and power lines, when routed through sensitive ecosystems and habitats.

Green infrastructure must promote both smart growth and smart conservation

Green Infrastructure: *Principles*

- Sensitive planning and design to protect wildlife
- Connectivity is the key
- Context matters
- Grounded in science, land use theory and practice
- Pre-identifies ecologically significant lands and suitable development areas
- Designed to provide a framework for growth
- Planned and protected ***before*** development

Progressive Trends in Linear Development Sectors in India

Road sector

NATIONAL HIGHWAYS	STATE HIGHWAYS	OTHER ROADS
1,00,475 km	1,48,256 km	49,83,579 km

Source: *Ministry of Road Transport and Highways (http://pib.nic.in/newsite/PrintRelease.aspx?relid=133917)*

Contracts for 5331 km length of national highways have been awarded while 3480 km have been constructed in 2015-16.

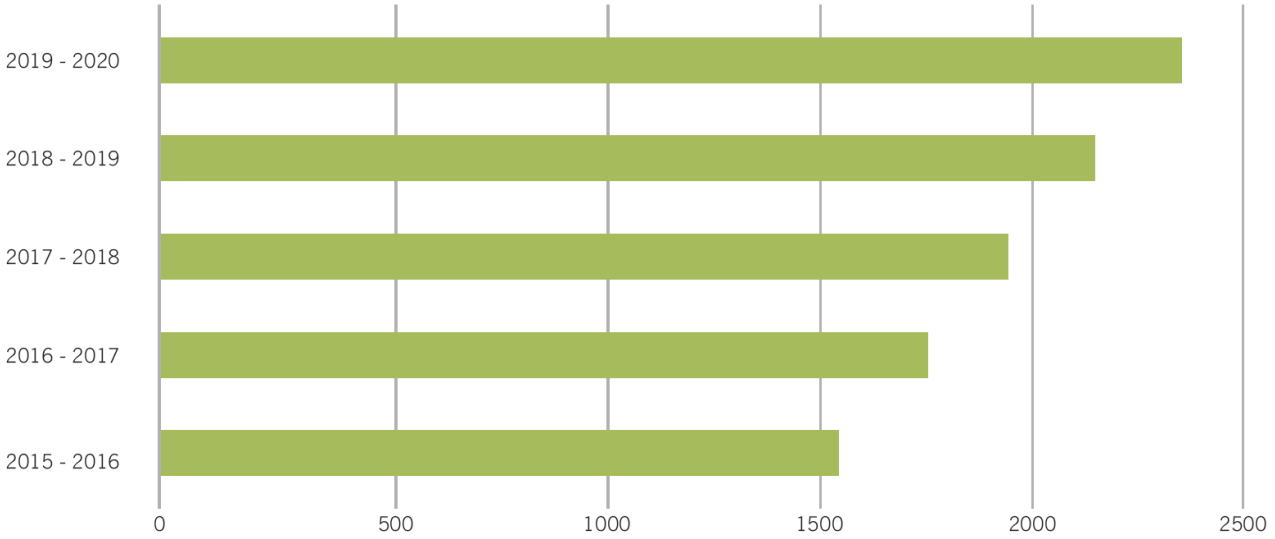
Sl. No.	NHDP component	Total length (km)	Completed length (km) as on 30.10.15	Under implemen -tation (km)	Balance for award of civil works (km)	Estimated cost (Rs. in crores)
1.	GQ under NHDP Phase I	5,846	5,846	0	0	30,300 (NHDP Phase I) + 34,339 (NHDP Phase II) = 64639
2.	NS-EW Corridors under NHDP Phase I & II	7,142	6,414	461	267	NHDP Phase I & II
3.	Port Connectivity under NHAI	402	379	23	0	
4.	Other NHs with NHAI	1859	1518	341	0	
5.	NHDP Phase III	12,403	6,634	3,602	2,167	80,626
6.	NHDP Phase IV	20,000	2,441	8,034	9,525	27,800
7.	NHDP Phase V	6,500	2,264	1,401	2,835	41,210
8.	NHDP Phase VI	1,000	0	135	865	16,680
9.	NHDP Phase VII	700	22	19	659	16,680
	Total	**55,852#**	**25,518**	**14,016**	**16,318**	**247,635**

Progressive Trends in Linear Development in Rail Sector in India

Gauge-wise Indian Railways network (percentage share).

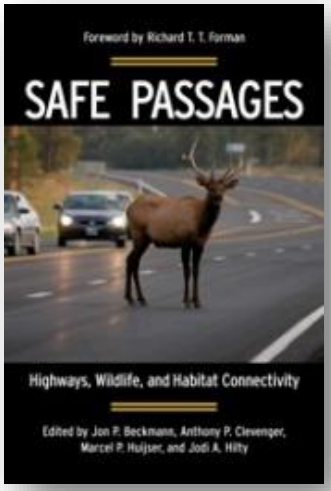
GAUGE	ROUTE KM	RUNNING TRACK KM	TOTAL TRACK KM
Broad Gauge (1676 mm)	86.62	89.96	90.99
Meter Gauge (1000 mm)	9.83	7.49	6.78
Narrow Gauge (762 mm and 610 mm)	3.56	2.56	2.23
Total (km)	**64,600**	**89,801**	**115,062**

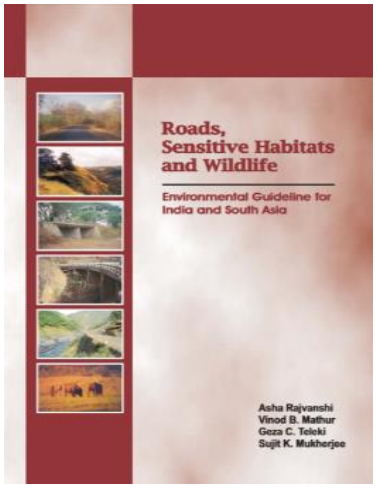
Source: *Ministry of Railways (2012)*

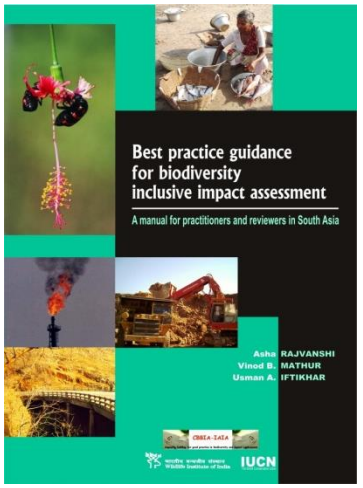


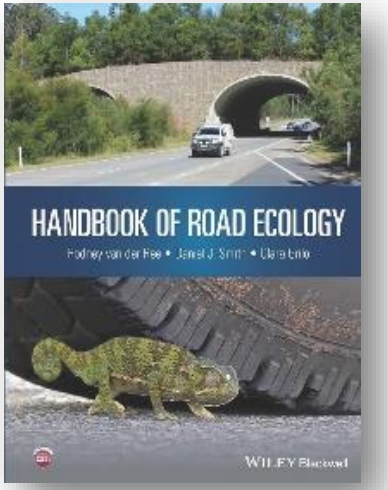
Targets for electrification (route km). **Source:** *http://www.indianrailways.gov.in*

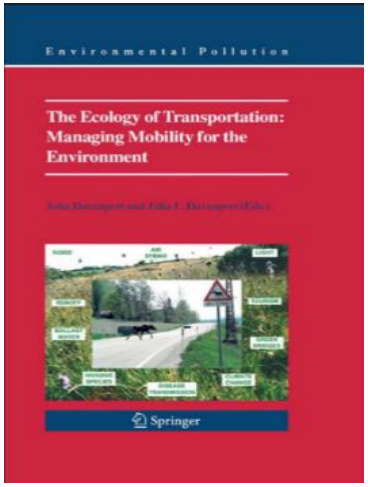
Available guidance

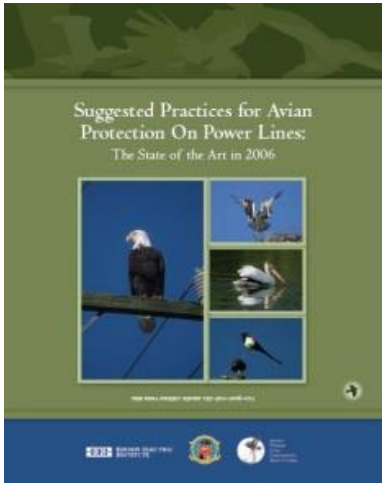


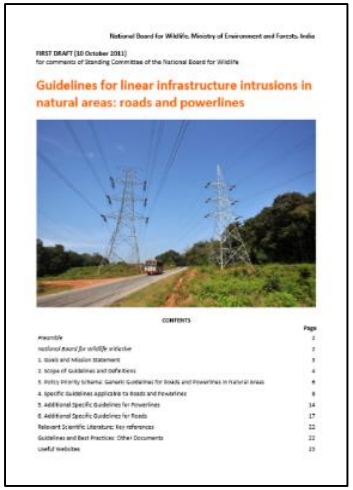












Why a new guide?

