Staying Connected: Addressing the Impacts of Linear Intrusions on Wildlife in the Western Ghats

Final Report

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Staying Connected: Addressing the Impacts of Linear Intrusions on Wildlife in the Western Ghats

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Executive Summary

The development of linear infrastructures like road, railways and power lines for connectivity and generating power are the essential ingredients to a growing economy like India. However, these aspirations and economic development have also conflicted with environmental concerns and life of people. Some of the negative impact of the linear development includes degradation, fragmentation and loss of natural habitats, animal mortality due to accidents, spread of invasive alien species, barrier and genetic effects on animals, pollution, affects animal behavior, displacement of people, etc.

The major challenge in a developing country like India is how to balance and harmonize the challenge of economic growth and development and the protection of environment. This could be achieved through identifying and understanding the ecological cost of these linear developments and works towards mitigating them to minimize the footprint of development on environment.

Studies on effect of these linear intrusions on natural forest and animals have been conducted in various parts of the world including India and there are global examples of successful mitigation measures. However, in absence of a National guideline on construction and maintenance of these linear intrusions through forest areas, the wildlife has been threatened by the growing number and extent of such infrastructure without heed to ecological and social impacts, given the economic and industrial boom in the country in last few decades.

The National Board of Wildlife in 2011 came up with a draft "Guidelines for Linear Infrastructure Intrusions in Natural Areas," with a goal "to establish, as an essential part of long-term sustainable development in India, ecologically sound policy and practice in the creation, maintenance, removal, and realignment of linear infrastructures in order to avoid or minimize the negative impacts on natural areas and biodiversity." This however, has not been formally recognised by MoEFCC or any other linear agencies.

The wildlife Trust of India (WTI) felt the need of strengthening discussions (between scientific community, planners, linear agencies and political decision makers) through providing supportive evidences and information, in order to move towards a sound policy and legislation on linear infrastructure. The study was undertaken in Nilgiri-Mysore landscape with financial support from Critical Ecosystem Partnership Fund (CEPF) with an aim to contribute towards

formulating a sound policy and legislation for avoiding, reducing and mitigating the negative impacts of linear infrastructure on wildlife in Western Ghats in particular, and at a national level. The study mainly looked at identifying and mapping the linear intrusion passing through forest in the landscape, assesses impact of these infrastructures on forest and animals in critical biological corridors through pilot studies and develop comprehensive mitigations plans and work towards incorporation of these plans in various Government policies on linear development.

Among the four railway line passing in the landscape, the Coimbatore – Palakkad (Podanur to Kottekad Railway track) was selected due to high elephant mortality on this track. The idea is to use this as an example of the impact of railways for the whole area and along with WTI previous experience of working on railways in Uttarakhand, Assam, Uttar Pradesh and Odisha and information, use it in strengthening mitigation strategy and guidelines.

Of the 117 various roads passing through forest in the landscape, two roads (NH-67 Gudalur to Mysore and NH 209- Sathyamangalam to Mysore) were selected for detailed study based on the intensity of vehicular movement, vegetation type, Protected Area status, length of road through forest and presence of elephant corridors.

There are only two canals (Maravakandy to Moyar flume channel and Parali canal) in the project area and seven pipelines of which two (Glenmorgan to Singara and Kundah PH3 at Parali) were selected for studyto understand their impact on natural forest and animal.

In total 31 power lines run through the various forests for the length of 208.16 km in Nilgiri-Mysore landscape. These power lines were ranked based on 5 factors- voltage, width of the vegetation clearance, protected area status, vegetation type and length of the line through forests. Gudalur-Singara and Upper Bhavani to Kundah Powerhouse 5 selected to understand their impact.

Survey of NH 209 indicated vehicular intensity of 116.8 vehicles per hour and overall road kill of 0.196 kills/ km with highest individuals of road kills recorded was Common Indian toad (*Duttaphrynus melanostictus)* (0.017 road kills/km). Most of the road kills were on plain (level) road (0.281 road kills/km) and minor curves. There are hardly any physical barriers such as barry guards on the road or speed breakers to prohibit speeding of vehicles nor signboards to sensitize vehicle drivers. The impact of road on vegetation and habitat usage by animals indicated less tree density near roads. Apart from this, 20 weed species were recorded and showed positively correlated with the proximity of the road and their abundance decreased with increasing distance from road. This could be attributed to periodic clearing of vegetation along the roads that encourages weed colonization. The study suggests construction of speed breakers at critical locations (indicated with GPS locations) within four stretches of the road. The study also suggests speed regulation, restricted vehicle movement (in convoy) and high road toll between 9PM and 6AM as well as fixing of scientifically designed sign boards at critical locations to sensitize public and drivers and periodic maintenance and modification of underpasses to facilitate animal movement.

NH-67 with vehicle intensity of 200 vehicles per hour revealed an average of 0.073 road kills per km. This is very less compared to 0.42 kills per km reported by Selvan *et al*. 2011 who conducted the study prior to the night traffic ban. Thus the night ban has significantly contributed to reducing the road kill apart from other management interventions like speed breakers and sensitization of public. Most of road kills (89.5%) was reported from straight road. Evaluation of the efficacy of speed breakers indicates that road kills were recorded high in 1101-1200m distance class (11.3 road kills/km) and revealed significant correlation between the inter speed breaker distance and corresponding road kills. The present study shows that with speed breaker distance of maximum 600m, the vertebrate road kills did not show significant difference, but when the inter speed breaker distance was at 1100-1200m, there was a significant increase in the road kills. Hence, not only having speed breakers but maintaining the correct distance between speed breakers is equally important. The study strongly advocates continuing the night traffic ban between 9.00 PM to 6.00 AM.

Survey was conducted to understand the ecological influences of railway line (on both sides of the track) frequent elephant movements across the track and elephant mortality. Several factors contribute to these accidents and the resultant animal mortality by train hits and these range from physical factors (Curve of the railway track, visibility), ecological factors (presence of water along railway tracks, Crops and farmlands) as well as the frequency and speed of the train, which was found to be high in the night hours. Our survey has identified critical accident prone and high elephant use areas along the railway track through direct survey and secondary information through questionnaire survey of villagers, railway and forest department officials. Identification of these spots is expected to help in implementation of short and long term mitigation measures.

Railway has imposed permanent speed restriction on critical sections and caution orders to loco pilots to keep eye for animals and blow long whistle throughout critical sections. Forest Department has fixed power fences on critical section. But there is a need to undertake more comprehensive and firm steps to implement both short and long term mitigation measures jointly by the Indian Railway and Forest Departments. These include leveling of critical cuttings, fencing of some of the accident prone areas using discarded old rails, installation of caution signage along the track, improving visibility along the curve, improving lights of the locomotives and installing animal detection device on the track to alert drivers and guards. Simultaneously it is also important to undertake short term mitigation measures like, speed restrictions, joint night patrolling, regular improvements of the visibility along the track, awareness activities for the loco pilots and train passengers etc till the long term measures are put into place.

The high demand of hydroelectric has also resulted in large number of pipelines and canals. The Parali pipeline in southern Nilgiris measuring about a km with three pipelines is a hindrance for movement of larger mammals and has been affirmed by the study that reflects low animal density close to pipelines and increases with distance from the pipeline. The lone bridge on the pipeline for human movement is also at times used by animals at night. However, some small animals use the gap below the pipeline (maximum gap of 1 m from ground) for movement. It is suggested to construct an over passage/ramp on penstock near anchor no 5 (GPS location N 11.24569 and E 76.76479) where the penstock is between two embankments and the study found large evidence of animal usage on both ends. Many participants acknowledged the need of such ramps/bridges on the pipeline without affecting the structure and this will help facilitate animal movement.

Glenmorgan-Singara pipeline run through a distance of about 2.8 km in Mudumalai Tiger Reserve carrying water to Singara Power house from Glenmorgan. No correlation of mammal dung density with different distance class from pipelines observed due to large number of small crossing structures on the pipeline for smaller animals and two crossing structures (winch house 1 and German point) for larger mammals like elephants, gaur, samber, etc. No correlation of invasive species or trees at different distance class from pipeline seen. Construction of new crossing structure between Winch house 1 and 2 will facilitate crossing of large mammals especially elephants and gaur. The study also suggests maintenance and restructuring of existing crossing structures like gap below the pipeline, over bridges and concrete poles over the pipeline for facilitating movement of animals.

