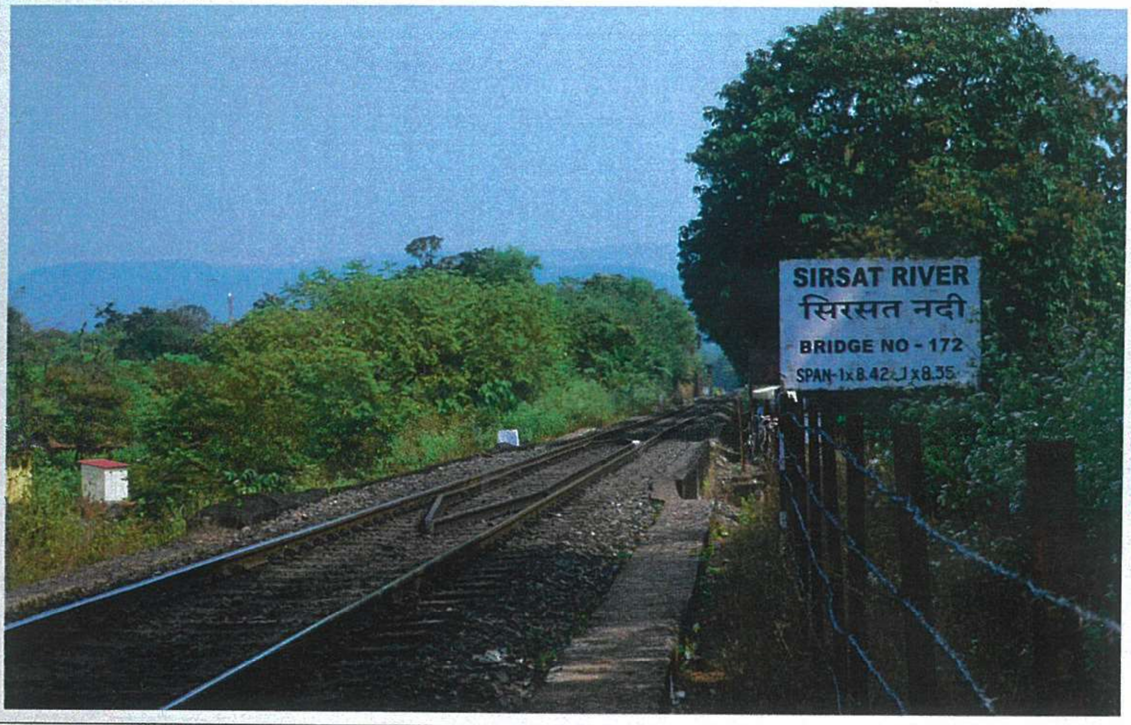
Environmental impact assessment and mitigation measures for Kulem - Madgoan Railway Line Doubling Project, Goa.

Final report submitted to

Rail Vikas Nigam Limited,

Ministry of Railways, Government of India



Principal Investigator:

Prof. R. Sukumar

Center for Ecological Sciences

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

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Acknowledgements:

We would like to thank Railway Vikas Nigam Limited (RVNL), Bangalore, for giving us this opportunity to work with them again after completion of the study on the Castlerock – Kulem sector. We thank Mr. S. Sahu, AGM, RVNL, Madgoan, and Mr. S. P. Vasta, retired forest officer currently with RVNL, Madgoan for their help and support during the field work. We express our gratitude to staff of RVNL office, Madgaon, for their support and cooperation during the field work.

We also thank Mr. Shambu, IFS, Conservator of Forests, Goa Forest Department, and the staff of Mollem Range office for their cooperation and support during the field work. The people of Mollem were extremely hospitable to our field staff during this study.

We thank Mr. C. M. Bharanaiah, Mr. Sridhar G. Patagar, Mr. Govind, Mr. Sunapa, and Mr. Kumar for their assistance at various stages during the study.

Research team

1. Dr. H. S. Suresh (Vegetation studies)
2. Dr. Mukti M. Roy (Animal studies)
3. Ms Sunipa Chatterjee (GIS expert)

Preamble:

Rail Vikas Nigam Limited (RVNL), Bangalore, of South Western Railways, has undertaken the execution of proposed doubling of the existing rail line Hospet-Tinaighat-Vasco port (345km) sanctioned by the Ministry of Railways. There are two phases of the current project. Phase–I, involving doubling of the existing line between Hospet and Tinaighat (245 km), is parallel to existing line and within the railway land. Phase-II between Tinaighat and Kulem is on detour with an intention of reducing the constraints on the operation. The proposed line passes through natural forests of the Western Ghats between Kulem (Sangem Taluk, South Goa District, and Goa State) and Castle rock (Joida Taluk, Karwar District, and Karnataka State). An Environmental Impact Study and mitigation plan is generally necessary for obtaining clearance from both central and state governments as well as the Supreme Court's Centrally-Empowered Committee and the National Board for Wildlife for diversion of forest land from Protected Areas for non-forestry purposes. The proposed railway project will have impact on the local ecology and environment of the area that includes a wildlife sanctuary. The main objective of the environmental impact assessment is to study the impacts on the overall biodiversity and the environment of the proposed line, as part of the planning and design process, and to formulate necessary measures to reduce the impacts to acceptable levels. Though the development of railways is for the betterment of economic and social condition of people, it is not ruled out that there would be negative impacts on environment and people living in the immediate vicinity.

The Center for Ecological Sciences (CES), Indian Institute of Science (IISc) submitted a report on biodiversity and geo-technical aspects of doubling of existing railway track between Castlerock and Kulem. The Forest Department of Goa asked RVNL to also study the forests between Kulem and Kalem stations. Hence, RVNL requested CES, IISc, to undertake the study on biodiversity in this sector broadly on similar lines with a focus on recording woody plant diversity and mammalian diversity with the help of camera traps. Recently, the Kulem to Kalem section forest areas were also included in Bhagawan Mahavir Wildlife Sanctuary, hence necessitating a study on biodiversity in this area.

Results:

We laid 15 (0.1 ha transects) along Kulem – Kalem- Madgaon section of the proposed railway line doubling project. A total of 3147 individuals >1 cm dbh belonging to 110 species of flowering plants were enumerated. Most abundant tree species was *Terminalia paniculata* (443 individuals,14.07% rel. abundance) followed by *Terminalia crenulata* (314 individuals, 9.97% rel. abundance) and *Xylia xylocarpa* (252 individuals, 8.0% rel. abundance). In fact, these three species constitute over 30% of the total abundance. Other dominant species include *Helicteres isora* (shrub), *Grewia tiliifolia* (canopy), *Ervatamia heyeana* (shrub) *and Leea indica* (shrub).

We calculated the Importance Value Index (IVI) (Sum of relative abundance, relative dominance and relative frequency) a measure of importance of a species in the community. Species that had highest IVI was *Terminalia paniculata* (IVI = 138.8), *Terminalia crenulata* (IVI = 131.2), *Careya arborea* (IVI = 106.7) and *Macaranga peltata* (IVI = 103.8). List of species with their IVI values are listed in the appendix 1.1.

Diversity patterns:

The mean species richness among the transects was 32.6±6.73 (23 – 43, N= 15). Community wide dominance was 0.12 or dominance by a single species was 12% suggesting considerable scope for coexistence of several species. Community wide Simpson's index (probability of picking two individuals belonging to two different species) was 0.87±0.03, Shannon-Weiner's index (a measure of heterogeneity in a system) was 2.67±0.25 and Fisher's alpha (measure not influenced by sampling size) was 10.95±2.08. The evenness distribution of individuals among different species was 0.46±0.09 suggesting considerable heterogeneity.

Structure:

The mean density of individuals >1 cm dbh was 209.8±61.12 (113 – 345, N = 15) resulting in 2100 stems a hectare. Basal area was 40.8 m^2/ha while biomass was 321.7 tons/ha. The structural details are tabulated in the following table 1.

Table 1. *Structural details of vegetation of the proposed project area.*

Size	**Density** (mean±SD) /per 0.1 ha	**Basal area** (mean±SD) sq.m/ha	**Biomass** (mean±SD) tons/ha
>1 cm dbh	209.8±61.10	40.9±15.47	321.8±77.21
>10 cm dbh	50.5±19.50	37.5±16.10	213.6±81.00
>30 cm dbh	14.4±9.10	27.02±15.70	112.0±67.10

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The size class distribution of all individuals enumerated along the transects showed typical inverted "J" shaped distribution suggesting a predominance of individuals in lower size classes. More than 50% of the individuals were less than 5 cm dbh (Figure 1). While distribution of biomass among different size class showed that biomass in higher size classes was considerably more than the biomass in the lower size class. It is the large trees that contribute to biomass and hence the carbon stocks (Figure 1.1).

Size class distribution of individuals among different canopy species was interesting. General pattern among all species was similar. But in *Terminalia bellirica* and *Terminalia crenulata* there was almost equal proportion of adults and juveniles in the population (Figure 1.2). In *Hoigarna arnottiana* and *Grewia tiliifolia* there were few individuals in higher size classes. In other species such as *Terminalia paniculata, Xylia xylocarpa, Careya arborea* and *Lagerstroemia microcarpa* there was a slight increase in adult trees suggesting a healthy population (Figure 1.2).