- Provide solutions so that conservation values and actions are aligned to land development, growth management and linear infrastructure planning in the Indian context.
- Means to sensitize developers to plan, implement and pursue development objectives in sink with conservation priorities.
- Serve as a '*How to*' guide for planning biodiversity-friendly developments especially by agencies such as NHAI, Indian Railways, Powergrid Corporation.

The new Best Practice Guide '*Eco-Friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife*'

High Resolution:

http://www.wii.gov.in/images//images/documents/eia/EIA_BPG_Report_2017.pdf

Low Resolution:

http://www.wii.gov.in/images//images/documents/eia/EIA_BPG_Report_2017_low.pdf

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PART 2: MITIGATION OF IMPACTS OF ROADS AND RAILWAY LINES

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Overview of Ecological Impacts of Linear Developments

Fragmentation of forests by rail and road infrastructure

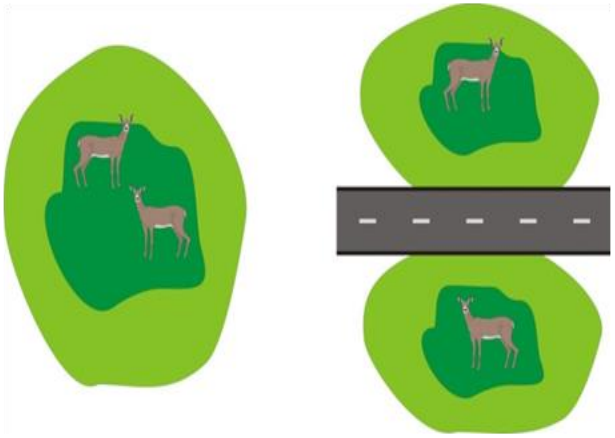
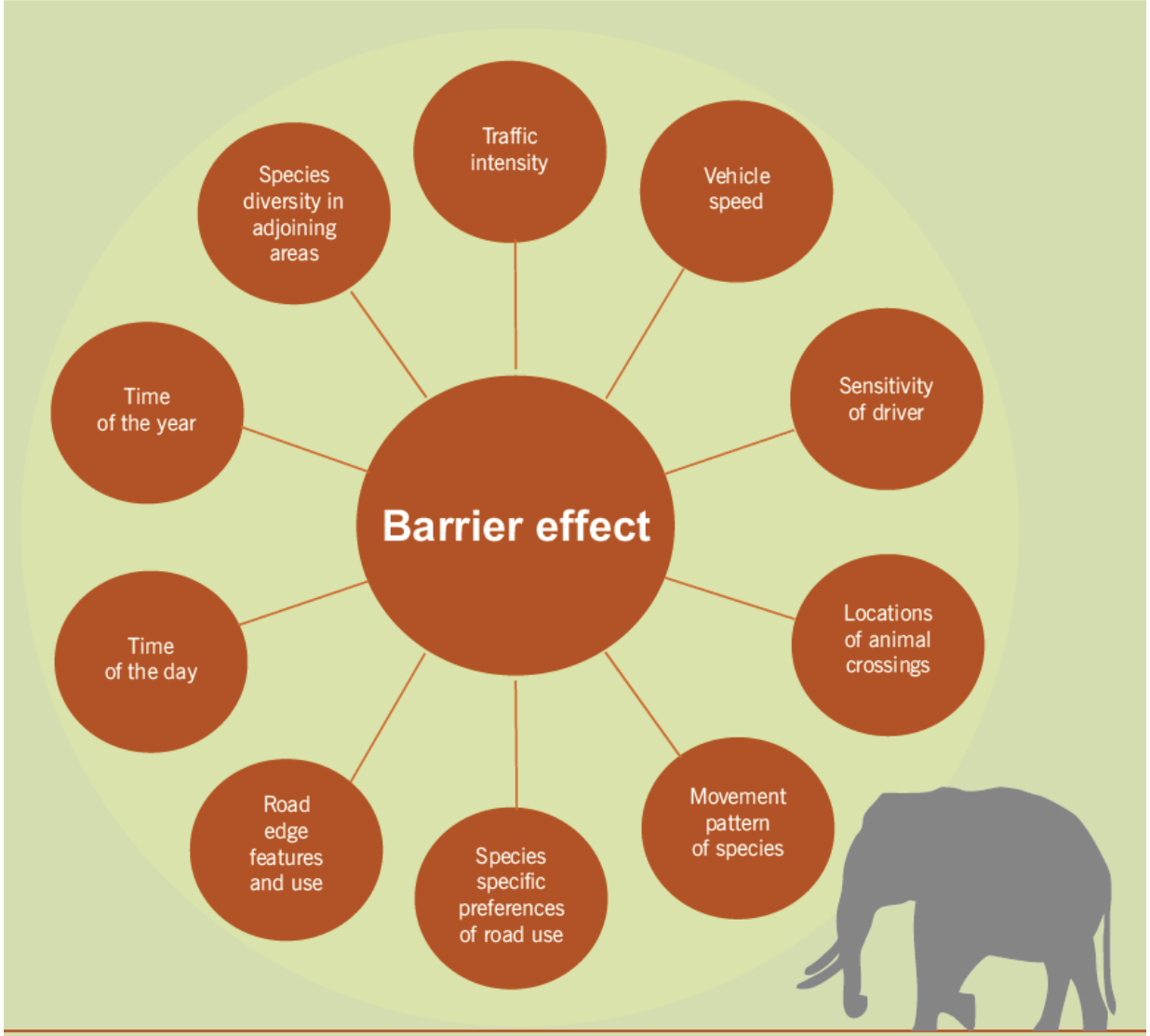


Figure 3.3. Habitat fragmentation results in far greater reduction in area of available habitat for species in bisected patches *(Source: Rajvanshi et al. 2013)*.

(Picture: A. Pragatheesh and Mohamed Zahir)

Mortality of Wild Animals

Barrier Effect…



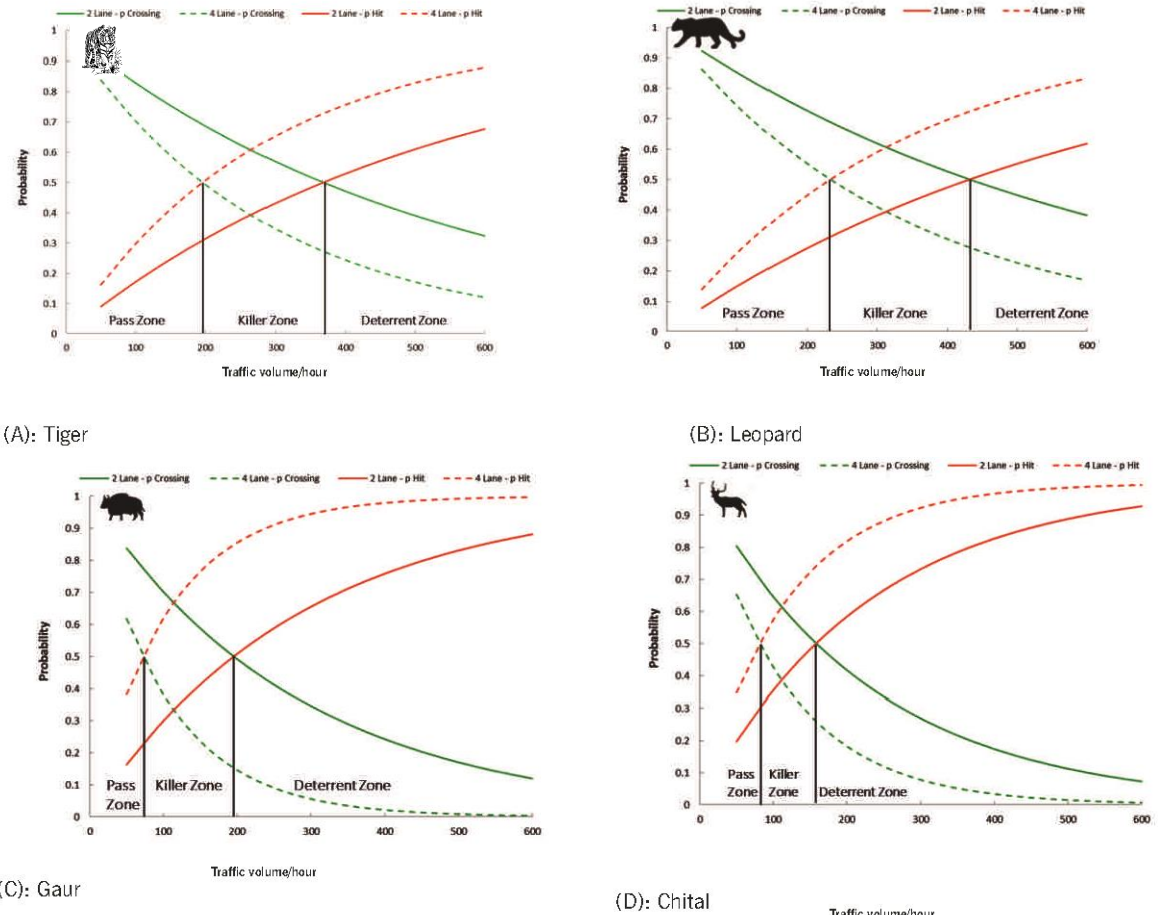
Factors influencing barrier effects of roads.