Parali canal (one km length) carries water from Parali power house to Bhavani River in Coimbatore Forest Division. The width of the channel is around nine meter and the depth is around seven meter. The channel does not allow movement of any wildlife throughout its length except at a bridge on a road crossing the channel. The study on dung density of mammals with respect to proximity of canal revealed that animal abundance was low near the canal and increases with distance from the canal for species such as gaur, sambar deer, sloth bear spotted deer and dholes. There is only one bridge over the pipeline near the Executive Engineer Office, Parali Power house III and the other over the canal for use by villages (Neeralipallam, Paralikkadu, Nellimarathur, Pillur etc. settlement) that is also used by wild animals at night. Apart from these two bridges, movement of larger mammals is completely blocked for the distance about 1km by 8 foot high pipeline followed by steep canal for the distance about 800 m. Hence it is suggested to construct green bridge over the canal for the free movement of all mammalian species. The suitable location of the bridges could be between GPS location N11.23922^{o}/ E76.77408^{o} and N11.24033^{o} /E76.77391^{o}.

Maravakandy to Moyar flume channel carries water from Singara Power house to Moyar Power house in Mudumalai Tiger Reserve. The flume channel runs through a largely cemented structure for 6.81 km from Maravakandy to Moyar power house. The width of the channel varies from 11-13m and passes through the Moyar- Avarahalla elephant corridor (Varma *et al.*, 2005). The dung density of mammals (elephants, gaur, porcupine, sloth bear and tiger) was high along the canal. On the contrary, abundance was low near the canal for the small carnivores and increased according to increase of distance from canal. Since small carnivores cannot cross the canal, they might not prefer the habitats close to canal. The canal acts as a barrier for smaller carnivores even though there are two wide bridges, two under passes, three narrow bridges and 13 narrow bridges with cross bars (to prevent entry of cattle in forests). All the narrow bridges are mostly covered with cactus and other thick vegetation restricting animal movement. The use of larger species like elephants could be attributed to better vegetation along the canal and presence of about 39 elephant crossing points along the flume channel. The study suggests to remove the cross bars on the narrow bridges and their periodic maintenance to facilitate the movement of animals across the flume channel.

The impact of Power line is mainly habitat fragmentation, weed infestation and electrocution of animals. The impact of Gudalur-Singara powerline (110kV) passing through deciduous forests in Mudumalai Tiger Reserve for the length of 13 km revealed higher mean cover of invasive species under the power line (68.7%) compared to forest (5.3%). The vista cleared area was also less used by the animals. Similar study in Upper Bhavani to Kundah Powerhouse 5 (110kV) passing through evergreen and shola forests of Nilgiri South Forest Division indicated infestation of invasive species under the power line.

The information collected and mitigation plan on select linear infrastructures in the project area was discussed in a consultative meeting held on 29th September 2015 at Coimbatore, Tamil Nadu with officials from State Forest Departments of Kerala and Tamil Nadu, linear agencies (Railways, Highways and Power), conservation organsiations, professors and researchers and their comment/ suggestions incorporated in the report.

The study on linear intrusions in Nilgiri-Mysore landscape and consultation with various stakeholders (linear agencies, forest managers, conservationists and researchers) suggested that the foot print of linear developments on natural forest could be drastically minimized through proper understanding of the threat and planning to minimize it. Wildlife mitigation plan should form an integral component of the project proposal and this could be jointly prepared by the linear development agency in consultation with forest department, conservation organizations and researchers. Although the one time mitigation cost will be slightly higher but this will minimize the recurring cost to mitigate the negative impacts of these linear intrusions like increased human wildlife conflict, habitat fragmentation, etc that we are forced upon due to these intrusions as well as human safety. There are global examples to mitigate the impact using modern technology. The onus is on us to explain to Policy makers the alternatives and solutions through good working models.

1. INTRODUCTION

The last few decades have seen emphasis on the development of linear infrastructures (railways, highways, power-lines, irrigation canals, etc), especially improving connectivity and generation and transmission of power, essential ingredients to a growing economy like India. However, these aspirations and economic development have also conflicted with environmental concerns and life of people. Some of the impact of the linear development includes over exploitation of natural resources, disruption of ecological services, degradation, fragmentation and loss of natural habitats, animal mortality due to accidents and poaching, spread of invasive alien species, pollution, fires, barrier and genetic effects on animals, pollution, affects animal behavior, displacement of people, etc (Rajvanshi *et al*, 2001, Raman, 2011). Indian wildlife has been particularly threatened by the growing number and extent of such infrastructure developed without heed to ecological and social impacts, given the economic and industrial boom in the country in last few decades. Long-ranging species such as elephants and tigers that require a large landscape to fulfill their ecological needs have been the most affected ones.

One of the major challenges in a developing country like India is how to balance and harmonize the challenge of economic growth and development and the protection of environment. It is important to identify and understand the ecological cost of these linear developments and works towards mitigating them to minimize the cost of development on environment to make it sustainable.

Railways and highways have been recorded to be the major sources of wildlife mortality (Clevenger, 1997; Buckingham, 1997; Van der Grift 1999; Jackson, 1999, Singh *et al*., 2001, Menon *et al*, 2003, Raman 2011), threatening wildlife populations throughout the world. These are a potential threat to the survival of several endangered species and affect their populations (Maehr *et al.*, 1991; Fisher, 1991; Rudolph *et al.*, 1999) in many ways like, acting as barriers to the wildlife movement (Gibeau and Heuer, 1996; Menon *et al.*, 2005), reducing access to the vital habitats (Jackson, 2000), disrupting their social activities (Gibeau, and Heuer, 1996) and creating population isolation (Reh and Seitz, 1990; Gibeau, and Heuer, 1996; Jackson, 2000). Railways and highways also cause direct loss of habitat, degradation of habitat quality and habitat fragmentation (Van, 1998, Raman, 2011).

In India, a large number of wild animals are killed annually due to accidents on the railway tracks (Kumar, 1995; Johnsingh and Williams, 1999; Singh and Sharma 2001, Singh *et al*., 2001, Menon *et al*, 2003, Sarma *et al*, 2006, Rangarajan *et al*, 2010) and highways (Gokula, 1997; Singh and Sharma 2001, Vijayakumar *et al*, 2001; Chhangani, 2004, Das *et al*. 2007; Seshadri *et al*, 2009; Baskaran and Boominathan, 2010; Selvan *et al*, 2011; Gubbi *et al*, 2012). Railways alone have been responsible for death of over 250 elephants since 1987 (Singh *et al*., 2001, Sarma *et al*, 2006, Menon *et al*, 2003, Rangarajan *et al*, 2010). This exacerbates the already existing threats such as large scale habitat degradation, loss of habitat quality, fragmentation, and conflict with humans.

Similarly other linear developments like canals, pipelines, power-lines have also severely fragmented the wildlife habitat. The British ways of intruding into the tropical forests of Western Ghats through the construction of railways, roads and dams, have been followed and intensified by the post-independent Indian governments. Proliferation of dams and hydroelectric production led to kilometers of hydro-electric lines, irrigation canals and roads. Other impacts of these infrastructure development, such as increase in human intrusion, settlements, encroachments (and consequent legitimization), plantations, etc., has not been studied much.

The Western Ghats is one of the 34 global biodiversity hotspots of the world (Myers *et al*, 2000, Mittermeier *et al* 2005) harbouring almost 30% of plant and animal species found in India with high level of endemism. The area also has a large assemblage of larger mammals and is home to approximately 25% of the global population of Asian elephants (Sukumar 2011, Baskaran *et al*. 2011). The Wildlife habitats and populations in the Western Ghats have also been severely affected due to railways, roads, powerline, pielines and canals; fragmentation of habitats, barrier and mortalities are the direct manifestations of this. For example, railway track passing through prime elephant habitats of Coimbatore (Tamil Nadu) and Palakkad (Kerala) Forest Divisions between Coimbatore and Palakkad section of the Southern Railway have been responsible for death of 15 elephants since 1978; a multitude of minor wildlife deaths go unreported. Similarly highways passing through critical wildlife habitats in Wayanad, Nagarahole, Bandipur, Mudumalai, BRT, Sathyamangalam and other areas have also contributed significantly to the mortality of wild animals and fragmentation of wildlife habitats.