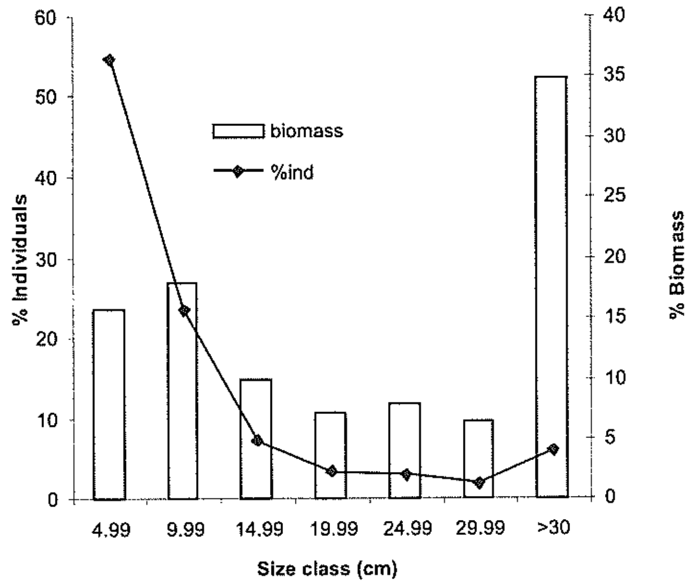
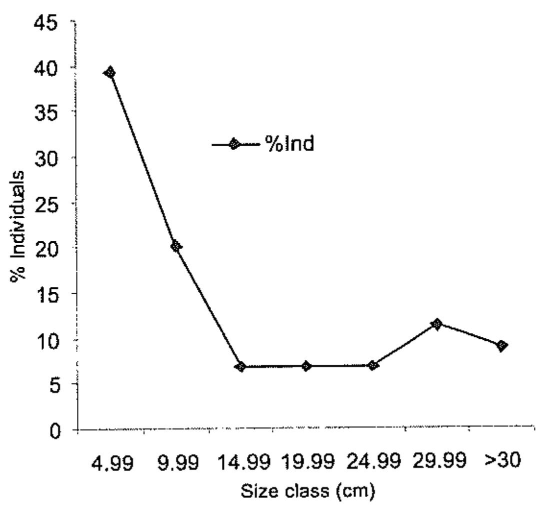
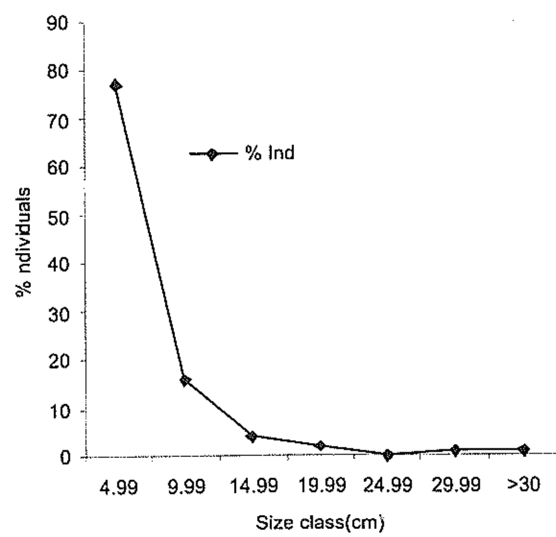


Figure 1.1. *Distribution of individuals and biomass in different size classes in the forests of the proposed project area.*



CARARB



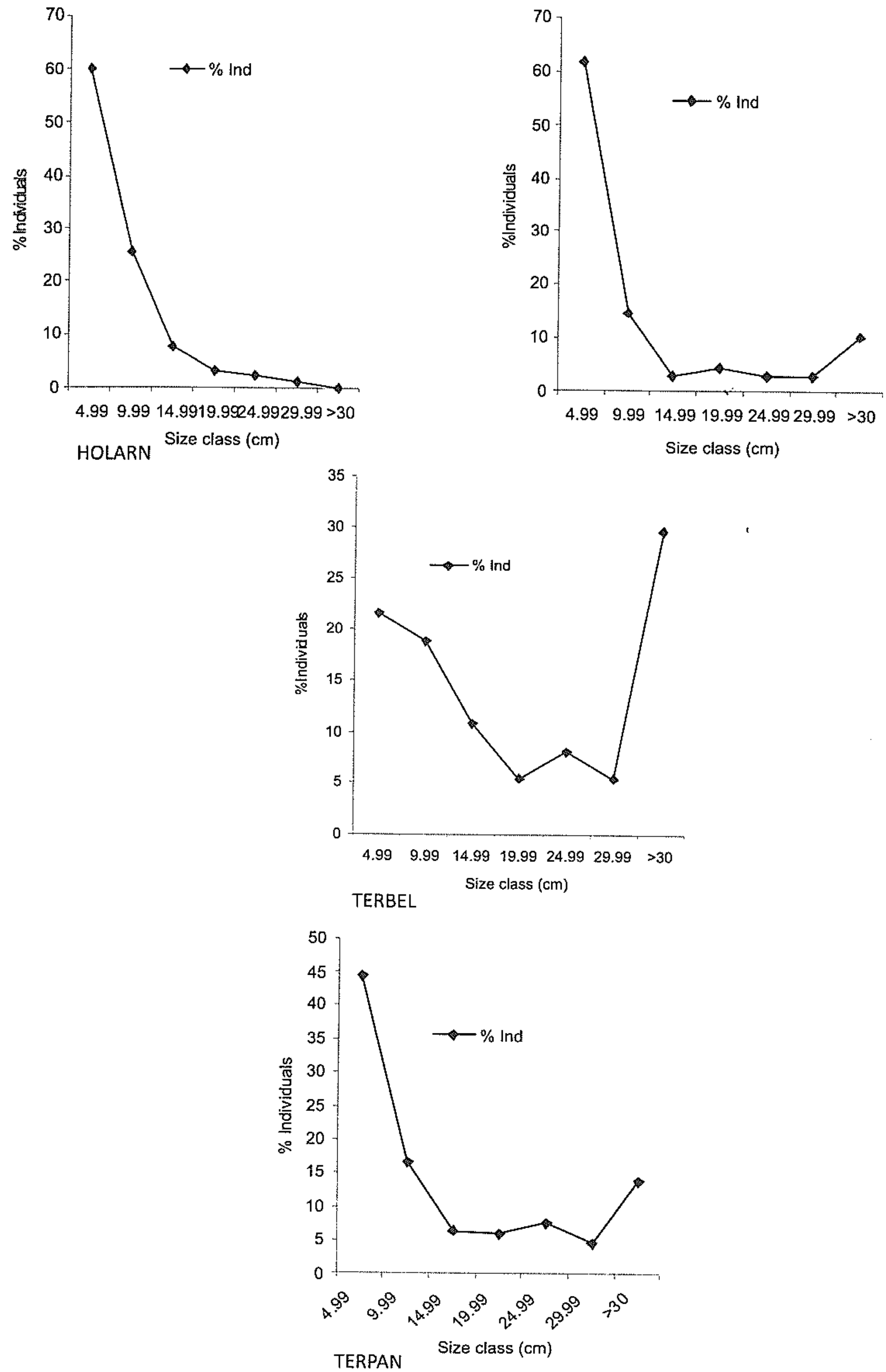


Figure 1.2. Size class distribution of selected species from the proposed project area (Kulem-Madgoan section).

Carbon stocks:

Mean standing carbon stock was 160.8±38.6 (range = 81.6 - 227.8 tons, N = 15) tons per hectare. There is considerable variation in the standing stocks of carbon across plots. Important species that contributed significantly to the carbon pool are *Terminalia crenulata* (35.2±31.7 tons/ha), *Terminalia paniculata* (33.0±26.7 tons/ha), *Xylia xylocarpa* (20.5±27.9 tons/ha), *Holigarna arnottiana* (12.43±19.7 tons/ha), *Erythrina indica* (10.7±18.3 tons/ha), *Trema orientalis* (10.3±8.61 tons/ha), *Acacia chundra* (9.24±8.32 tons/ha), *Terminalia bellirica* (8.36±6.04 tons/ha), *Ficus glomerata* (7.48±9.28 tons/ha). There is also a considerable variation in contribution to carbon pool by individual species.

Floristics:

There were 38 families of flowering plants recorded during the enumeration. Fabaceae (legumes) was the most speciose with 16 species followed by Euphorbiaceae (10 species) and Rubiaceae (9 species). There were 20 families with one species which includes families such as Bombacaeae, Burseraceae, Dilleniaceae and Ebenaceae. In terms of abundance, the family Combretaceae (870 individuals) was the most common followed by Fabaceae (439 individuals) and Tiliaceae (232 individuals) while in terms of basal area Combretaceae accounted for 59.6% of the total followed by Fabaceae (8.9%) and Anacardiaceae (4.4%). We calculated an index that measures the importance of each family found in the community, the Family Importance Value index (FIV) which is the sum of relative species frequency, relative abundance and relative dominance (basal area). Family Combretaceae had the highest FIV (91.91) followed by Fabaceae (37.70) and Euphorbiaceae (17.86). FIV of all families is reported in the Appendix 1.2.

Similarity measures:

We estimated the Jaccard's similarity between the sampling units. This is estimated as ratio of shared species between two transects to the total number of species between transects. The Jaccard's similarity yielded four distinct clusters based on species compositions. Sampling unit 2 and 15 had the least similarity (0.08) and, hence, they stand out as distinct units (Figure 1.3). These two units had relatively low similarity with other units also. Sampling units 10, 6, 11, 7, 8 and 1, 5, 13, 14, 9, 12 form a distinct cluster at the next level of similarity while sampling units 3 and 4 form a distinct cluster within the similarity level (Figure 1.3). Maximum similarity (0.64) was seen between sampling unit 9 and 12.

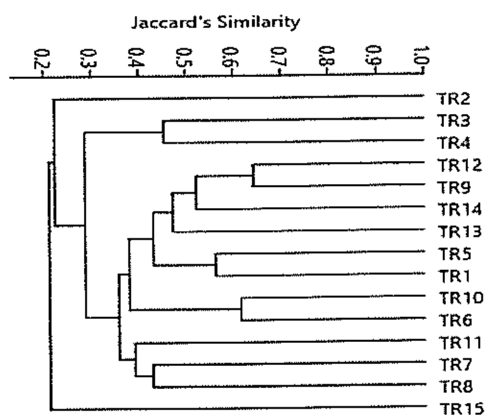


Figure 1.3. *Jaccard's similarity measure between different forest sampling units in the proposed project area.*

Appendix 1.1

List of all woody plant species enumerated with their IVI values in the proposed project area.