Barrier Effect: *What are the implications?*

Modelling the '*barrier effect*' on Indian roads

We have modelled the probability of successful crossing for different animals.

This probability is a function of road characteristics (width, verge), traffic characteristics (volume, heterogeneity) and species-specific characteristics (body length, behaviour, average group size and average time taken to cross the road)

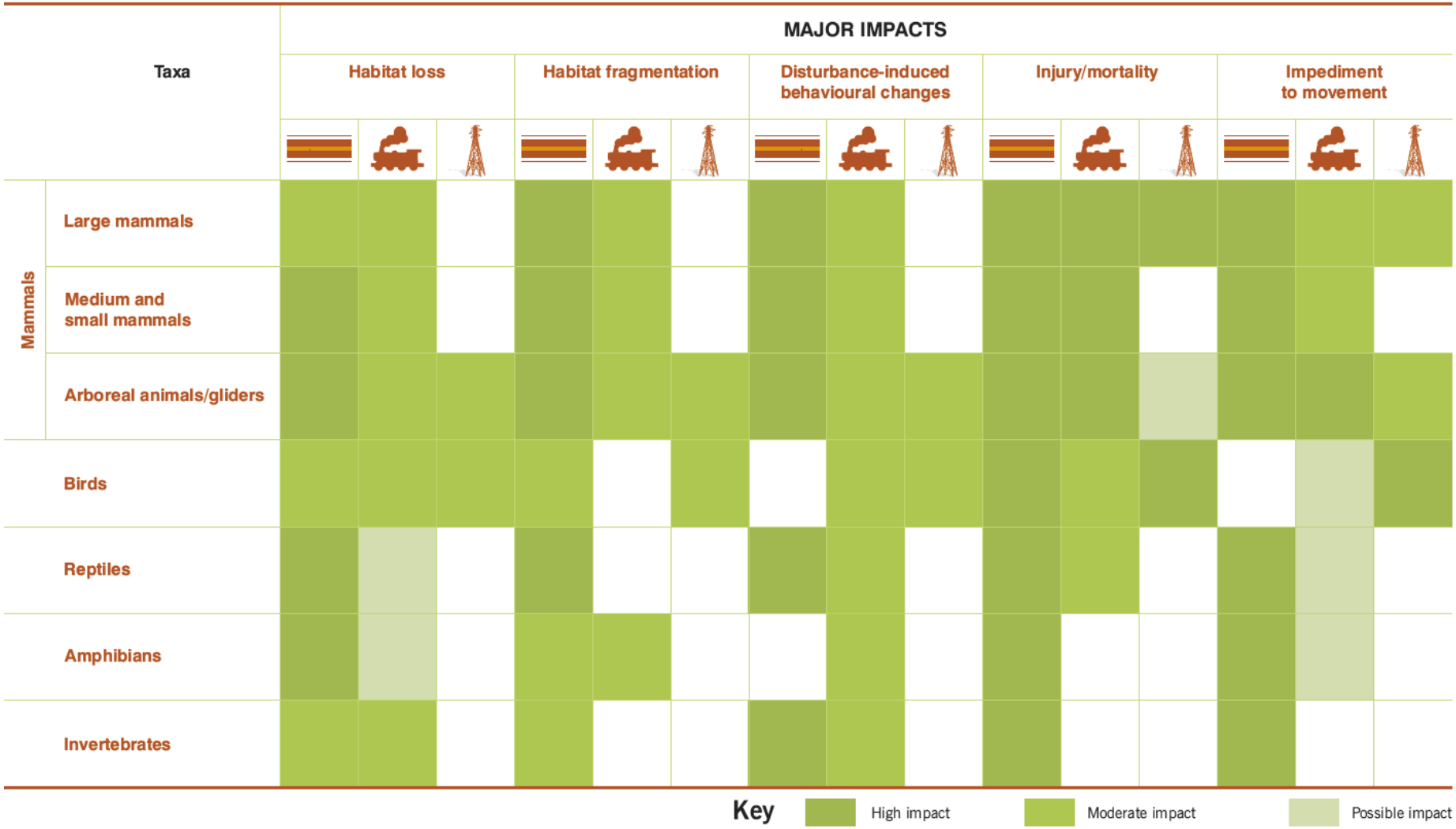


Traversability models showing probability of hit (red lines) or successful crossing (green lines) of (A) Tiger (B) Leopard (C) Gaur and (D) Chital on NH 7 with respect to available traffic volume (452 vehicles/hr) and heterogeneity as on March, 2015

Source: Habib et al. 2015

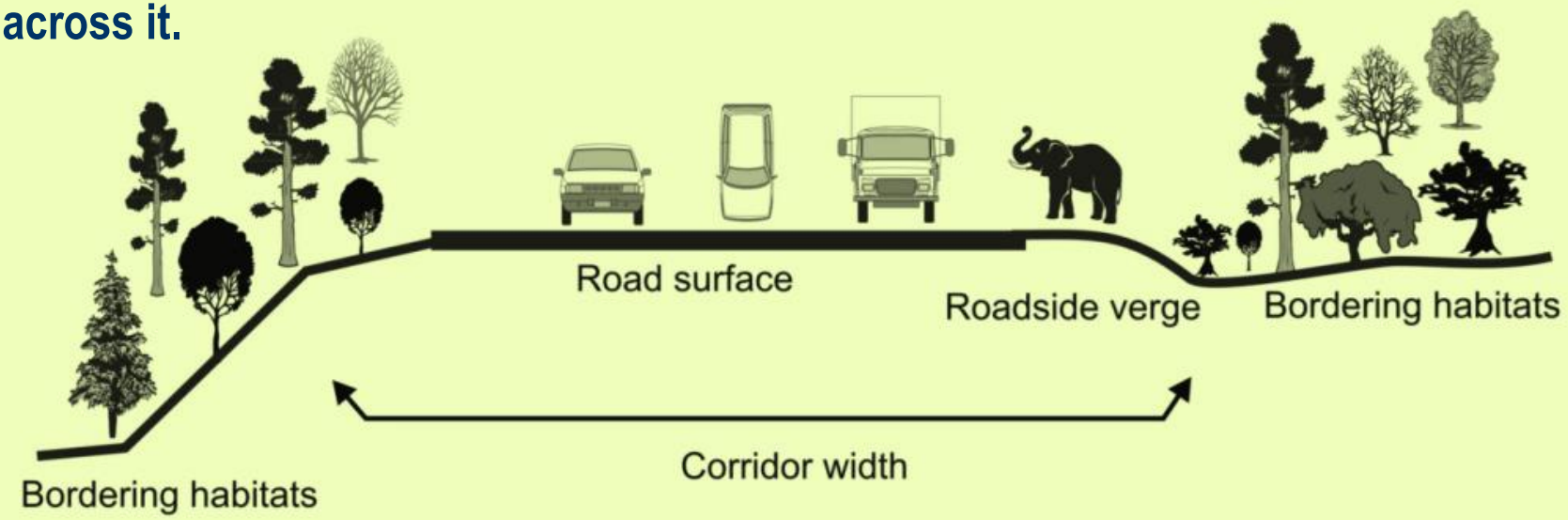
Summary of Major Impacts on Taxonomic Groups…

Table 4.2. Relative impacts of roads, railway lines and powerlines on different animal groups.



General Guidelines for Mitigating Impacts on Wildlife

The SMART roads must essentially aim to reduce injury/ mortality related to linear infrastructure and make linear structures conducive for movement of animals across it.