The forest cover in the southern Malnad and Coorg plateau (forest divisions such as Chikkamagalur, Hassan, Madikere territorial) has been exploited extensively for commercial plantations (mainly coffee), forest-based industries (paper mills), and irrigation and hydroelectric projects (Prasad *et al.*, 1974) resulting in higher fragmentation of traditional elephant habitats along the plateau. Therefore, the forest contiguity between the Malnad and Coorg plateaus is cut off and bulls can rarely move along the plateaus from Coorg to Malnad or vice versa using the isolated forest patches available between the coffee plantations and cultivation/settlements (Baskaran 2013).

The Hindustan Petroleum Corporation Limited (HPCL) pipeline project, being laid between Mangalore and Bengaluru, which would have broken contiguity between the Malnad and Mysore plateaus via Pushpagiri-Brahmagiri, has been halted (Varma 2000). The construction of a series of hydroelectric projects (Pykara), especially on the eastern side of Mudumalai, brought with them a large influx of human population and infrastructure development, which has created many bottlenecks threatening the habitat contiguity with the Sigur Plateau that in turn connects the Eastern Ghats. Similarly, there were proposals for infrastructure developmental plans for: (i) creation of a highway from Kozhikode to Coimbatore by widening the existing road from Vazhaithottam to Sigur and linking it to Bhavanisagar to bypass the existing Ghats section highway that goes via Nilgiris, and (ii) extending the Mysore-Chamarajanagar railway line to Coimbatore via Bhavanisagar-Sathyamangalam cutting across the Moyar Valley, the connecting link between the Western and Eastern Ghats (Baskaran, 2013). If any of these projects get implemented, it could decimate a large number of wild animals directly through road kills as well as fragmenting the link between the Western and Eastern Ghats. Additionally, such development would also encourage people to encroach onto the forested revenue patches available in the Sigur Plateau and further aggravate the habitat fragmentation, biotic pressure, and their resultant human-wildlife conflict in the region (Baskaran 2013).

The Nilgiri- Mysore landscape in the Western Ghats covers around 19,153 sq km containing some of the best habitats and populations for the conservation of landscape species such as elephant, tiger, and wild dog (Bawa *et al*, 2007). It supports the largest population (about 8000+)

of Asian elephants. Nagarahole-Mudumalai-Wayanad complex has probably the largest single tiger population in the world (Jhala 2010).

Few Protected Areas in the landscape have implemented regulations and mitigation measures in the roads running through them like night traffic ban, speed breakers, regular patrolling etc to reduce the impact on wildlife. Since June 2009, the National highways 212 and 67 running through Bandipur Tiger Reserve are closed for traffic from 9 PM to 6 AM in order to reduce the impact of the road on wildlife. Similarly road was realigned and night traffic was banned in the Mananthavady- Mysore road passing through Nagarhole Tiger Reserve.

There are many new linear development proposals in the Mysore- Nilgiri landscape through forest areas of the railway lines Nilambur- Nanjangud and Mettupalayam- Banglore, of roads, Nilambur- Meppadi hill highway, Chippilithode- Maruthilavu bypass, Padinjarathara- Poozhithod and Kunhome- Vilangad. The political pressure to install new roads and railway lines in the landscape is huge. In places like Wayanad, Mysore and Nilambur there are well established committees to push for the new proposals. Mysore-Wayanad Railway Action Council, Nilambur Rail Road Action Council, Thalassery- Mysore Railline Action Council, Nilambur- Mysore (Nanjangud) Railway Action Council, Nilgiris- Wayanad Railway & NH Action Committee and Wayanad Railway Action Committee are few of them. Commerce and industry related associations like Wayanad Chamber of Commerce and Industry and Mysore Chamber of Commerce and Industry also actively lobby for the lifting of night traffic ban and for the establishment of Nanjangud- Nilambur rail line. A detailed and intensive study on the linear intrusions in the landscape is imperative to formation of policy for these structures with stringent Environment Impact Assesment (EIA) for each project.

Understanding the way that an animal reacts to a development is important when choosing measures to reduce impacts. Reducing the negative effects of roads, railway tracks, canals, power lines will only be possible if more dialogue and planning is achieved between the scientific community, planners, linear agencies and political decision makers.

In 2011, the National Board of Wildlife came up with a draft “Guidelines for Linear Infrastructure Intrusions in Natural Areas,” with a goal “to establish, as an essential part of long-term sustainable development in India, ecologically sound policy and practice in the creation, maintenance, removal, and realignment of linear infrastructures such as roads and electricity transmission lines (power lines) in order to avoid or minimize the negative impacts on natural areas and biodiversity.” The current project identifies the relevance of strengthening discussions through providing supportive evidences and information, in order to move towards a sound policy and legislation for avoiding, reducing and mitigating the negative impacts of linear infrastructure on wildlife in Western Ghats in particular, and at a national level. Thus this study was undertaken in the Nilgiri – Mysore corridor identified by CEPF with the following objectives.

Aim

To contribute towards formulating a sound policy and legislation for avoiding, reducing and mitigating the negative impacts of linear infrastructure on wildlife in Western Ghats in particular, and at a national level.

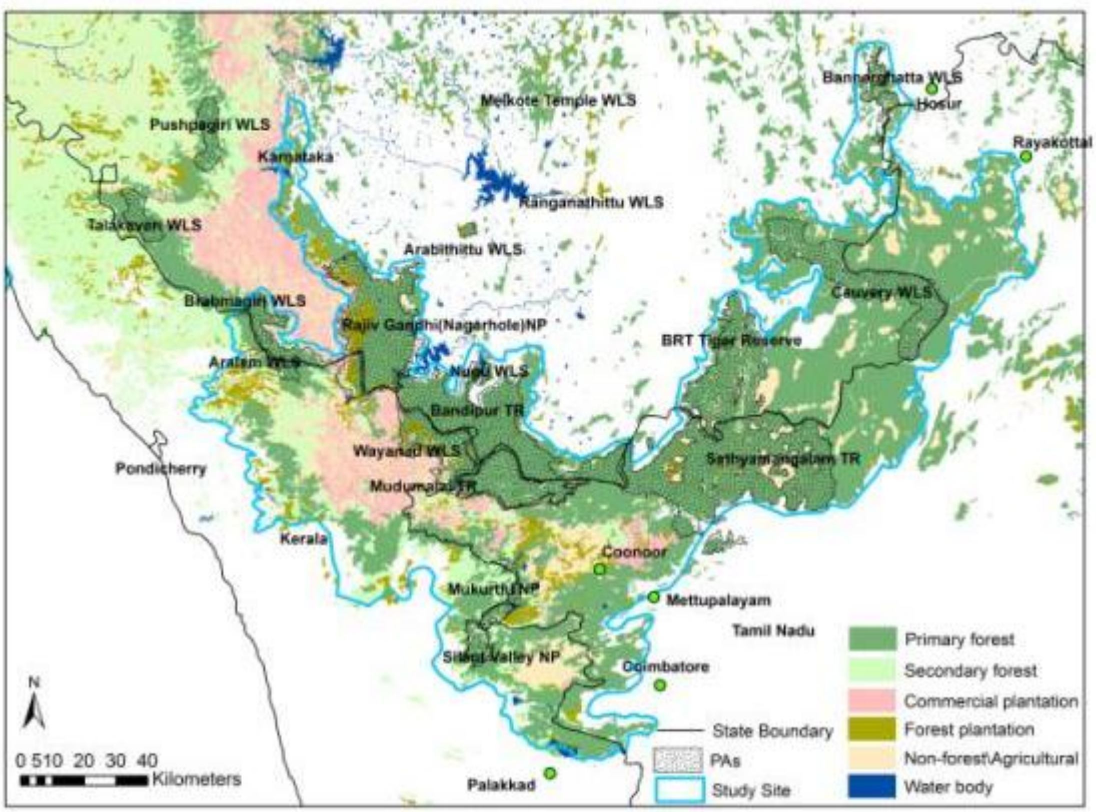
Objectives

1. Identify linear infrastructure (roads, railway tracks, pipelines, canals and power lines) in forest areas of Nilgiri-Mysore landscape
2. Assess impact of these infrastructures on forest and animals in critical biological corridors and wildlife areas through pilot studies
3. Priorities issues to be addressed and develop site specific mitigation plan based on pilot studies
4. Develop comprehensive plans and work towards incorporation of these plans in various Govt policies on linear development