Species	Relative Abundance (%)	Relative Frequency (%)	Relative Dominance (%)	Importance Value Index (IVI)
Acacia auriculiformis	0.70	33.33	0.44	34.48
Acacia chundra	1.40	26.67	0.86	28.93
Acacia concinna	0.92	53.33	0.17	54.42
Adina cordifolia	0.25	13.33	0.10	13.69
Albizia chinensis	0.29	40.00	0.28	40.56
Albizia procera	0.29	20.00	0.23	20.52
Allophyllus cobbe	2.86	60.00	0.10	62.96
Alstonia scholaris	0.64	46.67	1.32	48.62
Alseodaphne semecarpifolia	0.10	13.33	0.23	13.66
Antidesma diandum	0.70	33.33	0.09	34.12
Aporusa lindleyeana	0.76	40.00	0.07	40.84
Bambusa arundinacea	0.03	6.67	0.00	6.70
Bauhinia malabarica	0.03	6.67	0.01	6.70
Bischofia javanica	0.03	6.67	0.81	7.51
Bombx cieba	0.89	73.33	2.20	76.43
Breynia retusa	0.32	40.00	0.04	40.36
Bridelia scandens	0.67	46.67	0.25	47.58
Buchanania lanzan	0.70	60.00	0.39	61.09
Butea monosperma	0.03	6.67	0.02	6.72
Calicopteris floribunda	2.45	86.67	0.77	89.88
Calicarpa tomentosa	0.41	26.67	0.06	27.14
Canthium diococcum	0.03	6.67	0.03	6.73
Caralia brachiata	2.51	100.00	4.23	106.74
Carissa carandas	0.16	33.33	0.01	33.50
Caralia integrima	0.19	13.33	0.00	13.53
Caryota urens	0.06	13.33	0.24	13.64
Cassia fistula	0.19	26.67	0.04	26.90
Casearia ovoides	0.06	13.33	0.00	13.40
Casearia tomentosa	0.06	6.67	0.00	6.73
Chukrasia tabularis	0.03	6.67	0.84	7.54
Cinnamomum malabathrum	0.03	6.67	0.00	6.70
Clereodendron viscosum	0.32	26.67	0.01	26.99
Dalbergia lanceolaria	0.03	6.67	0.00	6.70
Dalbergia latifolia	0.51	53.33	0.16	54.00

Appendix 1.1 (Continued)

Species	Relative Abundance (%)	Relative Frequency (%)	Relative Dominance (%)	Importance Value Index (IVI)
Dalbergia paniculata	0.03	6.67	0.17	6.87
Dalbergia smpathetica	0.10	6.67	0.00	6.77
Dillenia pentagyna	1.02	60.00	1.43	62.44
Diospyros montana	0.95	66.67	0.45	68.07
Polyalthia cerasoides	0.03	6.67	0.00	6.70
Embelia ribes	0.06	13.33	0.00	13.40
Ervatamia heneana	3.91	86.67	0.94	91.51
Erythrina indica	0.89	26.67	1.87	29.42
Eugenia flocossa	0.16	6.67	0.01	6.84
Ficus asperimma	0.51	33.33	0.22	34.07
Ficus glomerata	0.86	26.67	1.16	28.69
Ficus hispida	0.89	26.67	0.33	27.88
Ficus religiosa	0.03	6.67	0.00	6.70
Flacourtia indica	0.03	6.67	0.00	6.70
Flacourtia montana	0.32	53.33	0.05	53.71
Fluggea leucopyros	0.03	6.67	0.00	6.70
Garcinia indica	0.06	6.67	0.00	6.73
Garuga pinnta	1.11	60.00	0.81	61.92
Garcinia talbtii	0.03	6.67	0.00	6.70
Glochidion velutinum	0.25	26.67	0.03	26.95
Gmelina arborea	0.06	6.67	0.01	6.74
Gnetum ulva	0.03	6.67	0.00	6.70
Grewia disperma	2.07	53.33	0.64	56.04
Grewia orbiculata	0.06	13.33	0.00	13.40
Grewia sp.	0.03	6.67	0.00	6.70
Grewia tiliifolia	4.58	86.67	1.18	92.42
Helicteres isora	4.99	60.00	0.37	65.35
Holarrhena antydysenterica	1.02	73.33	0.10	74.45
Holigarna arnottiana	2.76	20.00	0.71	23.47
Holoptelea integrifolia	0.03	6.67	0.00	6.70
Ixora arborea	0.03	6.67	0.00	6.70
Ixora brachiata	0.32	20.00	0.27	20.59
Lagerstroemia microcarpa	2.00	66.67	2.75	71.42
Lagerstroemia parviflora	0.35	20.00	0.18	20.53
Lannea coromandelica	0.10	13.33	0.04	13.47
Leea indica	3.08	46.67	0.26	50.01
Macaranga peltata	2.99	100.00	0.85	103.84

Appendix 1.1 (Continued)

Species	Relative Abundance (%)	Relative Frequency (%)	Relative Dominance (%)	Importance Value Index (IVI)
Mallotus philippensis	0.54	46.67	0.14	47.34
Mangifera indica	0.22	33.33	3.26	36.81
Memecylon malabaricum	0.13	6.67	0.01	6.80
Mitragyna parvifolia	0.22	26.67	0.05	26.94
Nothopodytes heneana	0.13	6.67	0.00	6.80
Olea dioica	0.16	6.67	0.00	6.83
Pavetta indica	0.60	20.00	0.03	20.63
Persea macrantha	0.03	6.67	0.00	6.70
Phllanthus emblica	0.03	6.67	0.00	6.70
Polyalthia fragrans	0.29	26.67	0.06	27.02
Psidium guajava	0.03	6.67	0.00	6.70
Pterocarpus marsupium	0.41	26.67	0.26	27.34
Randia dumetorum	1.94	86.67	0.34	88.95
Randia uliginosa	0.19	20.00	0.01	20.20
Sapindus emarginatus	0.03	6.67	0.19	6.89
Schleichera oleosa	0.35	20.00	0.57	20.92
Scolopia crenata	0.16	26.67	0.03	26.86
Stereospermum personatum	0.54	33.33	0.02	33.90
Strychnos nux-vomica	0.25	26.67	1.49	28.42
Syzygium cumini	0.32	26.67	0.04	27.02
Tectona grandis	0.03	6.67	0.05	6.75
Terminalia bellirica	1.05	60.00	6.03	67.08
Terminalia chebula	0.10	13.33	0.05	13.48
Terminalia crenulata	9.98	93.33	27.99	131.30
Terminalia paniculata	14.08	100.00	24.75	138.82
Tilia sp.	0.64	20.00	0.02	20.65
Trema orientalis	0.95	20.00	0.82	21.77
Viburnum punctatum	0.03	6.67	0.00	6.70
Vitex altissima	0.03	6.67	0.00	6.70
Wagatea spicata	0.13	20.00	0.12	20.25
Wenlandia thyrsoides	0.54	6.67	0.05	7.26
Wrightia tinctoria	0.13	20.00	0.02	20.15
Xantolis tomentosa	0.03	6.67	0.00	6.70
Xylia xylocarpa	8.01	53.33	4.30	65.64
Zanthoxylum rhetsa	0.64	33.33	0.18	34.15
Ziziphus oenoplea	0.25	40.00	0.01	40.26
Ziziphus rugosa	2.32	80.00	0.19	82.51

Appendix 1.2

Family Importance Value (FIV) of different families of woody plants enumerated in the proposed project area

Species	Relative Species Frequency (%)	Relative Abundance (%)	Relative Dominance (%)	Family Importance Value (FIV)
Anacardiaceae	4.63	3.91	4.40	12.94
Annonaceae	1.85	0.32	0.07	2.24
Apocyanaceae	4.63	5.85	2.38	12.86
Bignoniaceae	0.93	0.54	0.02	1.49
Bombacaceae	0.93	0.89	2.21	4.02
Burseraceae	0.93	1.11	0.81	2.85
Caprifoliaceae	0.93	0.03	0.00	0.96
Clusiaceae	1.85	0.10	0.00	1.95
Combretaceae	4.63	27.66	59.62	91.91
Dilleniaceae	0.93	1.02	1.43	3.37
Ebenaceae	0.93	0.95	0.45	2.33
Euphorbiaceae	9.26	6.33	2.28	17.86
Fabaceae	14.81	13.96	8.93	37.71
Flacourtiaceae	4.63	0.64	0.09	5.35
Gnetaceae	0.93	0.03	0.00	0.96
Lauraceae	2.78	0.16	0.23	3.17
Lecythidaceae	0.93	2.51	4.23	7.67
Leeaceae	0.93	3.08	0.26	4.27
Loganiaceae	0.93	0.25	1.50	2.68
Lythraceae	1.85	2.35	2.93	7.13
Melastomaceae	0.93	0.13	0.01	1.06
Meliaceae	0.93	0.03	0.84	1.80
Moraceae	3.70	2.29	1.72	7.71
Myrsinaceae	0.93	0.06	0.00	0.99
Myrtaceae	2.78	0.51	0.05	3.34
Oleaceae	0.93	0.16	0.00	1.09
Palmae	0.93	0.06	0.24	1.23
Poaceae	0.93	0.03	0.00	0.96
Rhizophorceae	0.93	0.19	0.00	1.12
Rhamnaceae	1.85	2.58	0.19	4.62
Rubiaceae	8.33	4.13	0.89	13.36
Rutaceae	0.93	0.64	0.18	1.74
Sapindaceae	2.78	3.24	0.86	6.88
Sapotaceae	0.93	0.03	0.00	0.96
Sterculiaceae	0.93	4.99	0.37	6.28
Tiliaceae	4.63	7.38	1.84	13.85
Ulmaceae	1.85	0.99	0.82	3.66
Verbenaceae	4.63	0.86	0.13	5.62
Grand Total	**100**	**100**	**100**	**300**

A survey of mammal species along Sonalium - Kulem - Kalem section railway track at Goa: Western Ghats.