Transportation induced impacts

Measures to alter human behaviour

Regulatory or prescriptive measures

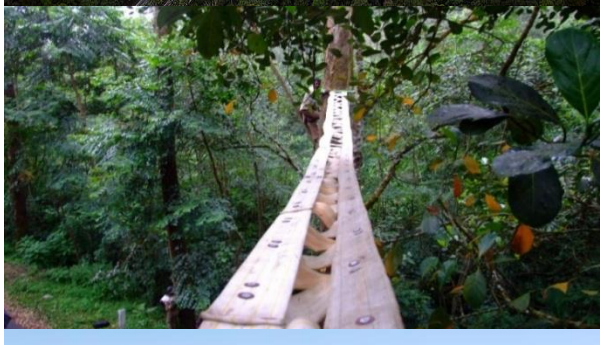
1. Speed control
2. Temporary road closure
3. Restriction on human facilitated feeding
4. Regulatory guidelines for laying/upgrading road through sensitive habitats and wilderness areas those applying to road surfacing
5. Prescriptions for width of verge to be retained in different landscapes and habitats
6. Control of human facilitated feeding on road
7. Restrictions on stopping/ parking of vehicles in vulnerable segments of the highway

Measures to alter animal responses

On-site construction and habitat

1. Clearing vegetation for improving visibility along road
2. Erection of animals proof fence to prevent animals entering road
3. Wildlife detection systems
4. Increase in permeability of a road corridor by facilitating movement through construction of appropriately designed and positioned culverts
5. Retrofitting existing drainage culverts to facilitate wildlife crossing by animals
6. Maintenance of a hedgerows along the road to serve as movement corridors

Engineering Options

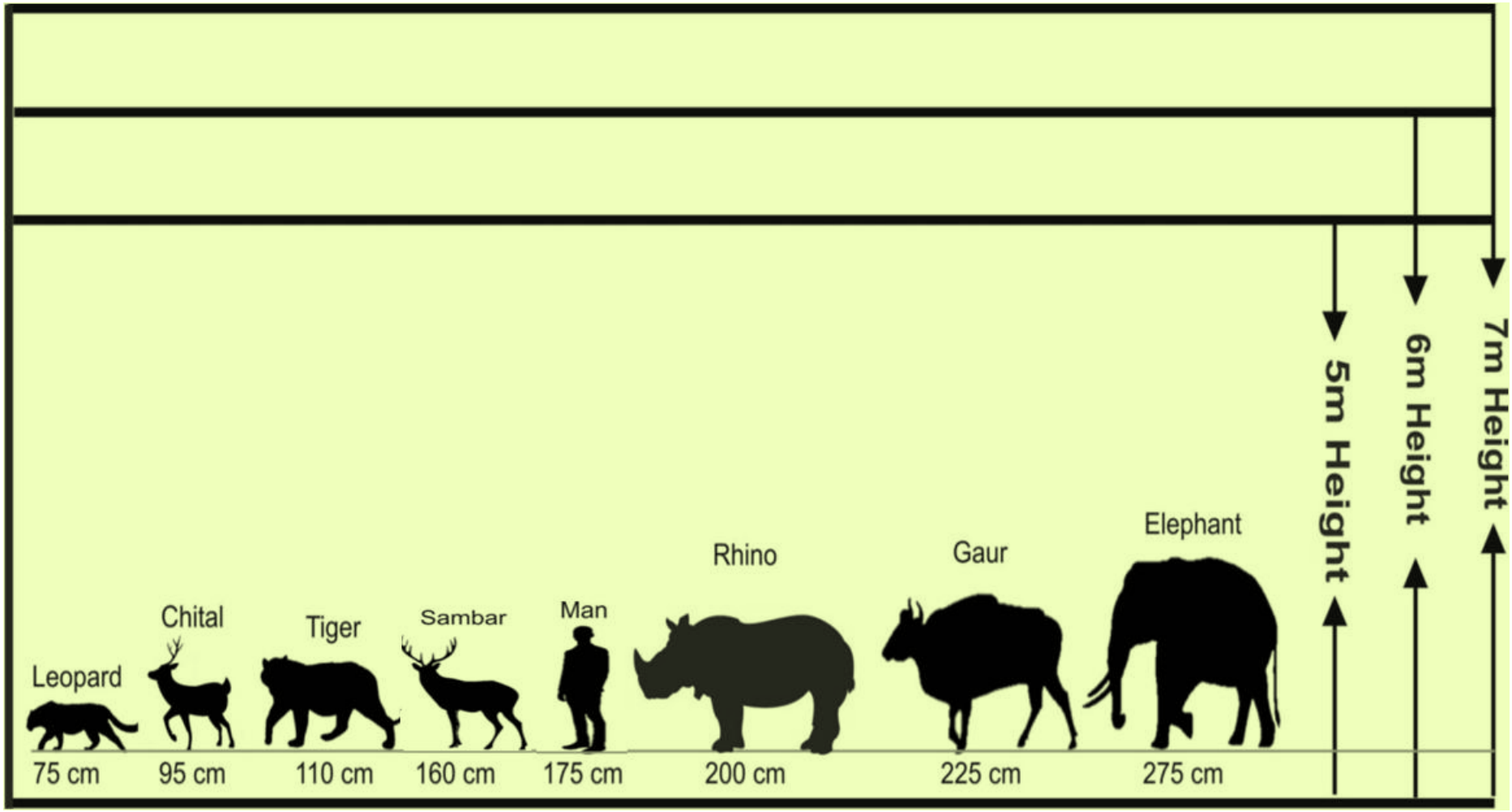


BRIDGES

UNDER PASSES

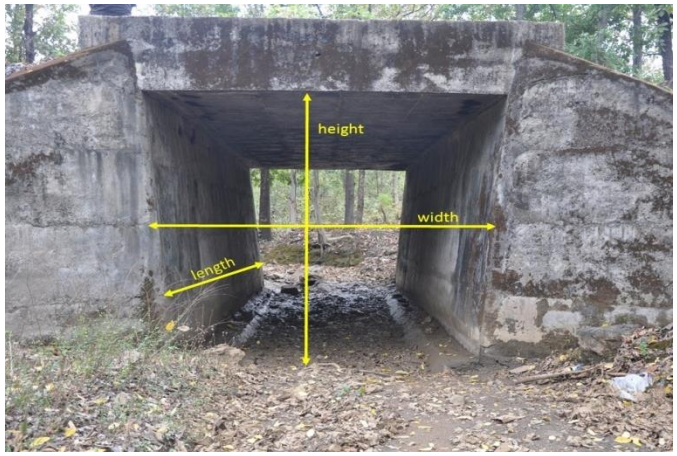
FENCES

Mitigation Measures for Connecting Landscapes and Species



Factors for Enhancing Permeability of Crossing Structures

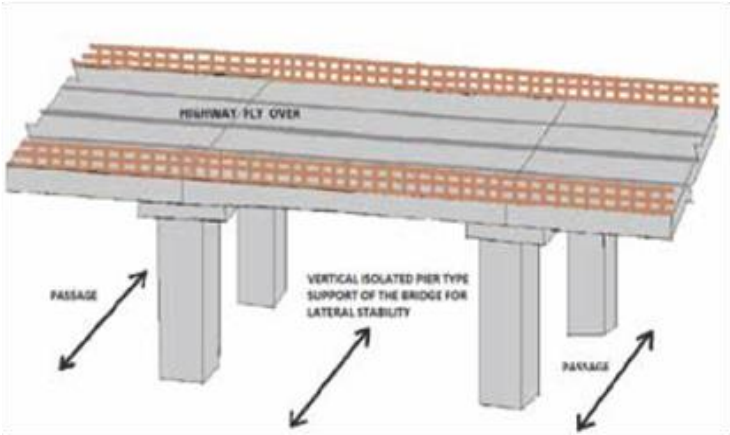
- STRUCTURE DESIGN AND SIZE
- LOCATION
- SPACING
- BOTTOM MATERIALS AND DESIGN
- NATURALNESS
- APPROACHES
- GOOD PRACTICE ‘DO’s AND DON’T’s’

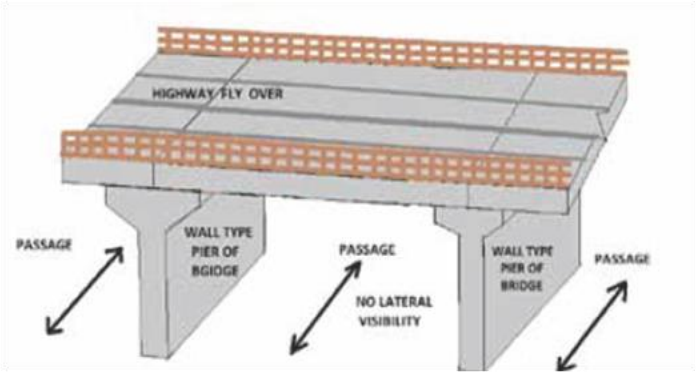


The efficacy of structures must be determined based on optimum benefits to facilitate animal movement across passages.