STUDY AREA

The study was carried out in the Brahmagiri - Nilgiri- Eastern ghats landscape with emphasize on the priority sites of Nilgiri-Mysore corridor (NMC) identified by CEPF (Bawa *et al*, 2007). It spreads across states of Kerala, Karnataka and Tamil Nadu and comprises of several Protected Areas and territorial forest divisions spreading contiguously over an area of about 11,500 km^2 forest cover. The forest divisions covered were Hunsur FD, Brahmagiri WLS, Nagarhole Tiger Reserve, Bandipur Tiger Reserve, BRT Tiger Reserve, Bannerghata NP, Kollegal FD, Cauvery WLS (all in Karnataka), Aralam WLS, Wayanad WLS, Wayanad North FD, Wayanad South FD, Nilambur North FD, Nilambur South FD, Silent Valley NP, Mannarkad FD, Palakkad FD (all in Kerala), Hosur FD, Erode FD, Sathyamangalam Tiger Reserve, Coimbatore FD, Nilgiri North FD, Nilgiri South FD, Mukuruthi NP, Gudalur FD, Mudumalai TR (all in Tamil Nadu). This landscape bounded on the North West by Brahmagiri WLS, North East by Bannerghatta NP and South by Coimbatore Forest Division.

Figure 1.1: Project area of Nilgiri- Mysore landscape



The elephant habitats along the crest line of the Ghats and on the western side, with a higher precipitation than the eastern side, have more close canopied tropical evergreen and moist forests. The habitats on the eastern side (slopes and the Malnad-Mysore and Nilgiri plateaus) have more open canopied tropical deciduous forests, with a higher biomass of grass cover. In fact the Mysore-Nilgiri plateaus with extensive tracts of tropical deciduous and dry thorn forests and with relatively less human interference in the deeper forests are potentially the most outstanding elephant habitats anywhere in Asia (Baskaran 2013). They also harbour a wide assemblage of other large mammals like Gaur, Sambar, Chital and langurs in high densities (Karanth & Sunquist 1992; Varman & Sukumar 1995) that support a substantial part of the large carnivorous population in the Ghats.

Ecological importance

Most of the area of CEPF's Nilgiri-Mysore corridor landscape lies in the Nilgiri Biosphere Reserve (NBR). A fascinating ecosystem of the hill ranges of Nilgiris and its surrounding environments covering a tract of over 5000 km^2 was constituted as Nilgiris Biosphere Reserve (NBR) by UNESCO in September 1986 under Man and Biosphere Programme. NBR is India's first and foremost Biosphere Reserves with a heritage, rich in flora and fauna. Also NBR is a World Heritage Site declared by UNESCO in 2012.

Diversity of Forests

The Nilgiri Biosphere Reserve includes all the important forest types that are found in South India as well as some that are just peculiar to the belt such as Tropical Thorn Forest, Tropical Dry Deciduous Forests, Tropical Moist Deciduous Forests, Tropical Semi Evergreen Forests, Sub Tropical Broad Leaved Forests, Tropical Wet Evergreen Forests, Southern Montane Wet Temperate Forests, Southern Montane Wet Grasslands and Subtropical Hill Savannas. The NBR is spread over a large area within three states and varied climatic zones. The forest divisions are as follows: Coimbatore Division, Nilgiri South Division, Erode Division, Satyamangalam Division, Nilambur Division, Mudumalai Sanctuary, Wyanad Division, Palghat Division

Chamrajnagar Division, Project Tiger Bandipur Mysore Division, Hunsur Division (Mohan Pai, 2008)

Flora

The NBR is very rich in plant diversity. About 3,300 species of flowering plants can be seen here. Of the 3,300 species 132 are endemic to the NBR. The genus *Baeolepis* is exclusively endemic to the Nilgiris. Some of the plants entirely restricted to the Nilgiri Biosphere Reserve include species of *Adenoon*, *Calacanthus*, *Baeolepis*, *Frerea*, *Jarodina*, *Wagatea*, *Poeciloneuron*, etc. Of the 175 species of orchids found in the NBR, 8 are endemic. These include endemic and endangered species of *Vanda*, *Liparis*, *Bulbophyllum*, *Spiranthes* and *Thrixspermum* (Mohan Pai 2008)

Fauna

The fauna of the Nilgiri Biosphere Reserve includes over 100 species of mammals, 350 species of birds, 80 species of reptiles and amphibians, 300 species of butterflies and innumerable invertebrates. 39 species of fish, 31 amphibians and 60 species of reptiles endemic to the Western Ghats also occur in the NBR. Freshwater fish such as *Danio neilgheriensis*, *Hypselobarbusdubuis* and *Puntius bovanicus* are restricted to the NBR (Mohan Pai 2008).

1.3.4.a. Elephant population

The elephant habitat of Mysore- Nilgiri Biosphere landscape marking the confluence of the Western and Eastern Ghats at the Nilgiris, supports one of the largest populations of elephants in the country and comprises five elephant reserves i.e. Wayanad ER, Nilambur ER, Nilgiri ER, Mysore ER and Coimbatore ER with contiguous forest cover of 15,100 km^2. The population at the tri-junction of three southern States (Karnataka, Kerala and Tamil Nadu), supports about 8000+ elephants. This is the largest Asian elephant population, and therefore this landscape, which also has significant populations of other charismatic species such as the tiger, the dhole and the gaur, warrants the best possible protection and management. However, the landscape is also dominated by large human population which has resulted in degradation and fragmentation of the habitat and increased incidences of human-wildlife conflict. The landscape has about 17 identified elephant corridors (Varma *et al*, 2005).

1.3.4.b. Tiger Population

The tiger population in this landscape stretches across three states, viz., Karnataka (Nagarahole – Bandipur), Tamil Nadu (Mudumalai-Segur plateau-Moyar Gorge-Sathyamangalam) and Kerala (Wayanad). The tiger population in Karnataka side (Nagarahole, Bandipur, BRT, Cauvery WLS and adjoining forests) was estimated at 231 (214-249) tigers covering an area of 4,460 km^2. Tiger densities within the Mudumalai TR were high 11.06 (3.04) per 100 km^2. Interestingly, camera trapping also revealed that Reserved Forests (Moyar gorge-Segur plateau region) surrounding the Tiger Reserve has high abundance of tigers 7.65 (0.93 per 100 km2). The tiger occupancy within the Tamilnadu part of this landscape was 4,261 km^2 with an estimated 97 to 113 tigers. Tiger occupancy within Karnataka- Kerala in this landscape (Nagarahole-Mudumalai-Wayanad) was 2,387 km^2 with an estimated population of 40 (37-43) tigers. The total tiger population for this landscape inclusive of Karnataka, Tamil Nadu and Kerala (Nagarahole, Bandipur, Wayanad, Mudumalai, Brahmagiri, Sathyamangalam, BRT and Cauvery WLS) is probably the largest contiguous single population in the world with 354-411 tigers (Jhala *et.al.*, 2010).