The forest area between Sonalium-Kulem-Kalem is presently under the Bhagavan Mahavir Wildlife Sanctuary. Though there is no area specific study on the fauna of this area, there are some anecdotal studies that records different faunal assemblages in the state of Goa. Jadav & Pati (2012) from Zoological Survey of India, recorded fauna such as Tiger- *Panthera tigris*, leopard-*Panthera pardus*, barking deer-*Muntiacus muntjak*, mouse deer- *Moschiola indica*, sambar- *Rusa unicolor*, spotted deer-*Axis axis*, wild boar-*Sus scorfa*, pangolin -*Manias crassicaudata*, slender loris- *Loris tardigradus*, bonnet macaque- *Macaca radiata*, common langur- *Semnopithecus dussumieri*, Civet cat -*Viverricula indica*, flying squirrel- *Petaurista petarauista*, Gaur- *Bos gaurus* and Giant squirrel -*Ratufa indica*. Forest Department of Goa listed 42 mammalian species in this area (http://www.forest.goa.gov.in/flora/). In our previous study (2017) from Castlerock to Kulem (field work done during 2013) we recorded twenty three species of different mammals at Bhagavan Mahavir Wildlife Sanctuary. Present study is aimed at understanding the mammalian species assemblage between Sonalium-Kulem-Kalem section using both direct and indirect methods including camera traps. Our study has the following objectives:

I) Recording the diversity of mammal species in this area both through direct sightings and indirect evidences.

ii) Identify the locations where the doubling of railway line is likely to make impacts on the mammalian community from deaths or injuries in train collisions due to increased rail traffic.

iii) Suggest mitigation plan to reduce the impacts of doubling of railway line on movement of mammals across the rail track.

2. Methods:

2.1. Study area:

The study area is Sonalium- Kulem –Kalem sector of railway line (Sangem Taluk, South Goa District, and Goa State)

2.2. Methods

i) Camera traps:

Camera trapping was carried out along the stretch of the present railway track that is proposed to be doubled, in order to record the movement of mammal species. Most camera trap models are triggered by a passive infrared sensor detecting a moving object warmer than the ambient temperature such as animals, people, or vehicles passing in front of them. Camera trapping is most often used to capture images of medium to large sized terrestrial mammals and birds, but has also been recently used for arboreal mammals (Oliveira-Santos *et al.*, 2008). Camera traps have been used to record fauna in a wide range of habitats, from snow leopard in the Himalayas (Jackson *et al.* 2006) and bobcat in northern California (Larrucea *et al.* 2007) to a wealth of studies in tropical forests (*e.g.* Karanth & Nichols 1998; Karanth et al. 2000; Rovero & De Luca 2007; Tobler *et al.* 2008a). Besides their use for carrying out faunal inventories and obtaining information on activity pattern and habitat preference, scientifically robust, inferential sampling studies using camera traps can allow the estimation of occupancy and animal density.

Cudde-back X-Change Infrared camera trap model was used in this survey. At each location four camera traps were kept for 2 or 3 nights. Camera traps were fixed within a maximum distance of 100 meters on either side of the railway track. The spacing between two cameras traps varied between 50 meters to 250 meters. The distance between Kulem to Kalem is 7.4 km. Camera traps were deployed along the animal tracks and paths in order to get photographs of species along the railway track. Four camera traps were used for this survey. Every location of Camera trap (GPS location) was recorded by hand held Garmin GPS.

ii) Indirect methods: Transects, parallel to the existing railway track, were laid on both sides of the track up to 25 metres, and animal signs were searched visually. Every animal sign (foot print/track sign, feeding sign, scat/pellets/faeces, and scrapes/stretches) was recorded, GPS locations of all evidences taken by handheld Garmin GPS and locations plotted on map using GIS software (Sathyakumar et al. 2011, Roy & Sukumar 2017). A kernel density map was generated in Arc GIS software after plotting indirect signs. "Kernel density is an estimate nonparametric way to estimate the probability density function of random variable and calculates the density of point features around each output raster cell. Raster cell is a spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an attribute value and location coordinates" (**http://support.esri.com/other-resources/gis-dictionary/term/raste**). By default, the unit is selected by the input feature and depending on projection system selected. If input feature is in meter the output area will be by default square km by a multiplier of 100,0000 (1000m*1000m). Theoretically, a smoothly curved surface is built-in over each point. The surface value is highest at the location of the point and reduces with increasing distance from the point, reaching zero at the search radius distance from the point and will only take a circular neighborhood. The volume under the surface equals the population field value for the point, or 1 if none is specified. The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell centre. The kernel function is based on the quadratic kernel function described in Silverman (1986).

In this study we used Kernel density estimate algorithm to understand and locate the areas where maximum number and types of animal signs were recorded along the railway track. This type of analysis is also helpful for identifying the kind of mitigation procedure we have to take for a particular location as it gives a picture of High to Low sign density areas. Using Arcgis KDE tool, it is possible to figure out the cluster formation of some point data, and this tool also creates some zones depending on distance of point data.

3. Results:

A total of 112 camera traps nights (4 camera x 28 days) were kept and a total of 85 photographs were captured at Sonalium-Kulem-Kalem section. In between Kulem to Kalem, camera traps were operated for 48 trap nights (4 camera x 12 days) and 15 animal photographs were captured (0.31 photograph/camera trap night) in total. Between Kulem to Sonalium camera traps were ran for 64 traps nights (4 camera x 16 days) and 70 photographs taken (1.09 photographs/ camera trap night). When we calculated number of pictures captured per camera trap night (no of photos capture / Total camera trap night kept) it was found that wild boar *(Sus scorfa)* was the most abundant followed by Indian Porcupine (*Hystrix indica*) and Bonnet macaque (*Macaca radiata*). The details are given in (Table 2.1).

Table 2.1. Mammalian density by Camera trap (No of Picture taken / total no of Camera trap nights)

Animal capture	Kulem to Kalem*	Cap/CTN	Kulem to Sonalium**	Cap/CTN	Overall	Cap/CTN
Asian Palm civet	0	0.000	2	0.031	2	0.018
Black napped hare	2	0.042	0	0.000	2	0.018
Bonnet macaque	4	0.083	0	0.000	4	0.036
Brown Palm civet	0	0.000	0	0.000	1	0.009
Chital deer	2	0.042	1	0.016	2	0.018
Indian grey mongoose	1	0.021	0	0.000	1	0.009
Indian Porcupine	0	0.000	6	0.094	6	0.054
Leopard	1	0.021	1	0.016	2	0.018
Mouse deer	0	0.000	1	0.016	1	0.009
SG Hanuman langur	2	0.042	0	0.000	2	0.018
Sloth bear	0	0.000	1	0.016	1	0.009
Small Indian Civet	0	0.000	1	0.016	1	0.009
Wild boar	3	0.063	57	0.891	60	0.536
TOTAL	**15**	**0.313**	**70**	**1.094**	**85**	**0.759**

**Kulem to Kalem 48 camera trap nights kept,* ***Kulem to Sonalium 64 camera trap nights kept*

Cap = Capture, CTN = Camera trap nights,

3.1. Kulem to Kalem

3.1a. Camera trap findings: A total of 15 photographs were captured of which 7 different species were recorded as below:

Indian grey mongoose (*Herpestes edwardsii*) and Leopard (*Panthera pardus*) - one time;

Black naped hare, Chital deer (*Axis axis*) (*Lepus nigricollis*) and Southern plain Grey Hanuman langur (*Semnopithecus dussumieri)* - two times; Wild boar (*Sus scorfa*) - three times;

Bonnet macaque (*Macaca radiata*) - four times;

The details of camera traps deployed between Kulem to Kalem railway stations (Figure 2.1) are given in Appendix 3. Representative pictures from the camera trap survey (1-7) from the same area are also given in the following pages.

Camera trap locations in between Kulem and Kalem station

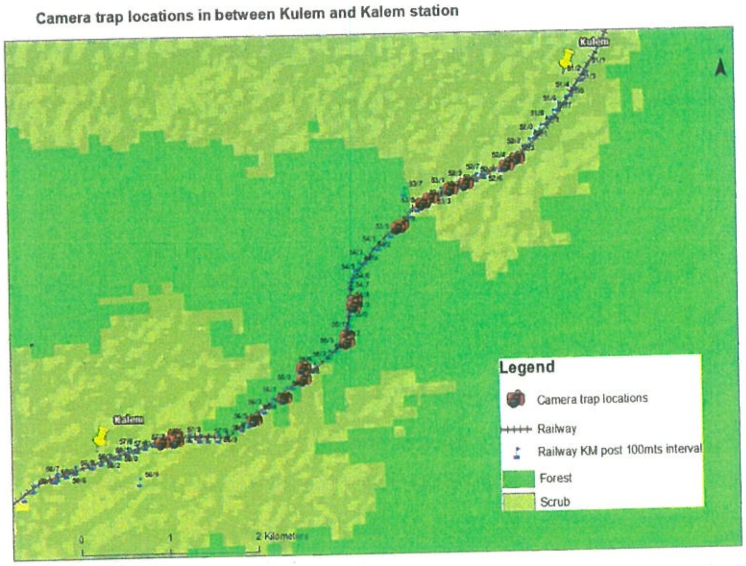


Fig 2.1. Location of camera traps between Kulem and Kalem Stations

Photo-1: (Kulem to Kalem): Black naped hare (Lepus nigricollis)

Photo-2:(Kulem to Kalem): Indian grey mongoose (Herpestes edwardsii)

Photo-3: (Kulem to Kalem): Wild boar (Sus scrofa)

Photo-4: (Kulem to Kalem): Bonnet macaque (Macaca radiata)

Photo-5: (Kulem to Kalem): Wild boar- (Sus scrofa)

Photo-6: (Kulem to Kalem): South Indian Plain Grey Hanuman langur (Semnopithus dussumieri)

Photo-7: (Kulem to Kalem): Chital deer (Axis axis)

Setting up a camera trap

4.1b. Indirect signs:

A total of 522 animal signs (pellets, scats, digging signs, foot prints and tracks) of 8 different animal species were found. Porcupine (*Hystrix indica*) signs were the most common (28% of all signs) followed by gaur (*Bos gaurus*) (26%) and wild boar(*Sus scrofa*) (26%). The details are given below (Table2.2).