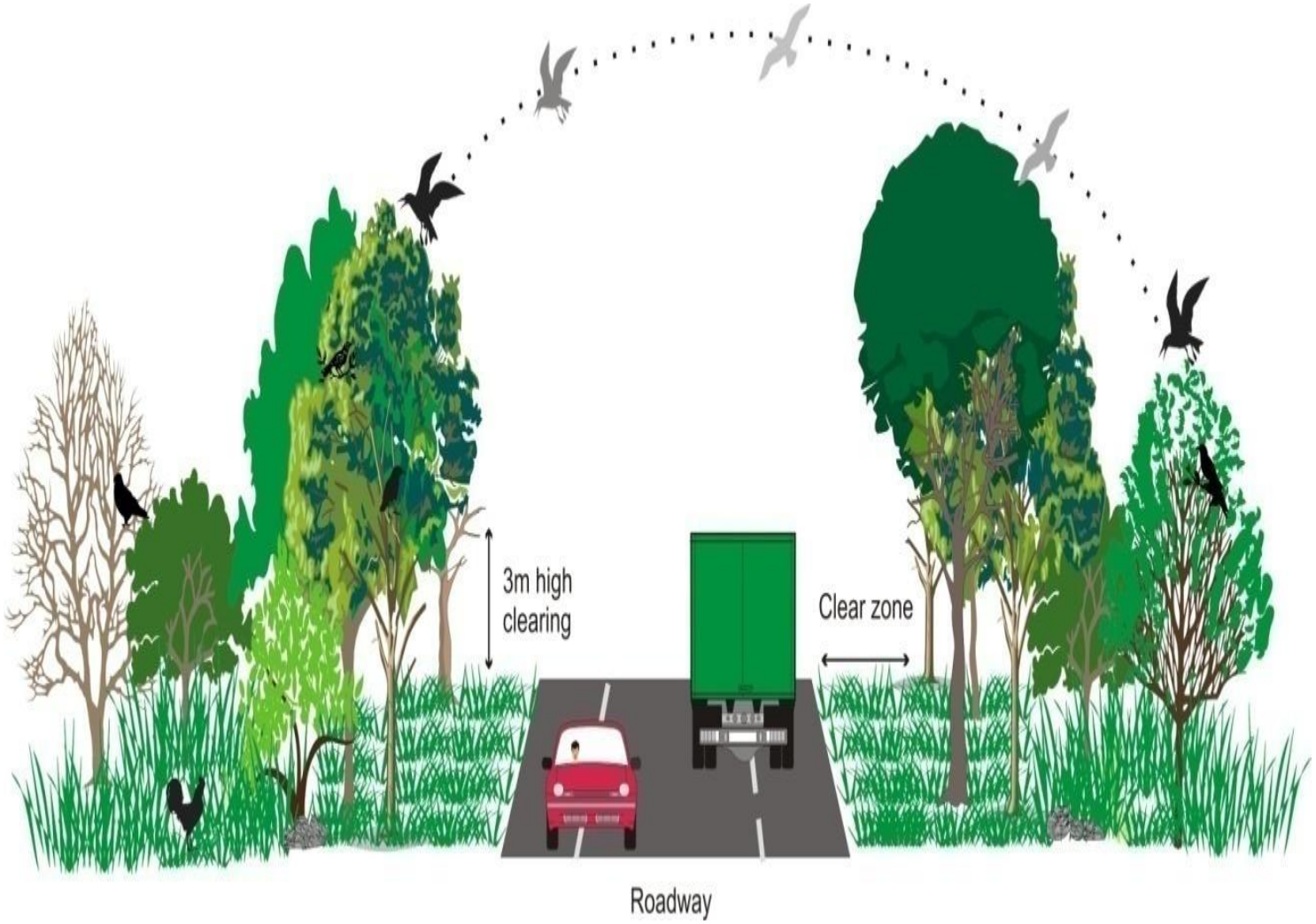
Landscape Specific Measures

TIGER AND ELEPHANT LANDSCAPES



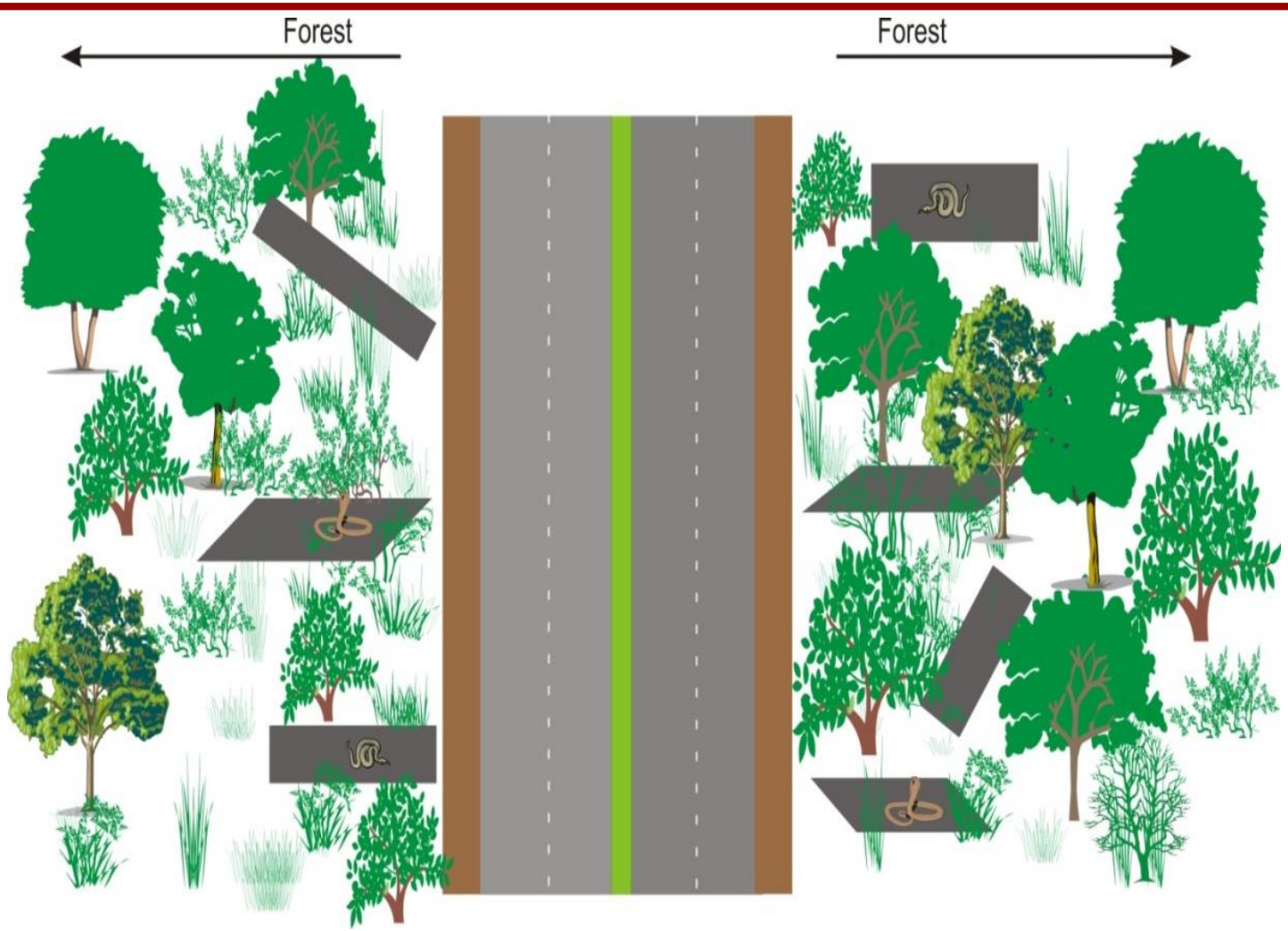


Structural Measures for Reducing Animal Mortality

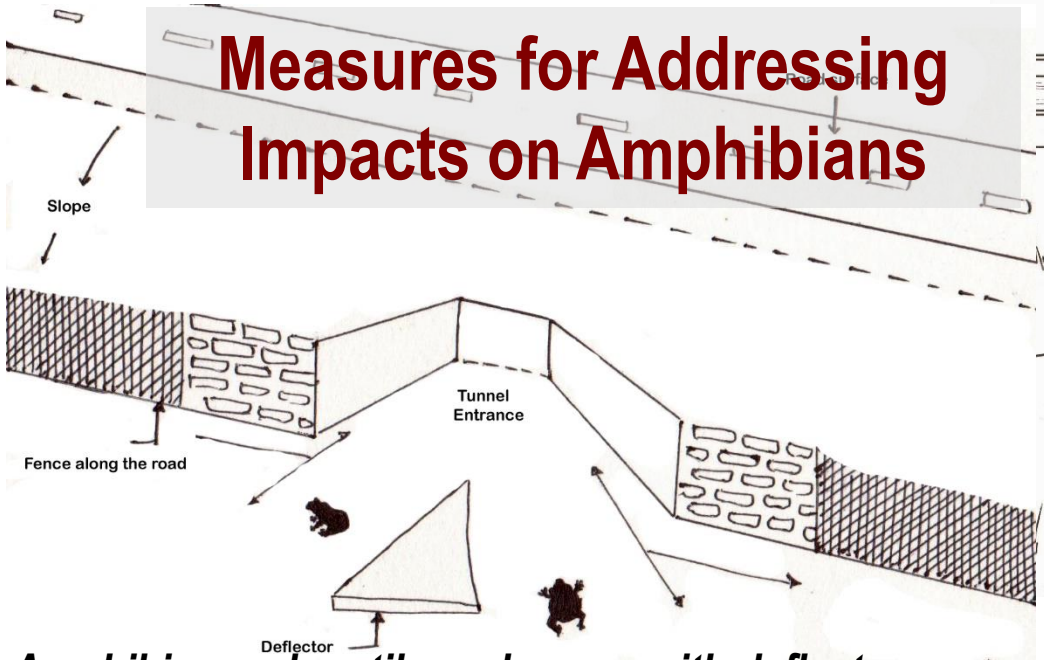


Managing roadside habitat to reduce attractiveness for birds

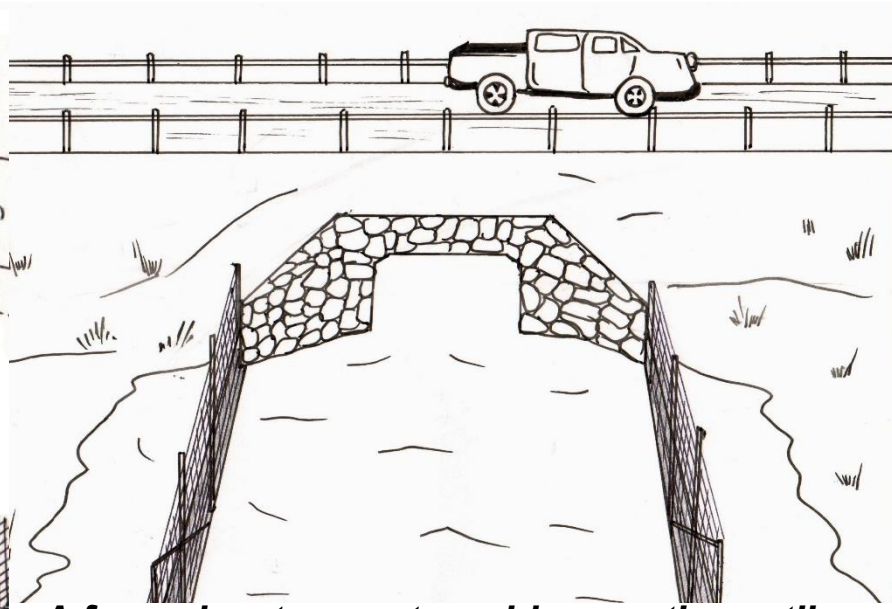
Creation of Alternative Sites for Thermoregulation of Snakes



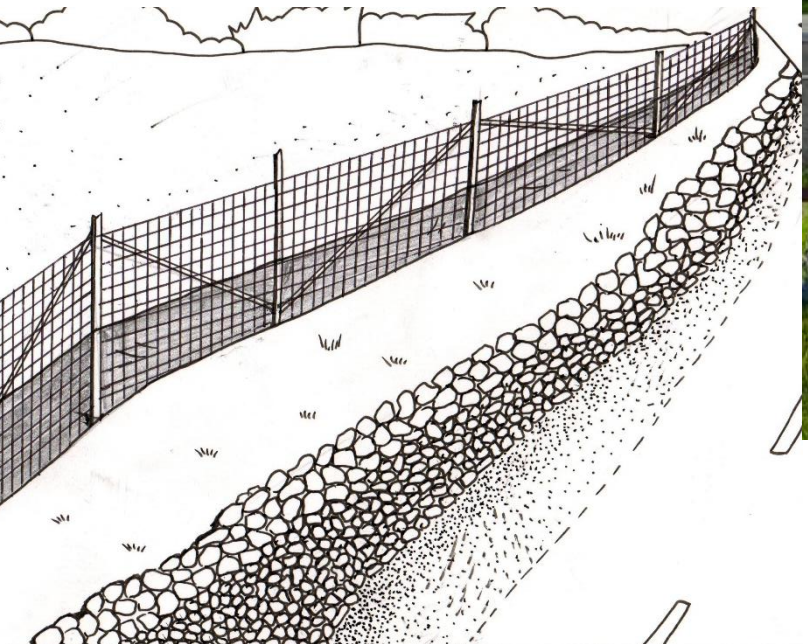
Measures for Addressing Impacts on Amphibians



Amphibian and reptile underpass with deflector



A fenced waterway to guide aquatic reptiles and amphibians through underpass



Fencing along roadside habitat to prevent herpetofauna getting on to the roadway (left), and herpetofaunal crossing structure across road (above)

Non-Structural Measures for Reducing Mortality: Signage and Warning Systems

CAUTION SIGNS

Do's & Dont's

Project phase	Do's	Don'ts
Planning and design phase	1. Organise a good team of professionals to review technical, financial and environmental/ecological aspects of the project. 2. Include an ecologist/wildlife expert on the team if the linear development would be routed through forested sections and natural landscapes. 3. Avoid aligning roads and railway line along or through sensitive habitats (wildlife movement corridors, flight paths of birds, areas of high biodiversity values, specialised habitats e.g. pools, dens, roosting sites, caves etc.). 4. Identify feasible alternatives of alignment to review the merits of different sites to arrive at the 'least impact' options. 5. Conduct a rigorous assessment of impacts on key wild species of animals and plants and habitats to integrate any special considerations in design features and structures. 6. Plan appropriate designs that facilitate animal movements 7. Include estimates of costs for constructing mitigation structures in the financial proposal to avoid cost overrun. 8. Prepare a schedule for implementation of mitigation measures, and institutional responsibilities for mitigation measures.	