Site Selection and Criteria for adoption of sites for preparation of site specific mitigation plan

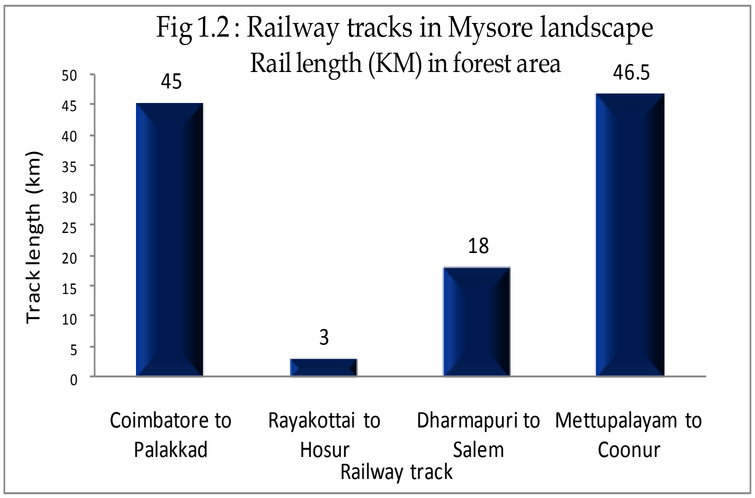
All Potected Areas and territorial Forest Divisions in Nilgiris-Mysore corridor were visited to collect baseline information on the linear intrusions such as road, railway track, power line, pipeline and flume channel/canal. The linear infrastructures in the study area were mapped and sites were prioritized based on various factors. Roads and power lines are the major intrusions in the study area, where as pipelines, rail and canals are also present. The prioritization of roads was based on various factors like traffic intensity, vegetation type, length of the road through forest, presence of elephant corridors and protected area status. The power lines were classified into two; with ground vegetation clearance and without vegetation clearance. These power lines wre prioritized based on factors like voltage of the line, width of the ground vegetation clearance, length of the line through forest, protected area status and vegetation type.

There are only two canals in the study area, both of them flume channels of hydroelectric power house. Both these flume channels were studied for its impact on natural forest and animals.

1.4.1. Railway track

The rail lines in the study area were mapped and information on the length of the track through forests, frequency of trains, speed of trains and elephant mortality data were collected for each railway track. Information on physical, ecological and man-made factors contributingto mortality of animals were also collected.

Four railway tracks run through forest and with varied scale of wildlife impacts through the project area.



1. **Mettupalayam - Coonur Track**

Nilgiri mountain train is one of the oldest establish by British government during the year 1908. The track width is 3 ft 3 ⅜ inches with Alternate Biting Tooth (ABT). The maximum speed of train is about only 13kmph and this low speed allows sufficient time to animals to move away from track to avoid collision, The track length is 45.88km and mostly pass through steep terrain inside forest. The train operates twice a day only in day time. The entire length of the track has 208 curves, 16 tunnels and 250 bridges, most of these bridges has sufficient space and lighting.

Kallar at Gandhapallayam elephant corridor in foothill extends through both National Highway and the track. Large number of elephant dung and indirect signs of elephants and other animals were found on track during the preliminary survey of the track.

2. **Salem - Hosur Track**

This broad gauge and un-electrified track passes through the edge of a shrubby & dry deciduous forest patch under Salem, Dhamapuri FD in Eastern ghats. Few evidences of animals recorded by the railway and forest department, due to discontinue forest patch as well as NH-7 as barrier between railway and forest. Train frequency is very less on this track (about 15 only per day).

3. **Dharmapuri - Hosure Railway track (Rayakottai).**

This stretch of the railway line passes through Hosur Forest Division, Tamil Nadu. In this stretch, five elephants were killed in 2003 and two elephants were killed in 2013 due to train hits (Anitha, 2013). The frequency of trains in this stretch is around 23 trains per day. The average speed of the trains through the stretch during day is 70km/h and 20km/h during night. In this stretch only two km is very dangerous for wild animals that run through forest edge between Rayakottai to Periyanagathunai Railway Stations. It has four cuttings and two blind curves.

Degraded forest patch is present only one side of the track and other side has cultivation lands. During summer (*October – March)* due to scarcity of food and water in forest, elephants come out, cross the track to move to cultivation land and at times get killed by speeding train.

Table 1.1: Sites of accident Dharmapuri to Hosur Railway track

<table>
<tr><th rowspan="2">S.No</th><th colspan="3">Cutting</th><th colspan="4">Curve</th><th rowspan="2">Accident details</th></tr>
<tr><th>From</th><th>To</th><th>Length (m)</th><th>Curve No</th><th>From</th><th>To</th><th>Length (m)</th></tr>
<tr><td>1</td><td>128/100</td><td>128/400</td><td>300</td><td>54</td><td>128/100</td><td>128/900</td><td>800</td><td>1st Accident: On 30th March 2003 around 09:15pm, in end of the cutting/curve five elephants were killed</td></tr>
<tr><td>2</td><td>129/300</td><td>129/700</td><td>200</td><td rowspan="2">55</td><td rowspan="2">129/431</td><td rowspan="2">129/781</td><td rowspan="2">360</td><td rowspan="2">2nd accident: on 04th February 2013 around 06:15am; in end of the cutting/curve two elephants killed</td></tr>
<tr><td>3</td><td>129/700</td><td>129/900</td><td>200</td></tr>
</table>

4. **Coimbatore - Palakkad (Podanur to Kottekad Railway track)**

The rail line passes through forests of Coimbatore Forest Division and Palakkad Forest Division through the Palakkad Gap of the Western Ghats for a length of around 31.7 km. In this stretch there are two lines. The frequency of trains is about 80 trains/day while the average speed of the trains is around 40km/h during night time and 75km/h during day time. There were 15 elephant mortalities in nine accidents between 1978 and 2010 of which 13 elephants have died on the railway track between 2002 and 2010 alone.

Table. 1.2. Railway tracks in the study area

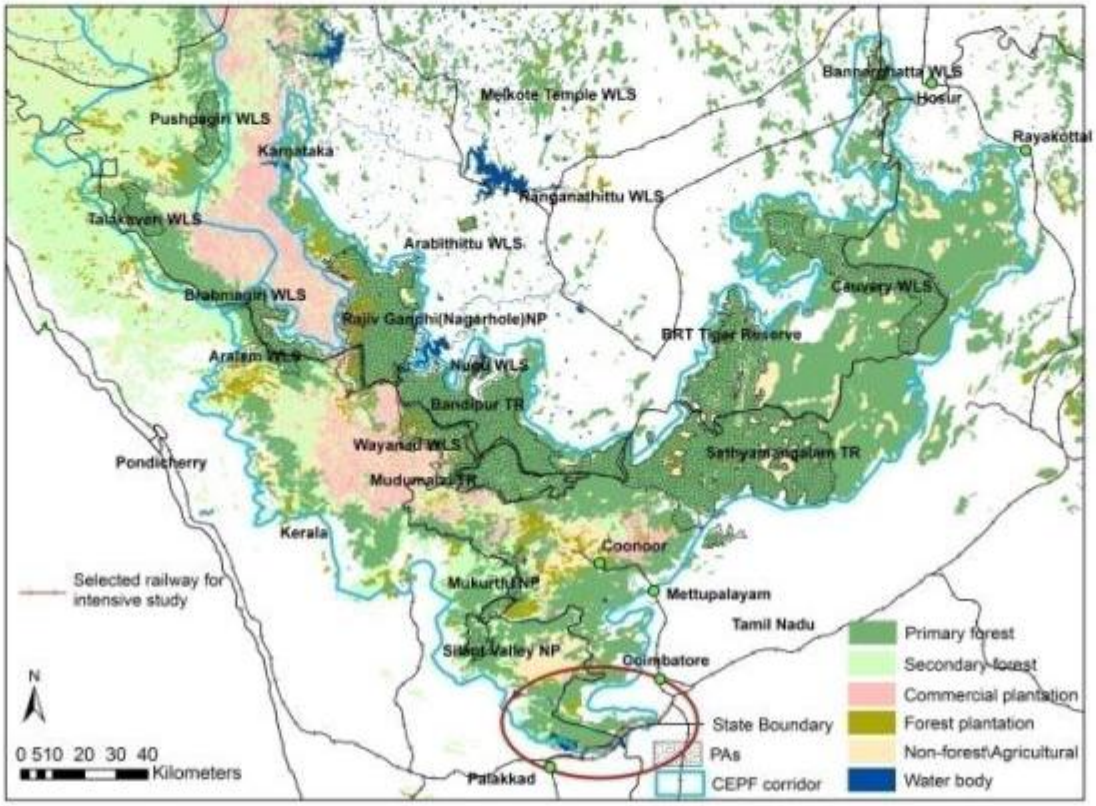
Name of the track	Major habitat type	Terrain	Number of tracks	Length of the stretch (km)	Number of trains per day	Average speed of trains (km/h)	Elephant mortality during 1978-2013	Presence of elephant corridor	PA/ Non PA
Dharmapuri to Hosur (Rayakottai)	Scrub	Flat	1	12	23	70	7	No	Non PA
Salem to Hosur	Scrub and dry deciduous	Flat	1	4	15	70	0	No	Non PA
Mettupalayam to Coonoor	Evergreen	Steep	1	18.9	2	13	0	Yes	Non PA
Coimbatore to Palakkad	Deciduous	Flat	2	31.7	80	75	15	No	Non PA

Site selected for detailed study

Among the four tracks, the Coimbatore to Palakkad track has been responsible for most elephant mortality and this was selected for the detailed study to understand the contributing factors of mortality of animals and preparation of site specific short-term and long-term mitigation plan.