Table 2.2. *Mammals recorded through indirect signs between Kulem and Kalem stations*

Animal	Scientific name	Pellet/ Scat/Dung	Foot prints/ track	Digging	Feeding sign	Others	Total	% age
Porcupine	*Hystrix indica*	4	0	143	0	0	147	28.2
Gaur	*Bos gaurus*	12	125	0	0	1	138	26.4
Wild boar	*Sus scrofa*	0	11	120	0	0	131	25.1
Mongoose	*Herpestes edwardsii*	0	0	94	0	0	94	18
Barking Deer	*Muntiacus muntjak*	4	0	0	0	0	4	0.8
Civet cat	*Viverricula indica*	3	0	0	0	0	3	0.6
Leopard	*Panthera pardus*	3	0	0	0	0	3	0.6
Hare	*Lepus nigricollis*	2	0	0	0	0	2	0.4
Sambar deer	*Rosa unicolor*	0	0	0	0	0	0	0
TOTAL		**28**	**136**	**357**	**0**	**1**	**522**	**100**

When we plotted all animal signs between Kulem and Kalem stations, we found that the major concentrations were between Rly Km Post 52/8 to 54/3 and 55/3 to 57/4 (Fig. 2.2). When we plotted gaur (*Bos gaurus*) signs only, we found that the concentration was between Rly Km post 52/7 to 54/0 and 57/2-58/1 (Fig.2.3). The existing underpass locations are shown in Figure 2.4.

Kernel density analysis for all types of animal signs concentration

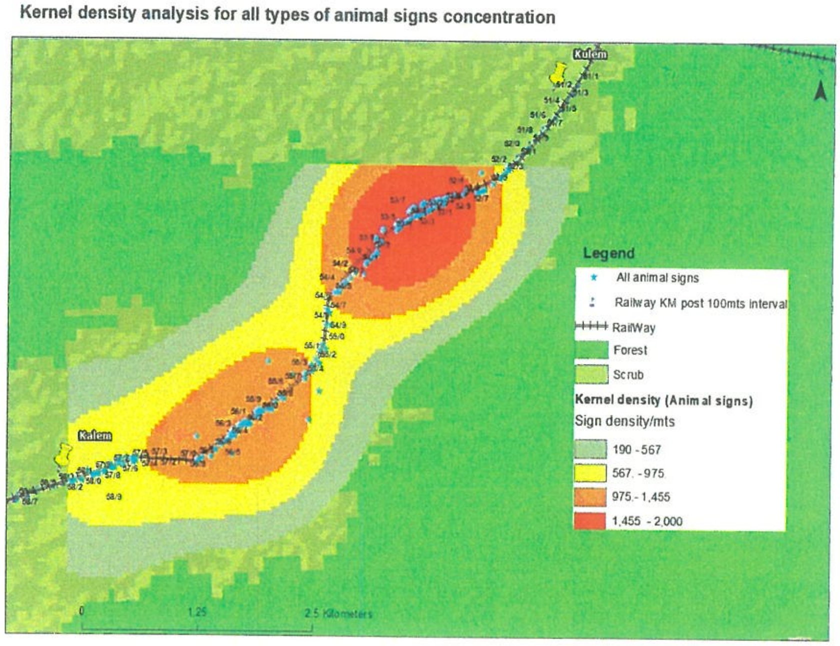


Figure 2.2. *Kernel density of all animal signs recorded between Kulem and Kalem Stations*

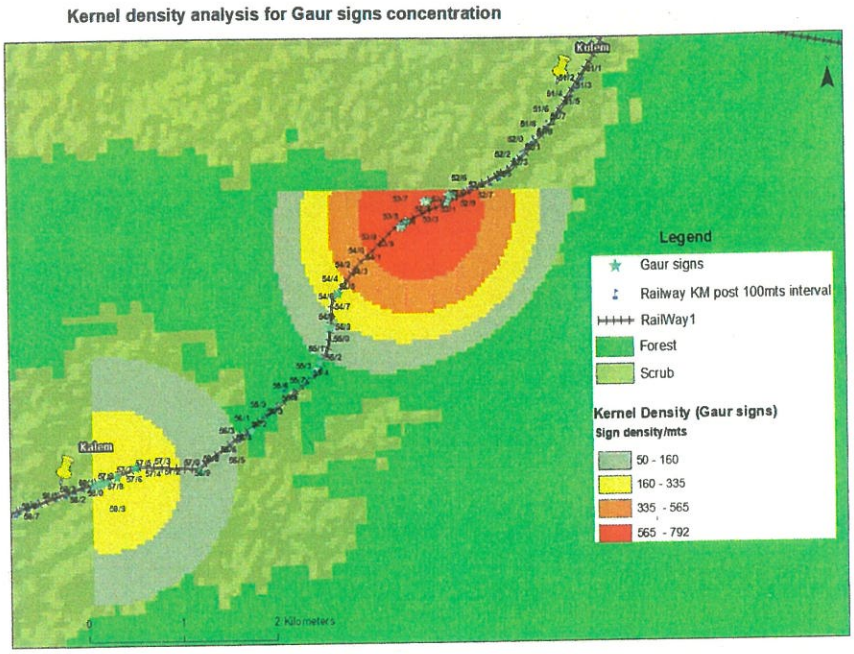


Figure 2.3. *Kernel density of Gaur signs between Kulem and Kalem Stations*

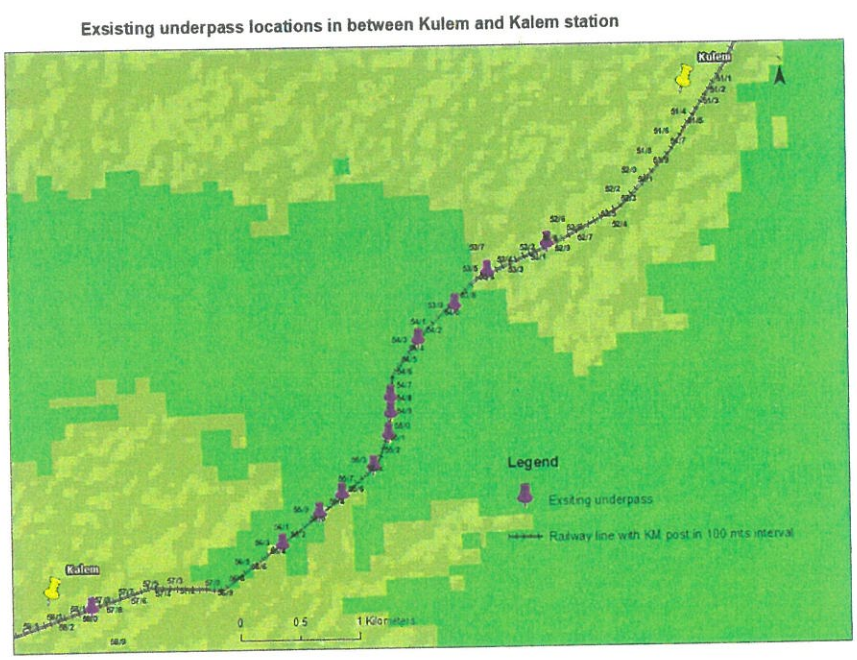


Figure 2.4. *Existing underpass locations between Kulem and Kalem Stations*

KDE analysis of Kalem to Kulem railway station;

In the map (Figure 2.2) we can clearly identify two major animal sign clusters. The red zone (railway post 52/6 to 54/2) has the maximum number and types of animal signs. We can therefore expect that for crossing this railway track, animals are using the three underpasses (near railway posts 52/8, 53/5, 53/8) located within this cluster frequently. Therefore, we can say that these three underpasses have the maximum importance along this entire stretch from Kalem to Kulem station and also that these locations need maximum maintenance to ensure that the passages are kept free for animal movement. The orange zone has two clusters which means that these two zones have medium density of animal signs. There are some underpasses (near railway posts 54/2, 55/3, 55/7, 55/9, 56/1) located along the orange zone, which also need attention.

4.2. Kulem to Sonalium

4.2a. Camera trap findings

Four camera traps were laid for a total of sixteen days (26.12.2017 to 11.01.2018) and a total of 64 camera traps nights (4 camera traps x 16 days) . A total of 70 mammal photographs were captured during this period. The distance between Kulem to Sonalium is 8.5 km. The following eight different species were recorded in the camera traps:

Brown Palm civet (*Paradoxurus jerdoni*), Leopard (*Panthera pardus*), Sloth bear (*Melursus ursinus*), Mouse deer, (*Moschiola indica*) and Small Indian Civet (*Viverricula undica*) - one time;

Asian Palm civet (*Aradoxurus hermaphrodites*) - two times;

Indian Porcupine (*Hystrix indica*) - six times; Wild boar (*Sus scrofa*) - 57 times.

The details of camera traps deployed between Kulem and Sonalium stations are given in Appendix-2.1. The locations of camera traps are shown below in Figure 2.5. Representative pictures (8-11) from camera trap survey along this sector are given in the following pages.