1. Do not undermine the importance of inter-agency coordination 2. Do not avoid consultation with wildlife experts and conservation agencies to understand challenges for wildlife that may come in way of environmental decision-making 3. Do not avoid field based surveys for generating primary information for impact assessment reports as a weak EIA would lead to subsequent delays in the implementation of the project 4. Do not split sections of the same road, rail or pipeline passing through different land use or states as separate projects for ease of implementation as this may pose difficulties in assessing the landscape level impacts on wildlife habitats and species with large home ranges 5. Do not plan mitigation structures around a single species but around all species of conservation importance in a landscape 6. Do not suggest mitigation measures without considering local ecology. Measures suitable for implementation in one landscape may not work in another site with different ecological conditions
Construction phase	1. Recommend construction schedule to avoid breeding/migration season of important species. 2. Take care to avoid direct impacts to land, water and habitats of wild animals due to labour camps, storage sheds and parking lots. 3. Initiate construction of mitigation structures along with road/rail upgradation projects so that damage/loss during this phase are minimised. Install sufficient drainage works under all access roads to avoid flooding land and damaging streams. 4. Protect top soil and implement measures to control soil erosion. 5. Avoid/minimise removal of natural vegetation. 6. Take measures to prevent animal injuries and mortality during earthwork, clearing of vegetation, and managing pools and streams. 7. Enforce good behaviour by construction workers to prevent illegal hunting, fishing and pilferage of resources. 8. Restore cleared areas wherever possible	1. Do not add to direct and physical impacts by careless material management and inducing avoidable disturbance 2. Do not violate conditions and specifications agreed upon as part of mitigation. 3. Do not dump/stack construction material inside sensitive habitats. 4. Do not dispose debris and other excavated material near water bodies and in valley bottoms. 5. Do not wash vehicles or change lubricants in waterways or wetlands.