Elephant mortality by train hit is a major problem in most part of the elephant habitats in India that has railway line passing through it. The idea is to use this as an example of the impact of railways for the whole area. WTI along with Uttarakhand Forest Department and Railways has also successfully worked on mitigating elephant mortality by train hit in Rajaji National Park, Uttarakhand and has developed a successful model. From this it has also worked on similar issues in Assam, Uttar Pradsh and Odisha. All these examples could help understand the issue and better mitigation strategy and guidelines.

Fig.1.3. Map showing the railway tracks in the project area and selected site for detailed study



Roads

All the roads except the ones used exclusively by forest department were visited. The roads were mapped using GPS and data were collected on aspects like the habitat type, Protected Area status of the forest, length of the road through forest, intensity of vehicular movement, elephant corridors, mitigation measures of the forest department, etc. Data on intensity of vehicular movement was based on the information from check posts, researchers and local people as collecting information directly would be impossible for all the roads in the region within the short period.

For selecting the pilot study areas, all the roads were then ranked based on the following parameters- intensity of vehicular movement, vegetation type, Protected Area status, length of road through forest and presence of elephant corridors.

A. Vehicle intensity ranks were determined as follows, 0-100 vehicles/ day= 0.5, 101-500 vehicles/ day = 1, 501-1000 vehicles/ day = 1.5, 1001- 5000 vehicles/ day = 2.

B. Rank for length of the road (through forests) was determined as follows, 0-5km=0.5, 5.1-10km=1, 10.1-20km=1.5, 20.1-60km=2.

C. Vegetation type: The vegetation type is broadly classified into four- primary forests, secondary forests, forest plantations, commercial plantations and non-forests + non-plantations. According to a global assessment of the impact of disturbance and land conversion on biodiversity in tropical forests, the detrimental effects on the biodiversity due to conversion is most in agriculture areas, followed by commercial shaded plantations, forest plantations and secondary forests (Gibson *et al.*, 2014). Based on this, we calculated the rank for vegetation type as follows

$$\text{Rank based on vegetation types} = \frac{(a*3)+(b*2)+(c*1)+(d*0.5)+(e*0)}{100}$$

Where ‘a’=percentage of road running through primary forests
‘b’= percentage of road running through secondary forests
‘c’= percentage of road running through forest plantation
‘d’= percentage of road running through commercial plantation
‘e’= percentage of road running through non-forests and non-plantations

D. The roads running through Protected Areas were given '1' point against '0' for non Protected Areas.

E. The roads were ranked also based on the importance of the elephant corridors through which it runs for which factors viz, area of habitat connected, elephant population and frequency of usage of the corridor was adapted (Menon *et al.*, 2005).

Rank for elephant corridor parameters was determined as follows

$$\text{Rank for the importance of the elephant corridor} = \frac{a+b+c}{9}$$

Where 'a'= rank for area of habitat being connected through the elephant corridor

'b'= rank for elephant population connected through the elephant corridor

'c'= rank for elephant usage of the elephant corridor

Parameters	Score		
	3	2	1
Area of habitat being connected through the elephant corridor	250 sq.km each or more than 500 sq.km combining both	<250 - 150 sq.km each or 300 - 500 sq.km combining both	<150 sq.km each or <300 sq.km combining both
Population connected through the elephant corridor	>400	200 - 400	<200
Elephant usage of the elephant corridor	Regular	Occasional	Rare

Source: (Menon *et al.*, 2005).

The integrated rank for each road was then calculated by adding the rank for the parameters- vehicle intensity (0.5- 2), length of the road through forest (0.5- 2), vegetation type (0-3), protected area status (0 & 1) and elephant corridor (0- 1) - as described above. Thus the maximum integrated rank for road is 9.

Totally 1384 km length of roads was assessed to select the roads for intensive study. There are four National highways (NH7, NH67, NH209 and NH212) that run through the forests for a length of about 174 kms in the NMC. The details are as follows.

1) NH7 passes through a small stretch of forest around 2 km in Hosur Forest Division.
2) NH67 passes through forests in Coimbatore Forest Division and Nilgiri North Forest Division between Mettupalayam and Coonoor for the length of 17 km.
3) The road between Ooty and Gudalur passes through Nilgiri North, Nilgiri South and Gudalur Forest Divisions for around 40km. NH67 then passes through Mudumalai Tiger Reserve and Bandipur Tiger Reserve for about 27 km.
4) NH 209 passes through Sathyamangalam Tiger Reserve and Bilgiri Ranganatha Temple (BRT) Tiger Reserve for a length of around 50km. The NH 212 bisects the evergreen forests of Kozhikode forest division between Thamarassery and Kalpeta. It also passes through forests of Wayanad Wildlife Sanctuary and Bandipur Tiger Reserve.

There are 17 identified elephant corridors in the Mysore- Nilgiri landscape and all of them except Kaniyanpura-Moyar corridor are disturbed by roads to some extent (Varma *et al.*, 2005). Four elephant corridors in the study area are bisected by NH 67 (Kallar at Gandhapalayam corridor) and NH209 (Talamalai- Guttiyalattur, Chamrajnagar- Talamali at Punjur, Chamrajnagar- Talamalai at Muddahalli)

There are about 17 state/ interstate highways passing through 33 forest stretches of 14 forest divisions covering about 414km in the study area. Of which, a total of 117 road stretches runs through various contiguous and fragmented forest patches in NMC (Table 1.3, Figure 1.4). First two roads which scored higher integrated ranking in major wildlife habitats (Tropical thorn, Tropical Deciduous and Evergreen/Semi evergreen) were selected for intensive study.

Table 1.3. Roads in the study area with priority ranks for the selection of intensive studies