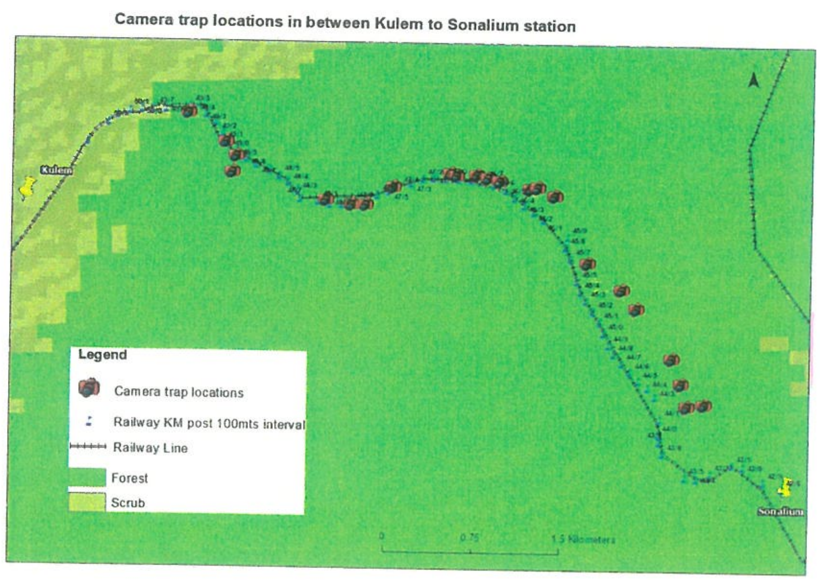


Figure 2.5. *Location of camera traps between Kulem and Sonalium stations*

Photo-8 (Kulem to Sonalium): Brown palm civet (Paradoxurus jerdoni)

Photo-9 (Kulem to Sonalium): Asian palm civet civet (Aradoxurus hermaphrodites)

Photo-10 (Kulem to Sonalium): Sloth bear (Melursus ursinus)

Photo-11 (Kulem to Sonalium): Leopard (Panthera pardus)

4.2b. Indirect sign survey findings (Kulem to Sonalium):

A total of 355 animal signs from 8 species were found. Gaur signs were the most common (51% of all signs) followed by porcupine (28.5%) and wild boar (12%). The details are given below (Table 2.3).

The mammalian species recorded in the camera traps between Kulem to Kalem and Kulem to Sonalium are given in Appendix 2.3.

Table 2.3. *Indirect sign survey findings between Kulem and Sonalium*

Animal	Scientific name	Pellet/ Scat/Dung	Foot prints/ track	Digging	Feeding sign	Total	% age
Gaur	*Bos gaurus*	11	172	0	1	184	51.8
Porcupine	*Hystrix indica*	19	0	82	0	101	28.5
Wild boar	*Sus scrofa*	0	0	44	0	44	12.4
Mongoose	*Herpestes edwardsii*	19	0	0	0	19	5.4
Barking Deer	*Muntiacus muntjak*	3	0	0	0	3	0.8
Civet cat	*Viverricula indica*	2	0	0	0	2	0.6
Hare	*Lepus nigricollis*	1	0	0	0	1	0.3
Sambar deer	*Rosa unicolor*	0	1	0	0	1	0.3
TOTAL		**55**	**173**	**126**	**1**	**355**	**100**

When all animal signs between Kulem to Sonalium station are plotted on a map, concentrations are seen between Rly Km Post 44/7 to 45/0, 45/7 to 46/3, 46/5 to 47/2 and 47/5 to 48/1, 48/7 to 49/3 (Figure 2.6). When we plotted only the gaur signs we found a concentration between Rly Km post 47/6 to 48/0 (Figure 2.7). The existing underpass locations are shown in Figure 2.8.

Kernel density analysis for all types of animal signs concentration

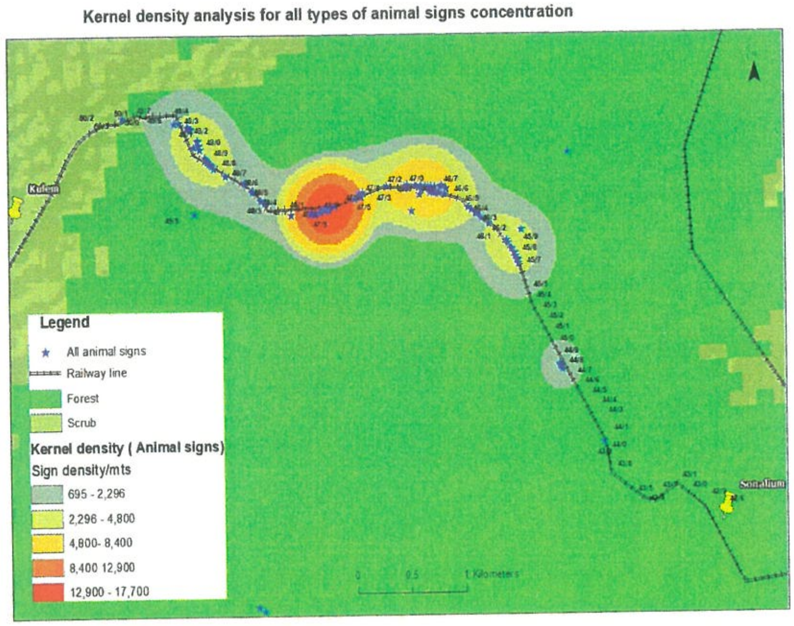


Figure 2.6. *Kernel density analysis of animal signs between Kulem and Sonalium stations*

Kernel density analysis of mammal signs in the Kulem to Sonalium sector:

In this zone we can see four cluster formations; within one of these clusters a zone of high animal sign density is marked in red. We can identify two underpasses (near railway posts 47/6 & 47/9) within this high-density area. Area marked with orange colour has medium density of animal signs covering a smaller area but with no underpass. Obviously, a couple of underpasses are needed for safer animal crossing in this area. Along this sector it was seen that many underpasses are located in low density animal sign areas.

Kernel density analysis for Gaur signs concentration

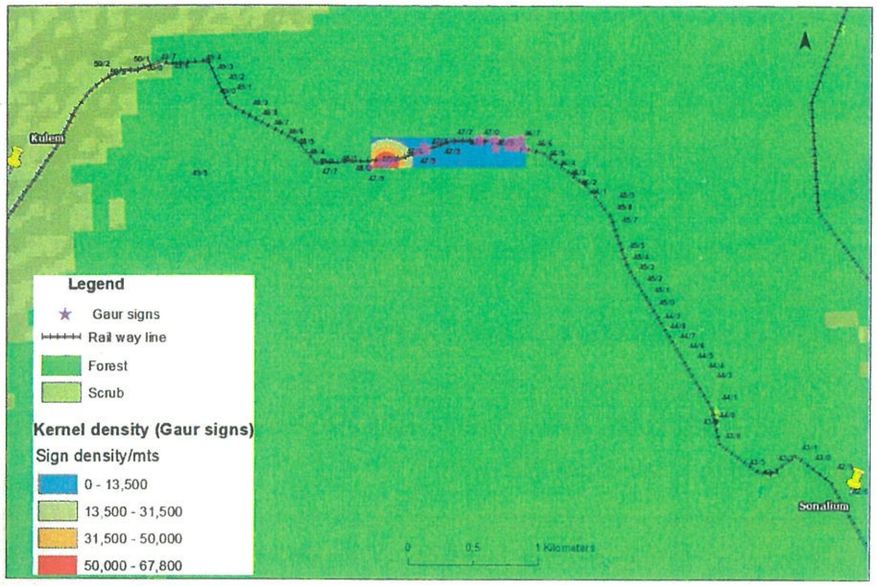


Figure 2.7. *Kernel density of gaur (Bos gaurus) signs between Kulem and Sonalium*

Exsisting underpass locations in between Kulem and Sonalium station

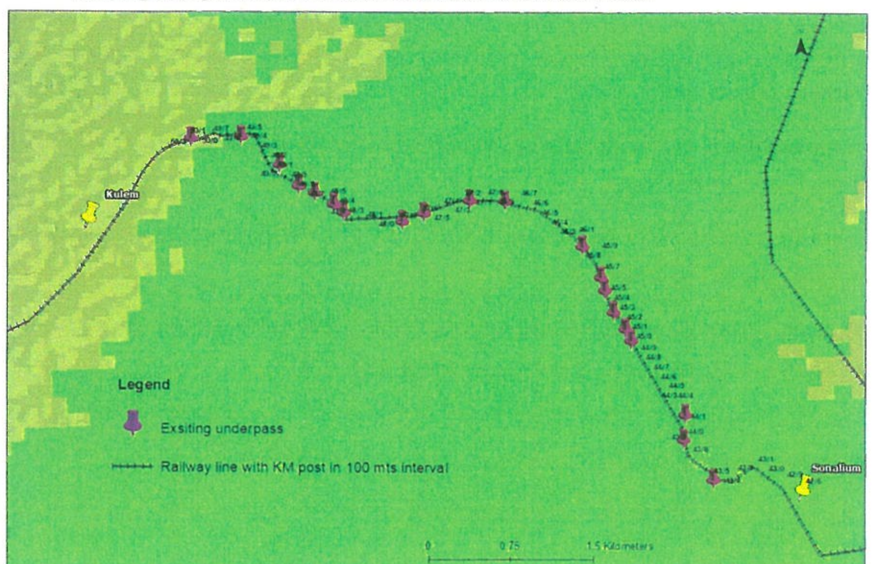


Figure 2.8. *Existing underpasses between Kulem and Sonalium stations*

5. Mitigating measures:

5.1. On site constructions & habitat connectivity:

Most of the existing underpasses are small and act largely as water ducts rather than as passages for the movement of animals across the track; hence, they need to provide additional larger underpasses that would permit the movement of animals, both small and large.

Some underpasses (Box culverts) can be made between Rly Km post 44/7 to 49/3 on the Kulem to Sonalium sector (Fig. 2.6). As gaur signs are concentrated between Rly Km post 47/6 to 48/0, one large-sized underpass (Box culvert) can be constructed along this stretch of the railway track.

Two large-size underpasses can also be provided in between Km post 52/7 to 54/0 and 57/2-58/1, where gaur signs were common in between Kulem to Kalem Station.

Existing underpass locations (Fig. 2.4 & Fig. 2.8) appear to be small in size for animal crossing and these can be made bigger size in terms of breadth and height so that animals can cross through them easily.

Low fencing can be erected on both sides of the railway track at certain places to funnel smaller mammals towards an underpass. Specific stretches, except for high terrain, may also be fenced where needed to guide larger animals towards a bigger underpass.

For arboreal species (especially Malabar Giant Squirrel but also primates such as Bonnet macaque and South Indian Grey plains langur) the construction of a canopy bridge using low cost material may be needed to ensure their crossing over the track.