Glossary

Barrier effect: The extent to which roads or other linear features prevent, or filter animal movement. The barrier effect can be quantified by species, populations and so on

Bottleneck: Defined area (e.g. Habitat corridor, or patch which due to the presence of transport infrastructure or other land use, has become a limiting factors to animal migration or dispersal

Corridor: Components of the landscape that facilitate movement of organisms and processes between areas of intact habitats

Meta-population: Set of local populations of a species within some larger area, where genetic diversity is maintained by the dispersal of individuals from one local population to another

Road verge: The vegetated area adjacent to roads; generally located outside the road shoulder

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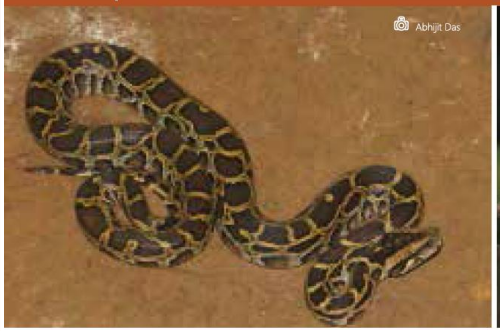
Plates (representative pictures of animal groups)

Animal groups	General animals considered (specific to India)
Large carnivores	Tiger, lion, common leopard
	Striped hyena, grey wolf, golden jackal, wild dog, Sloth bear
Large herbivores	Elephant, gaur, rhino
Medium-sized mammals	Ungulates: Sambar, spotted deer, nilgai, wild boar
	Primates: Rhesus macaque, northern plains langur
Small mammals	Jungle cat, leopard cat, Common palm civet, ruddy mongoose
Amphibians	Toads, frogs, salamanders
Reptiles	Snakes, lizards, turtles, tortoises

Reptiles:



Large herbivores

The guidance in practice…

Underpass on National Highway 7 under construction

Broadening of water drainage structure on National Highway 7 under construction

Monitoring of carnivore signs during National Highway 7 construction phase

Monitoring of carnivore signs during National Highway 7 construction phase

Monitoring of carnivore signs during National Highway 7 post construction phase

Monitoring of carnivore signs during National Highway 7 post construction phase

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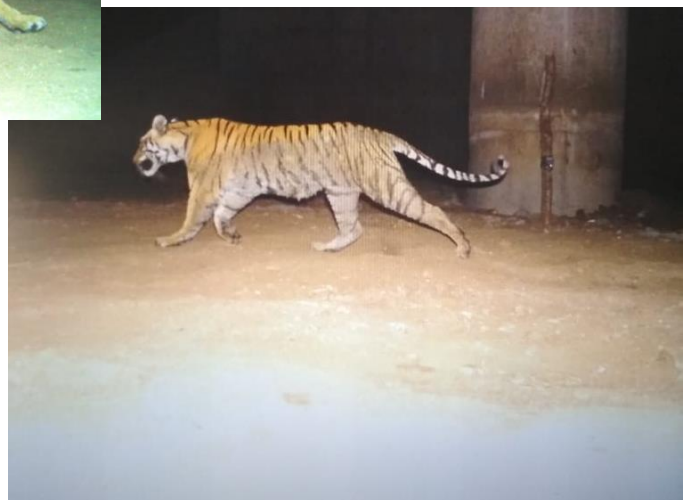


Monitoring of carnivore signs during National Highway 7 post construction phase

Design features to enhance use of underpass by wild animals

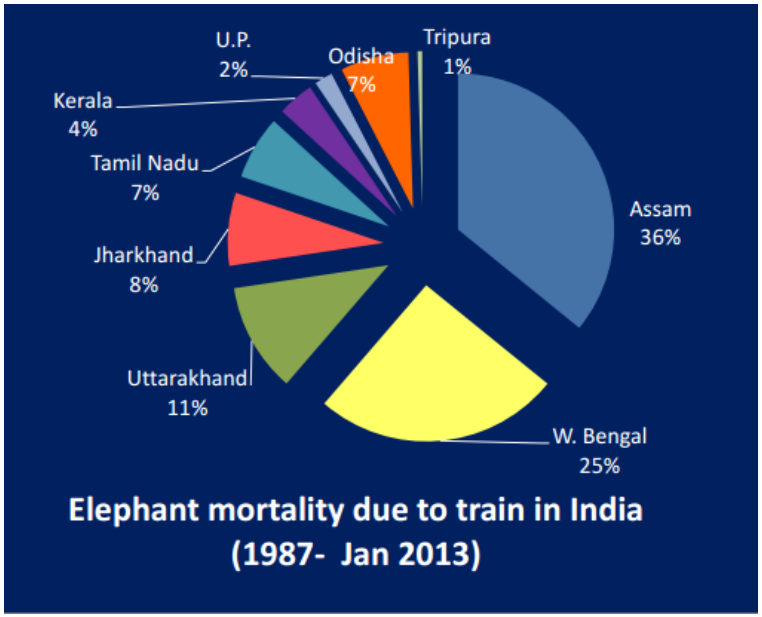
Design features to enhance use of underpass by wild animals

VIDEO

Wild Dog Use

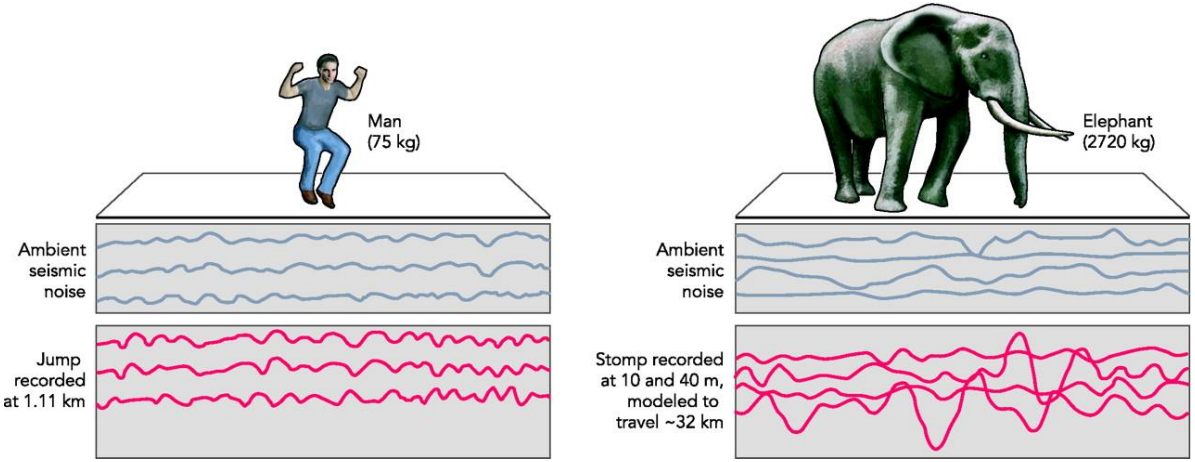
The need for R&D efforts in mitigating negative impacts of linear developments in the Rail Sector

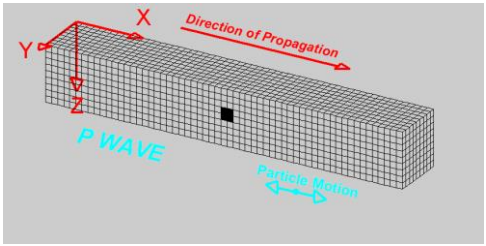
Rail-induced mortality of wild elephants…

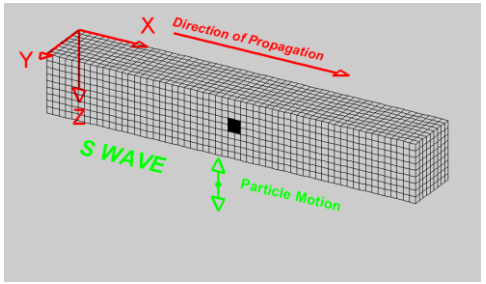


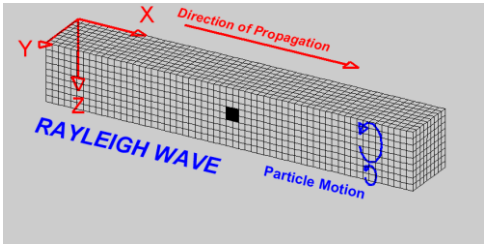
Seismic Sensing

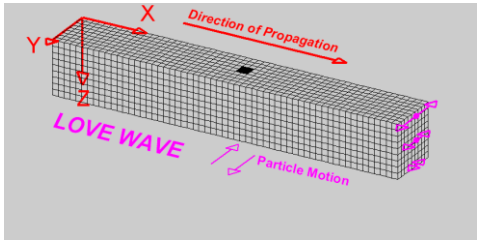
- *Seismic waves* are traveling vibrations that transport energy from any vibrating "source" region throughout the Earth.
- Mainly categorized into 4 types of waves:
  - Body waves*: Primary (6 km/s) and Secondary (4 km/s)*
  - Surface waves: *Love and Rayleigh*.