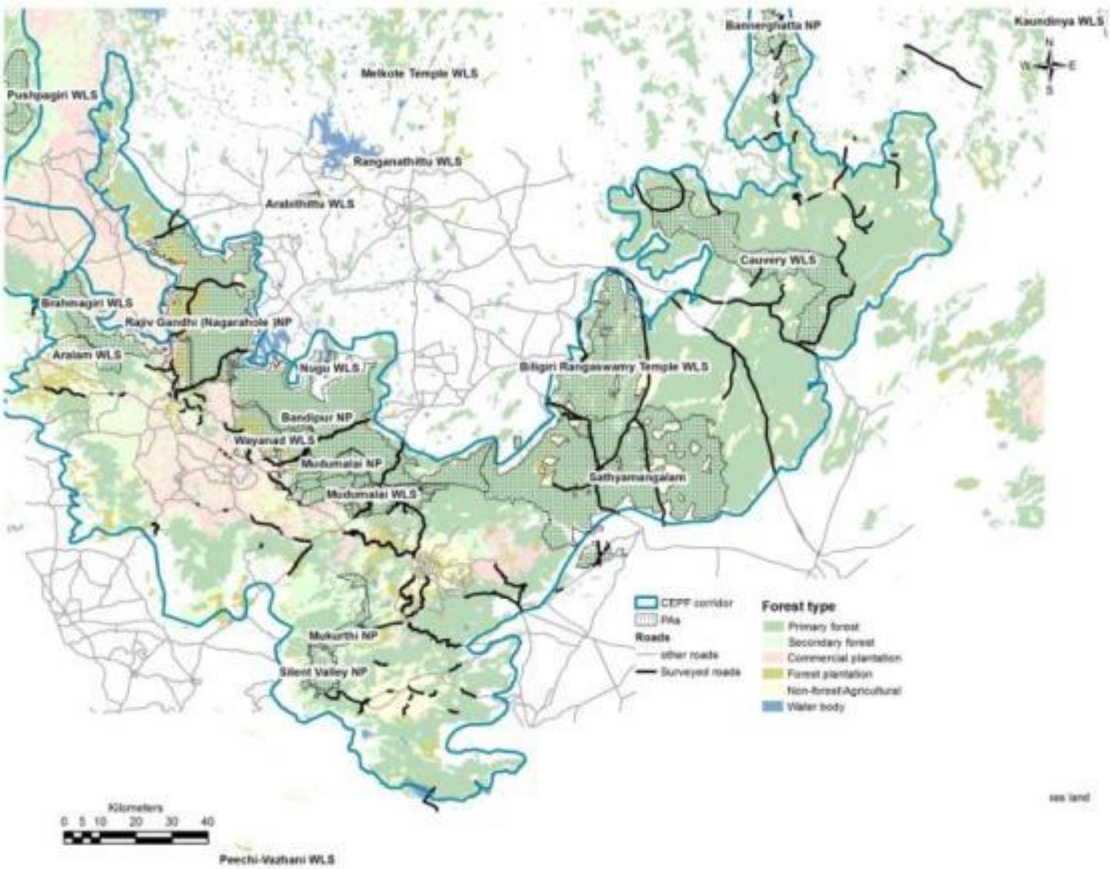
Name of the Road	Major forest type	Veg rank, A	Traffic intensity (per day)	Traffic rank, B	PA rank, C	Elephant corridor				Road length (km)	Road length rank, E	Total Rank, F=A+B+C+D+E
						Rank for Area of habitat being connected (X)	Rank for Pop connected (Y)	Rank for usage of the corridor (Z)	Elephant corridor rank, D= (X+Y+Z)/9			
Sathyamangalam to Mysore	Scrub	2.25	3000	2	1	3	3	3	1	50.0	2.0	8.25
Gudalur to Bandipur	Deciduous	2.82	3500	2	1	0	0	0	0	27.0	2.0	7.82
Mettupalayam to Kothagiri	Deciduous	2.88	2500	2	0	3	3	3	1	26.2	2.0	7.88
Muthanga-maddur	deciduous	2.58	1750	2	1	0	0	0	0	28.7	2.0	7.58
Mettupalayam to Coonoor	Evergreen/Semievergreen	2.92	3500	2	0	3	3	3	1	17.1	1.5	7.42
Masinakudi to Moyar	Deciduous	3.00	625	1.5	1	2	3	3	0.9	9.2	1.0	7.40
Kodihalli to Harohalli	Deciduous	3.00	125	1	1	2	2	3	0.8	14.6	1.5	7.30
Gumballi to Hondrabal	Deciduous	3.00	450	1	1	0	0	0	0	41.5	2.0	7.00
Halugur to Muthathi	Deciduous	3.00	225	1	1	0	0	0	0	21.1	2.0	7.00
Krishnagiri to Hosure	Deciduous	3.00	5000	2	0	0	0	0	0	51.0	2.0	7.00
Kowdalli to Thaalabetta	Scrub	2.57	1500	2	1	0	0	0	0	8.00	1.0	6.57
Masinakudi to Singara	Deciduous	2.64	150	1	1	3	3	3	1	6.8	1.0	6.64
Arepalyam to Lokkanhalli	Deciduous	2.52	125	1	1	0	0	0	0	25.7	2.0	6.52
Hannur to Kowdhalli	Scrub	3.00	1500	2	0	0	0	0	0	17.0	1.50	6.50
Harohalli to Jigani	Deciduous	3.00	350	1	1	1	1	3	0.6	5.5	1.0	6.60
Santhemala to Muthathi	Deciduous	3.00	125	1	1	0	0	0	0	19.4	1.50	6.50
Bavali to Udupura	Deciduous	2.41	250	1	1	0	0	0	0	22.58	2.0	6.41
Anachouk gate to Allur Gate	Deciduous	2.37	875	1.5	1	0	0	0	0	10.05	1.50	6.37
Mettur to MM Hills	Deciduous	2.83	350	1	1	0	0	0	0	17.5	1.50	6.33
Anjetti to Hokenakkal - 1	Deciduous	2.73	600	1.5	0	0	0	0	0	34.2	2.0	6.23
Palar to Gopinatham	Scrub	2.69	125	1	1	0	0	0	0	16.5	1.50	6.19
Kollegal to Sathyamangalam	Deciduous	1.25	125	1	1	3	3	3	1	28.9	2.0	6.25
Virajpetta to Iritty	Evergreen/Semievergreen	2.14	625	1.5	1	0	0	0	0	18.80	1.50	6.14
MM Hills to Thaalabetta	Deciduous	2.57	750	1.5	0	0	0	0	0	22.0	2.0	6.07
Ooty to Theppakad	Deciduous	2.06	250	1	1	0	0	0	0	25.0	2.0	6.06
Germala to Sathyamangalam	Deciduous	2.03	125	1	1	0	0	0	0	55.00	2.0	6.03
Pukalamalam to chethalayam	Deciduous	3.00	625	1.5	1	0	0	0	0	0.69	0.50	6.00

Nadugani to Vazhikkadav	Evergreen/ Semi-evergreen	2.33	625	1.5	0	2	2	1	0.6	14.00	1.50	5.93
Kattikulam to Kutta	Deciduous	1.82	625	1.5	1	0	0	0	0	13.00	1.50	5.82
Thetroad to Thirunelly	Deciduous	1.29	400	1	1	3	3	3	1	12.60	1.50	5.79
Dhimbham to Thalavadi	Deciduous	2.19	100	0.5	1	0	0	0	0	25.7	2.0	5.69
Lakkidi to Chippilithode	Evergreen/ Semi-evergreen	2.60	5000	2	0	0	0	0	0	8.85	1.0	5.60
Mulli to Manjur	Deciduous	2.55	125	1	0	0	0	0	0	22.5	2.0	5.55
Chethalayam to Kuppadi	Deciduous	2.04	625	1.5	1	0	0	0	0	8.65	1.0	5.54
Mannarkkad to Mukkali	Deciduous	1.50	875	1.5	1	0	0	0	0	16.90	1.50	5.50
naalu road to Puliyampatty	Scrub	3.00	125	1	1	0	0	0	0	1.3	0.50	5.50
Anachouk to Budithithi	Deciduous	3.00	175	1	1	0	0	0	0	5.00	0.50	5.50
Hannur to Ramapuram	Scrub	3.00	450	1	0	0	0	0	0	15.5	1.50	5.50
Harohalli to Banglore	Deciduous	3.00	35	0.5	1	1	1	3	0.6	1.2	0.50	5.60
Javalagiri to Gattigunda	Deciduous	3.00	125	1	1	0	0	0	0	2.5	0.50	5.50
Ramapuram to Pallam	Scrub	3.00	225	1	0	0	0	0	0	16.5	1.50	5.50
Sanamavu to Beerjepalli	Deciduous	3.00	1500	2	0	0	0	0	0	2.4	0.50	5.50
Mettupalayam to Bavani Sagar Dam	Scrub	3.00	175	1	1	0	0	0	0	4.5	0.50	5.50
Pallam to Anthiyur	Deciduous	2.48	250	1	0	0	0	0	0	42.5	2.0	5.48
Thadagam to Aanaikatti	Deciduous	2.40	275	1	0	3	2	3	0.9	6.4	1.0	5.30
Gudalur to Ooty	Evergreen/Se mievergreen	1.00	3500	2	0	0	0	0	0	40.0	2.0	5.00
Addapallam to Hokenakkal	Deciduous	3.00	40	0.5	0	0	0	0	0	19.0	1.50	5.00
Kottaipudur to Hannur	Scrub	3.00	75	0.5	1	0	0	0	0	2.5	0.50	5.00
Masinagudi to Bokkaburam	Deciduous	3.00	75	0.5	1	0	0	0	0	2.6	0.50	5.00
Urigam foresrt checkpost to Urigam	Deciduous	3.00	75	0.5	0	0	0	0	0	10.8	1.50	5.00
Urigam foresrt Checkpost to Anjetti	Deciduous	2.50	600	1.5	0	0	0	0	0	9.5	1.0	5.00
Kanakapura to Sangam	Deciduous	2.00	350	1	1	0	0	0	0	8.5	1.0	5.00
MM Hills to Ponnachi	Deciduous	2.45	15	0.5	1	0	0	0	0	9.2	1.0	4.95
Manjur to Upper Bavani	Evergreen/ Semievergree n	1.40	25	0.5	1	0	0	0	0	25.5	2.0	4.90
Kolipara To Thalavadi	Scrub	1.50	125	1	1	3	3	3	1	4.7	0.50	5.00