The report "Ecofriendly measures for mitigating linear Infrastructure" by Wildlife Institute of India (2017) can be taken as the standard reference for designing the appropriate type of structures for allowing animals of different body sizes to cross.

Specific decisions about the underpasses for animal crossing can be taken in consultation with the local forest officials and experts during the time of construction.

5.2. Regulatory measures:

1. Control of speed while moving through forest areas including visible boards for speed limit along various sections of the track
2. Drivers should be advised to sound the horn and have the lights of the loco-engine continuously while moving in the forested track.
3. Staff of the pantry car should be trained/educated not to throw food waste along the track in the forested area (Sonalium- Kulem-Kalem-Sanvordem).
4. Removal of garbage along the railway track so as not to attract animals close to the track, and awareness among railway passengers not to throw rubbish.
5. Regular clearing of bushes & trees on both sides of track for proper visibility.
6. Animal sign boards at various critical areas to alert train drivers.
7. Monitoring of existing underpasses for frequency of animal use.

8. Underpasses should be maintained such that there is no accumulation silt/mud and vegetation. There should be clear visibility for animals to move through.
9. Scheduling of trains (both passenger and goods) so that sufficient time is maintained between passage of each train. This is an important management task as the traffic is expected to increase considerably and animals such as gaur need to cross the track without any hindrance. During the study period there was hardly any movement of gaur in the area but this is expected to intensify during the cashew (*Anacardium occidentale*) fruiting season according to local foresters & villagers.

5.3. Specific mitigation measures as per the results from KDE analysis:

There are two distinct areas of high concentration of animal usage between Kulem – Kalem stations. These are between 52/4 railway post to 54/6 railway post (2.3 km stretch with four small underpasses existing) and another one between 55/3 to 57/3 railway posts (2.0 km stretch with four small underpasses) (Figure 2.2). In the stretch between 52/4 to 54/6 railway post, the total length of high animal usage is about 1.4 km extending between 52/7 and 54/2 railway posts (Figure 2.9) with three underpasses presently along this stretch.

We recommend the following underpasses for animal crossing:

a) One new large underpass (4 metres height x 4.5 metres width box, considering the passage for large mammal such as gaur) between 53/0 and 52/8, and a suitable engineering structure to allow animal funneling along the adjoining stretch to increase the chances of them crossing the underpass.

b) an underpass (figure 2.2) between 56/650 and 56/775 for the easy passage of small mammals and the rest can be designed with suitable engineering structure to funnel animals to a particular underpass.

c) A new large underpass (4 metres height x 4.5 metres width box) between 46/6 Rly km post-47/2 Rly km post for passage of large animals.

The above recommendations on underpasses are also depicted on Google Earth maps (Figure 2.9).

High concentration of animal usage between Kulem – Sonalium (Figure 2.6) spans between 46/6 and 48/1 railway posts covers a distance of 1.8 kms. However, very high concentration (red area, figure 2.10) of animal signs (animal usage) is found in about 800 meters length along the railway track. There are two existing underpasses along this stretch.

During the discussions there were suggestions for "barricading" certain high animal usage stretches of the track and allowing them entry only through the underpasses. However, barricading can introduce fresh problems such as animals straying on to the tracks and getting trapped, sneaking through an improperly designed barricade and unable to escape an approaching train, etc. The traffic on this track even after doubling may also not warrant any such drastic measures. We are therefore reluctant to recommend complete barricading (though some simple guidance or funneling of animals towards an underpass may be in order). However, the Railways should be prepared for barricading some sections of the track in consultation with the State Forest Department in future if the situations warrant this course of action.

Railways can also think of providing extra platforms at stations such as Kalem and Sanvordem for holding trains so that better scheduling of trains can be done. As far as possible night traffic can be minimized as a measure to avoid accidents relating to wildlife.

Railways can also think of experimenting with newer technology to alert the loco-pilots about the crossing of animals. A solar-powered laser detection system can be planted in the intense animal activity zone as per KDE analysis. Once the animal is detected near the track, warning either through alarm or flashing of lights (using colours that railways do not use normally) at regular intervals stretching to at least 5 KM on either direction so as to enable the loco-pilot to have knowledge about animal presence and control the speed accordingly to avoid wildlife accidents.

Finally, we recommend a year-long monitoring on effectiveness of the barricade as well as underpasses by a reputed technical institution that would help in course correction in both design and the strategy to permit animals to cross the tracks and avoid accidents.

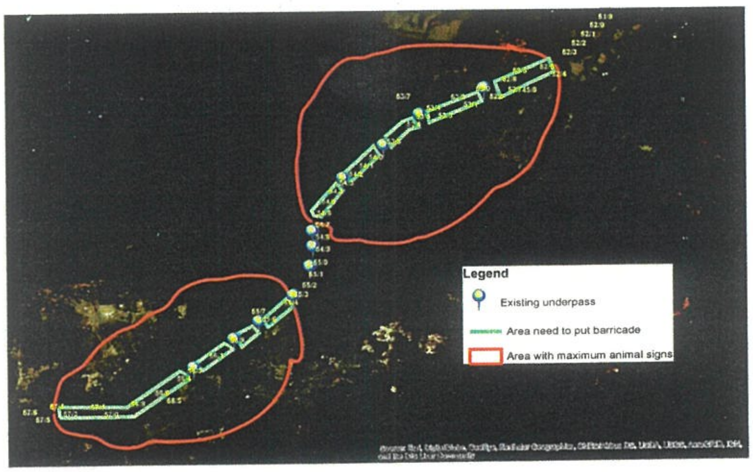


***Figure 2.8:** High concentration of animal usage (red circle) remedial measures suggested for the track between Kulem and Kalem, Goa.*

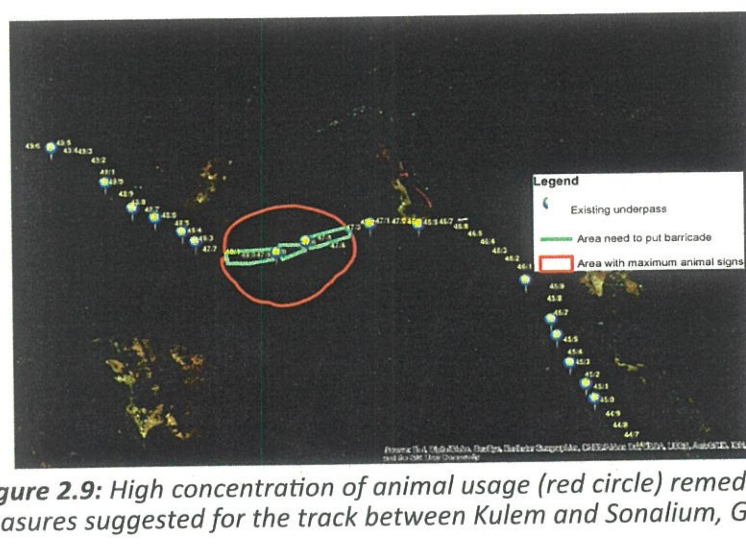


***Figure 2.9:** High concentration of animal usage (red circle) remedial measures suggested for the track between Kulem and Sonalium, Goa.*

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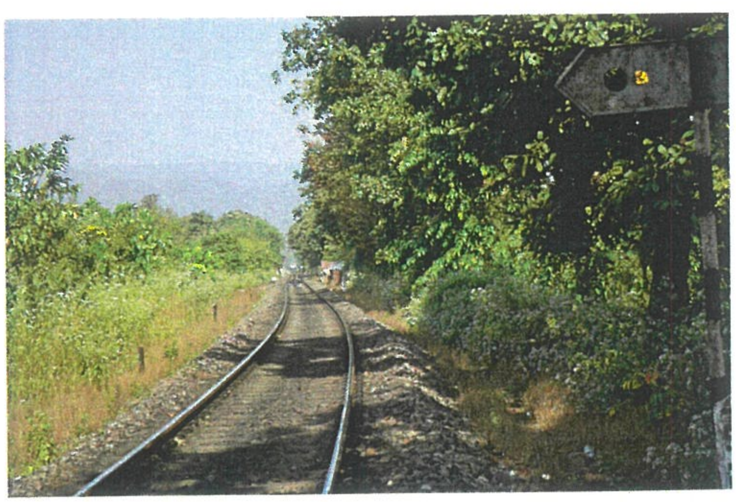
http://www.forest.goa.gov.in/flora/

Appendix 2.1

Details of camera trap set up in between stations Kulem to Kalem

Sl. No.	Ca Tr No.	Date deploy	Time	Date removal	Time	CT nights	Lat. (degree decimal)	Longi. (degree decimal)	Rly. km post
1.	C1	14-Dec-17	02:43 PM	17-Dec-17	02.44 PM	3	15.32259	74.23495	52/200
2.	C2	14-Dec-17	03:12 PM	17-Dec-17	03:18 PM	3	15.32190	74.23386	52/200-300
3.	C3	14-Dec-17	03:50 PM	17-Dec-17	03:28 PM	3	15.32028	74.22977	52/400
4.	C4	14-Dec-17	04:43 PM	17-Dec-17	04:00 PM	3	15.31975	74.22820	52/500
5.	C1	17-Dec-17	03:18 PM	20-Dec-17	10:24 AM	3	15.31899	74.22618	53/300
6.	C2	17-Dec-17	03:28 PM	20-Dec-17	10:12 AM	3	15.31849	74.22538	53/400-53/500
7.	C3	17-Dec-17	03:39 PM	20-Dec-17	09:38 AM	3	15.31652	74.22321	53/700
8.	C4	17-Dec-17	03:48 PM	20-Dec-17	11.00 AM	3	15.31623	74.22283	53/800
9.	C1	20-Dec-17	10:26 AM	22-Dec-17	10:20 AM	2	15.30949	74.21832	54/700
10.	C2	20-Dec-17	10:12 AM	22-Dec-17	10:24AM	2	15.30899	74.21820	54/800
11.	C3	20-Dec-17	10:40 AM	22-Dec-17	11:24 AM	2	15.30620	74.21746	55/100-55/200
12.	C4	20-Dec-17	11:02 AM	22-Dec-17	11:38AM	2	15.30556	74.21746	55/200
13.	C1	22-Dec-17	10:40 AM	24-Dec-17	10:26 AM	2	15.30328	74.21296	55/600-55/700
14.	C2	22-Dec-17	11:02 AM	24-Dec-17	10:32AM	2	15.30221	74.21296	55/800
15.	C3	22-Dec-17	10:49 AM	24-Dec-17	11:24AM	2	15.30052	74.21095	56/000
16.	C4	22-Dec-17	11:50 AM	24-Dec-17	11:31AM	2	15.29853	74.20792	56/400-56/500
17.	C1	24-Dec-17	10:54 AM	26-Dec-17	10:23 AM	2	15.29717	74.19975	56/700
18.	C2	24-Dec-17	11:12 AM	26-Dec-17	10:26AM	2	15.29714	74.19975	57/400
19.	C3	24-Dec-17	11:25 AM	26-Dec-17	12:11 PM	2	15.29668	74.19989	57/400-57/500
20.	C4	24-Dec-17	11:38 AM	26-Dec-17	11:51AM	2	15.29653	74.19848	57/500