Seismic energy transmitting into the earth and propagating along the surface of the earth as Rayleigh waves with a velocity in the range of 250 m/s

[CE O'Connell-Rodwell - 2007]

Seismic Sensors

Seismometer

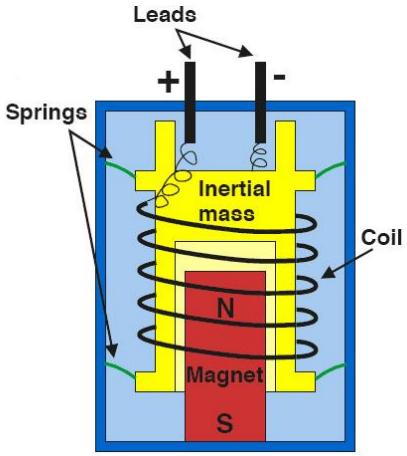
f_n <1 Hz

Accelerometer

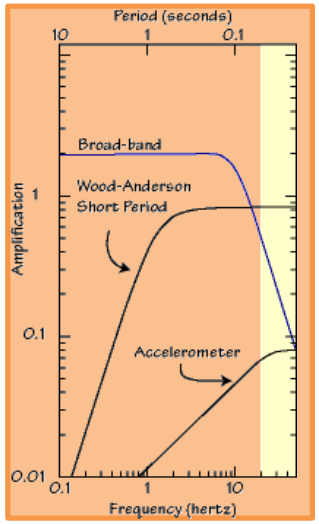
f_n :DC- 200 Hz

Geophone

4.5 Hz< f_n <40 Hz

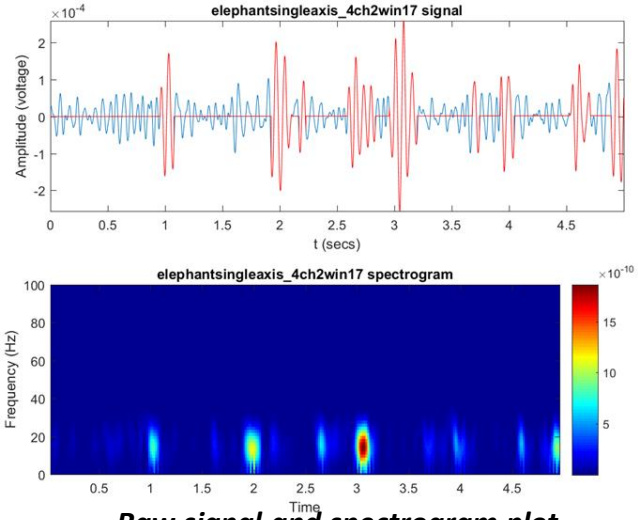


Internal structure of Geophone



Geophone sensor

Processing Unit



Raw signal and spectrogram plot

Feasibility Trials at Rajaji National Park, Dehradun

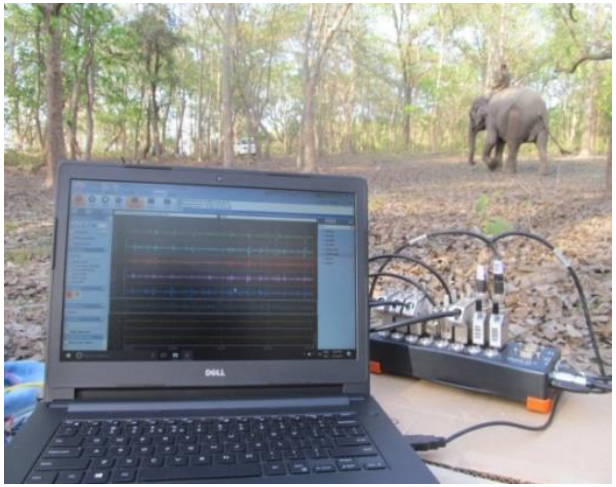
(A CSIR-CISO and Wildlife Institute of India collaborative project)

Phase I: Feasibility Study for Development of Intelligent Seismic Sensing Node for Elephant Movement Detection in the Context of Mitigating Threats to Wild Elephants by the Railways

Objectives

- Generation of Seismic Signature of Elephants
- Development of state of the art techniques for detection of moving elephants
- Preliminary field trials to establish Proof-of-concept in the context of mitigating threats to wild elephants by the railway tracks and operations.

GPS track route of elephant movement



Seismic data generation using captive elephants

Feasibility Trials at Rajaji National Park, Dehradun

(A CSIR-CISO and Wildlife Institute of India collaborative project)

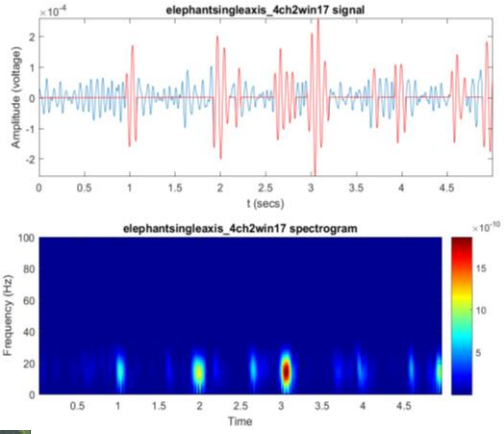
Design of Experiments

- Data generation were performed at different locations: plain grassland, uphill-downhill region, riverbed, near railway track.
- Number of elephant moving: single, two and three.
- Gender: One tusker and two female elephants.

Observations

- Seismic sensors could detect single elephant movement from a distance of approximately 30-50m.
- Seismic signal strength was high when the elephants were climbing up or down a slope.
- Seismic signal strength was low in the river bed due to loose soil and discontinuity.
- Typically the time interval between two footsteps is about 0.5 second in case of single elephant walking.
- Typically presence of lower frequencies which overlaps with other background noises.

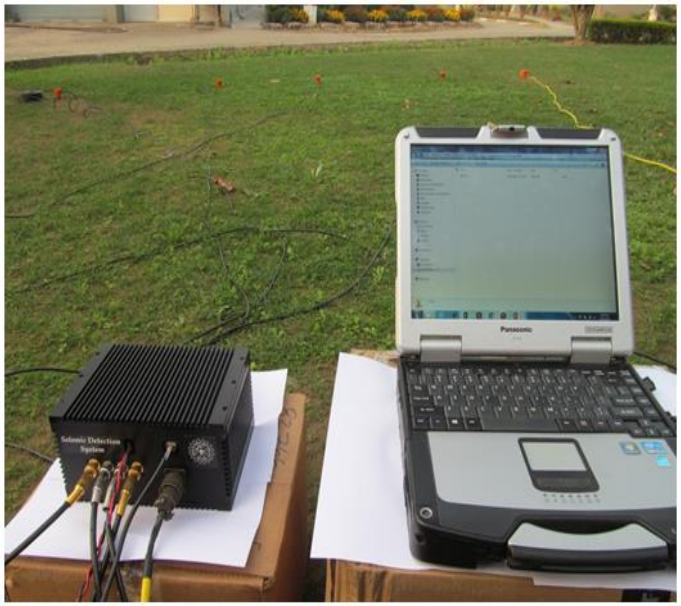
Real-time data processing unit

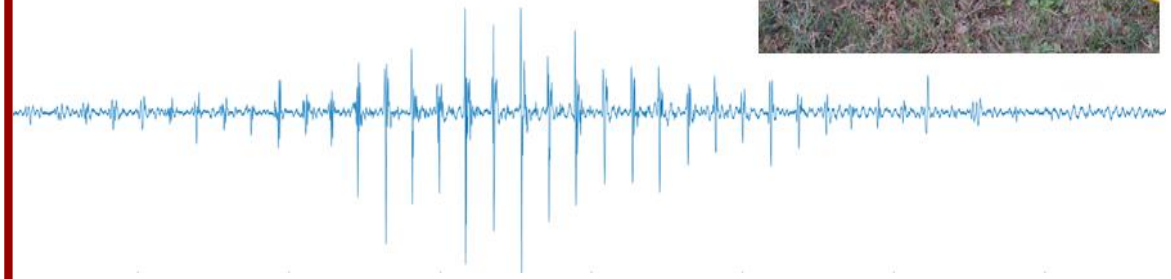


Top graph shows filtered seismic signal of single elephant walking (blue coloured). Red portion of the signal indicates automatic detection.

Train movement at Vedic Nagar

Seismic Detection System





Seismic Detection System with geophone sensor layout on the field

CSIR-CSIO has designed 'Seismic Detection System' during 12th FYP OMEGA.

It is a customizable intelligent system which is capable of interfacing with a number of seismic sensors and a number of detection and recognition algorithms.

This system can be adapted for a wide range of applications by training it in the relevant experimental sites.

Technology/S&T Gap

- Currently, non-technological measures like warning sign boards are put
- Slowing down the vehicles/trains
- Manual patrolling by human security personnel for identifying the presence of animals.

Elephant warning signboards near railway track crossing through Rajaji National Park, Dehradun

Presence of elephant dung on railway track


Dubi Shapiro
Nature Nurtures...
Conserve Nature
Together we can build a frame work that
nourishes and not depletes our natural assets...
Thank You !