Appendix 2.2

Details of camera trap set up in between stations Kulem to Sonalium

Sl. No.	Ca Tr No.	Date deploy	Time	Date removal	Time	CT nights	Lat. (degree decimal)	Longi. (degree decimal)
1.	C1	26-Dec-17	11:43 AM	28-Dec-17	02.44 PM	2	15.33772	74.25240
2.	C2	26-Dec-17	12:03 PM	28-Dec-17	03:18 PM	2	15.33317	74.25577
3.	C3	26-Dec-17	12:11 PM	28-Dec-17	03:28 PM	2	15.33554	74.25525
4.	C4	26-Dec-17	12:20 PM	28-Dec-17	04:00 PM	2	15.33443	74.25607
5.	C1	28-Dec-17	11:25 AM	30-Dec-17	10:24 AM	2	15.33114	74.26301
6.	C2	28-Dec-17	11:31 AM	30-Dec-17	10:12 AM	2	15.33083	74.26493
7.	C3	28-Dec-17	11:40 AM	30-Dec-17	09:38 AM	2	15.33083	74.26603
8.	C4	28-Dec-17	11:59 AM	30-Dec-17	11.00 AM	2	15.33221	74.26813
9.	C1	30-Dec-17	11:25 AM	02-Jan-18	10:20 AM	3	15.33327	74.27252
10.	C2	30-Dec-17	11:31 AM	02-Jan-18	10:24AM	3	15.33314	74.27300
11.	C3	30-Dec-17	11:40 AM	02-Jan-18	11:24 AM	3	15.33317	74.27453
12.	C4	30-Dec-17	11:54 AM	02-Jan-18	11:38AM	3	15.30556	74.21746
13.	C1	02-Jan-18	11:00 AM	05-Jan-18	10:26 AM	3	15.30328	74.21296
14.	C2	02-Jan-18	11:17 AM	05-Jan-18	10:32AM	3	15.30221	74.21296
15.	C3	02-Jan-18	11:20 AM	05-Jan-18	11:24AM	3	15.30052	74.21095
16.	C4	02-Jan-18	11:47 AM	05-Jan-18	11:31AM	3	15.29853	74.20792
17.	C1	05-Jan-18	11:00 AM	08-Jan-18	10:23 AM	3	15.29717	74.19975
18.	C2	05-Jan-18	11:10 AM	08-Jan-18	10:26 AM	3	15.29714	74.19975
19.	C3	05-Jan-18	11:15 AM	08-Jan-18	12:11 PM	3	15.29668	74.19989
20.	C4	05-Jan-18	11:30 AM	08-Jan-18	11:51 AM	3	15.29653	74.19848
21.	C1	08-Jan-18	02:00 PM	11-Jan-18	09:30 AM	3	15.29717	74.19975
22.	C2	08-Jan-18	02:20 PM	11-Jan-18	09:40 AM	3	15.29714	74.19975
23.	C3	08-Jan-18	02:25 PM	11-Jan-18	09:50 AM	3	15.29668	74.19989
24.	C4	08-Jan-18	03:00 PM	11-Jan-18	10:00 AM	3	15.29653	74.19848

Appendix 2.3

Mammals recorded in camera traps in two sectors (Kulem to Kalem & Kulem to Sonalium)

Animal	Scientific name	Kulem -Kalem	Kulem-Sonalium
1. Asian palm Civet	*Paradoxurus hermaphroditus*		✓
2. Black napped Hare	*Lepus nigricollis*	✓	
3. Bonnet Macaque	*Macaca radiata*	✓	
4. Brown palm Civet	*Paradoxurus jerdoni*		✓
5. Chital Deer	*Axis axis*	✓	
6. South Indian Hanuman langur	*Semnopithus dussumieri*	✓	
7. Indian grey Mongoose	*Herpestes edwardsii*	✓	
8. Indian Porcupine	*Hystrix indica*		✓
9. Leopard	*Panthera pardus*	✓	✓
10. Mouse Deer	*Moschiola indica*		✓
11. Sloth Bear	*Melursus ursinus*		✓
12. Small Indian Civet cat	*Viverricula indica*		✓
13. Wild boar	*Sus scrofa*	✓	✓

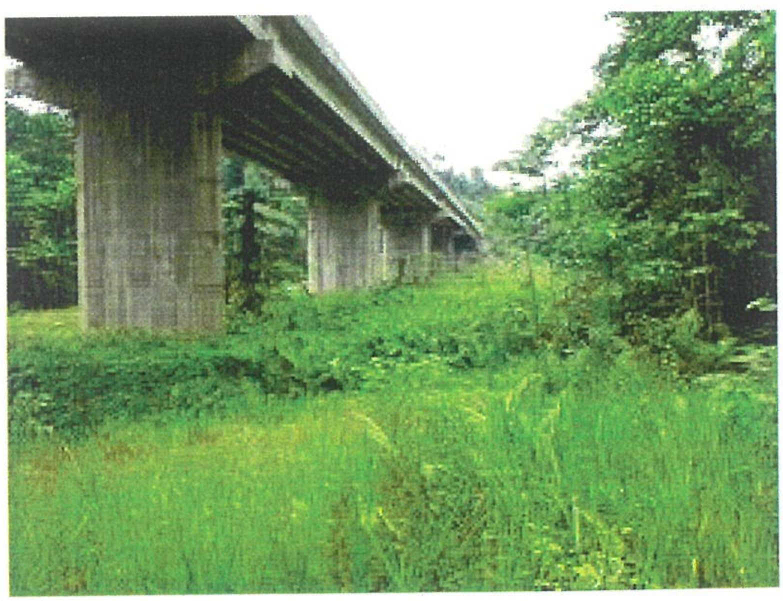
Research team with Mr. Vasta, RVNL while setting the camera trap (Kulem – Kalem section)

Research team with Rl Km post.

Pellet of Sambar deer- Rusa unicolor

Pellet of porcupine- Hystrix indica

Wildlife Underpass () https://conservationcorridor.org/corridors-in-conservation/man-made-corridors/)

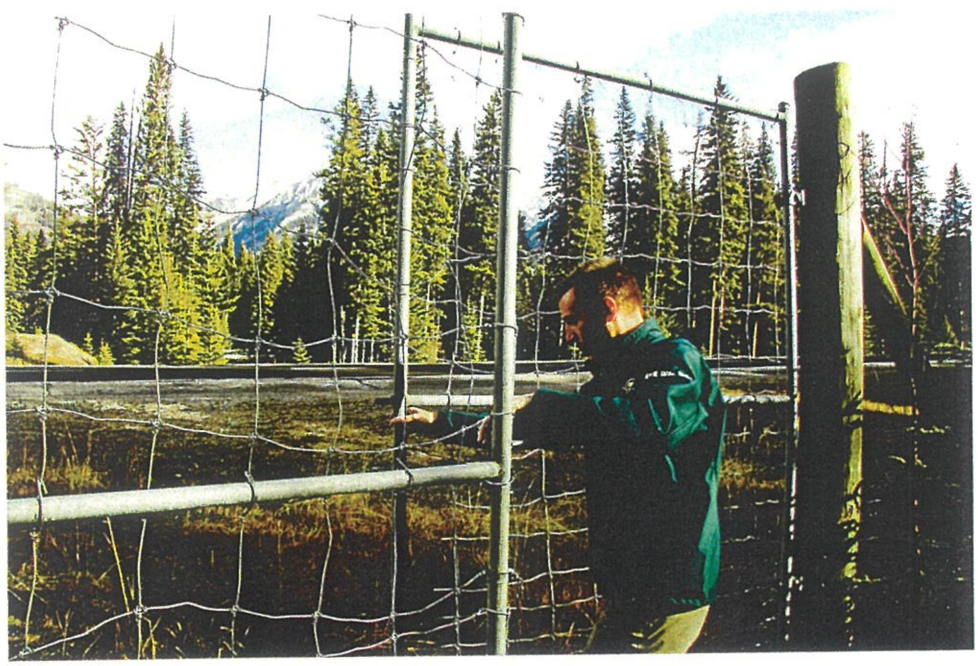


Overbridge to allow wildlife crossing (https://rimbaresearch.org/past-projects/s)

Viaduct for animal overpass (https://www.youtube.com/watch?v=U6lWv8enIAw)

Viaduct for animal overpass with guided fence

Fence to allow animals to cross particular areas (http://www.highcountryfence.com/projects/wildlife-fence/)



Fence to funnel animals and allow crossing at specific places (https://www.canadiangeographic.ca/article/banffs-famed-wildlife-overpasses-turn-20-world-looks-canada-conservation-inspiration)

Canopy bridge for arboreal animals (http://merelinc.com/art-and-design/tree-canopy-blueprint)

Canopy bridge for arboreal animals (http://sightseetexas.com/santa-ana-national-wildlife-refuge/)

Underpass for animal crossing