Nagarhole to Kallatti	Deciduous	2.40	75	0.5	1	0	0	0	0	7.54	1.0	4.90
Nagarhole to Veeranahosahalli	Deciduous	0.90	250	1	1	0	0	0	0	30.93	2.0	4.90
Katikulam to Bavali	Deciduous	1.83	400	1	1	0	0	0	0	6.00	1.0	4.83
Naaluroad to Ramapuram	Deciduous	2.33	75	0.5	0	0	0	0	0	57.2	2.0	4.83
Kowdalli to Dhandalli	Deciduous	2.70	35	0.5	0	0	0	0	0	17.5	1.50	4.70
Bathery to Pattavayal	Deciduous	1.05	750	1.5	1	0	0	0	0	9.88	1.0	4.55
Anakatty to Sholayur	Deciduous	3.00	150	1	0	0	0	0	0	3.40	0.50	4.50
Melekkurichippatta- Pakkom	Deciduous	3.00	400	1	0	0	0	0	0	1.30	0.50	4.50
Pethikuttai to Sittapalayam	Deciduous	3.00	425	1	0	0	0	0	0	2.0	0.50	4.50
Urigam to Kondappa Thoddi	Deciduous	3.00	15	0.5	0	0	0	0	0	5.5	1.0	4.50
Hansur to Manjur	Scrub	2.47	80	0.5	0	0	0	0	0	19.0	1.50	4.47
37th Mile-Nedumpoyil	Deciduous	1.41	750	1.5	0	0	0	0	0	16.81	1.50	4.41
Denkani kottai to Anjetti -2	Deciduous	2.33	175	1	0	0	0	0	0	8.5	1.0	4.33
Harohalli to Banglore	Deciduous	1.80	15	0.5	1	0	0	0	0	5.1	1.0	4.30
43rd Mile- 44th Mile	Deciduous	2.00	750	1.5	0	0	0	0	0	1.01	0.50	4.00
44th Mile (Mananthavady-Nedumpoyil)	Deciduous	2.00	750	1.5	0	0	0	0	0	0.35	0.50	4.00
Appankapp road	Evergreen/ Semi-evergreen	3.00	10	0.5	0	0	0	0	0	1.00	0.50	4.00
Devala	Deciduous	2.00	625	1.5	0	0	0	0	0	0.72	0.50	4.00
Nallasinga to Moolagangal	Evergreen/Semievergreen	3.00	7	0.5	0	0	0	0	0	2.10	0.50	4.00
Pudur to Aralikkonam	Deciduous	3.00	7	0.5	0	0	0	0	0	0.65	0.50	4.00
Pudur to Bhoothar Colony	Deciduous	3.00	7	0.5	0	0	0	0	0	4.40	0.50	4.00
Kuntha to Lovedale	Deciduous	1.39	75	0.5	0	0	0	0	0	31.5	2.0	3.89
Nagarhole to Kaarmaad	Deciduous	1.35	75	0.5	1	0	0	0	0	6	1.0	3.85
Irulam to Chethalayam	Deciduous	0.80	625	1.5	1	0	0	0	0	3.97	0.50	3.80
Bettamugilam	Deciduous	1.71	25	0.5	0	0	0	0	0	15.5	1.50	3.71
Neikuppa to Nadavayal	Deciduous	2.60	75	0.5	0	0	0	0	0	2.54	0.50	3.60
Cheeyambam to Irulam	Deciduous	0.50	625	1.5	1	0	0	0	0	1.00	0.50	3.50
Nedunkayam forest road	Deciduous	2.00	35	0.5	0	0	0	0	0	9.70	1.0	3.50
Kembakerai	Scrub	2.40	45	0.5	0	0	0	0	0	2.1	0.50	3.40
Kobanari to Kaaramadai	Scrub	2.40	75	0.5	0	0	0	0	0	4.0	0.50	3.40

Thoddamanji	Deciduous	2.40	10	0.5	0	0	0	0	0	5.0	0.50	3.40
Pandallur to Makkatti	Deciduous	1.25	625	1.5	0	0	0	0	0	0.77	0.50	3.25
Sivalingapuram to Pennagaram	Deciduous	1.67	25	0.5	0	0	0	0	0	9.2	1.0	3.17
Devala1	Deciduous	1.13	625	1.5	0	0	0	0	0	3.74	0.50	3.13
CC-Beenachi	Deciduous	1.00	750	1.5	0	0	0	0	0	0.43	0.50	3.00
Dasanakara-Pakkam	Deciduous	1.50	400	1	0	0	0	0	0	1.73	0.50	3.00
Santhanakal	Deciduous	2.00	25	0.5	0	0	0	0	0	2.2	0.50	3.00
Kuntha to West Mere	Deciduous	0.47	75	0.5	0	0	0	0	0	35.0	2.0	2.97
Erumad (Bathery-Gudallur)	Deciduous	0.75	750	1.5	0	0	0	0	0	1.74	0.50	2.75
Mango range (Gudallur-Calicut)	Deciduous	0.70	625	1.5	0	0	0	0	0	2.88	0.50	2.70
Cherambadi (Gudallur-Calicut)	Deciduous	0.62	625	1.5	0	0	0	0	0	4.52	0.50	2.62
Bidarkad (Bathery-Ooty)	Deciduous	0.50	750	1.5	0	0	0	0	0	0.23	0.50	2.50
Goolikkadav to Chittoor	Deciduous	1.00	150	1	0	0	0	0	0	1.90	0.50	2.50
Kottaipudur to Naalroad	Scrub	0.00	425	1	1	0	0	0	0	4.3	0.50	2.50
Naalroad to Shastri Nagar	Scrub	0.00	425	1	1	0	0	0	0	2.5	0.50	2.50
Moonnanakkuzhi	Deciduous	0.50	750	1.5	0	0	0	0	0	0.66	0.50	2.50
Padivayal (Gudallur- Vythiri)	Deciduous	0.50	625	1.5	0	0	0	0	0	0.74	0.50	2.50
Secondgate to Ammani	Deciduous	0.50	75	0.5	1	0	0	0	0	2.60	0.50	2.50
Agali to Kadambara	Deciduous	1.25	5	0.5	0	0	0	0	0	4.60	0.50	2.25
Eucalykkavala to Kurichippatta	Deciduous	0.67	400	1	0	0	0	0	0	1.89	0.50	2.17
Kalpanakkavala to Maddurkavala	Deciduous	0.00	750	1.5	0	0	0	0	0	1.01	0.50	2.00
Kavundikkal to Thavalam	Deciduous	0.00	875	1.5	0	0	0	0	0	1.70	0.50	2.00
Meppadi (Gudallur- Vythiri)	Deciduous	0.00	625	1.5	0	0	0	0	0	0.58	0.50	2.00
Varayal- 41st Mile	Deciduous	0.00	750	1.5	0	0	0	0	0	0.83	0.50	2.00
Chegady to Udayakkara	Deciduous	1.00	75	0.5	0	0	0	0	0	3.94	0.50	2.00
Pakkam to Chegady	Deciduous	0.83	75	0.5	0	0	0	0	0	4.11	0.50	1.83
Kunthukottai to Vannaathipatti	Deciduous	0.00	550	1	0	0	0	0	0	1.3	0.50	1.50
Katikulam to Kurukanmoola	Deciduous	0.50	75	0.5	0	0	0	0	0	1.78	0.50	1.50
Malampuzha Dam to Aanaikal	Deciduous	0.00	75	0.5	0	0	0	0	0	7.0	1.0	1.50
Chavadiyur to Mulli	Deciduous	1.25	35	0.5	0	0	0	0	0	0.11	0.50	2.25
Chittoor to Puliyara	Deciduous	0.75	25	0.5	0	0	0	0	0	3.70	0.50	1.75
Kanjikode to Malampuzha Dam	Deciduous	0.00	75	0.5	0	0	0	0	0	2.5	0.50	1.00

Fig 1.4a. Map showing roads in the study area



Roads selected for intensive study and preparation of mitigation plan

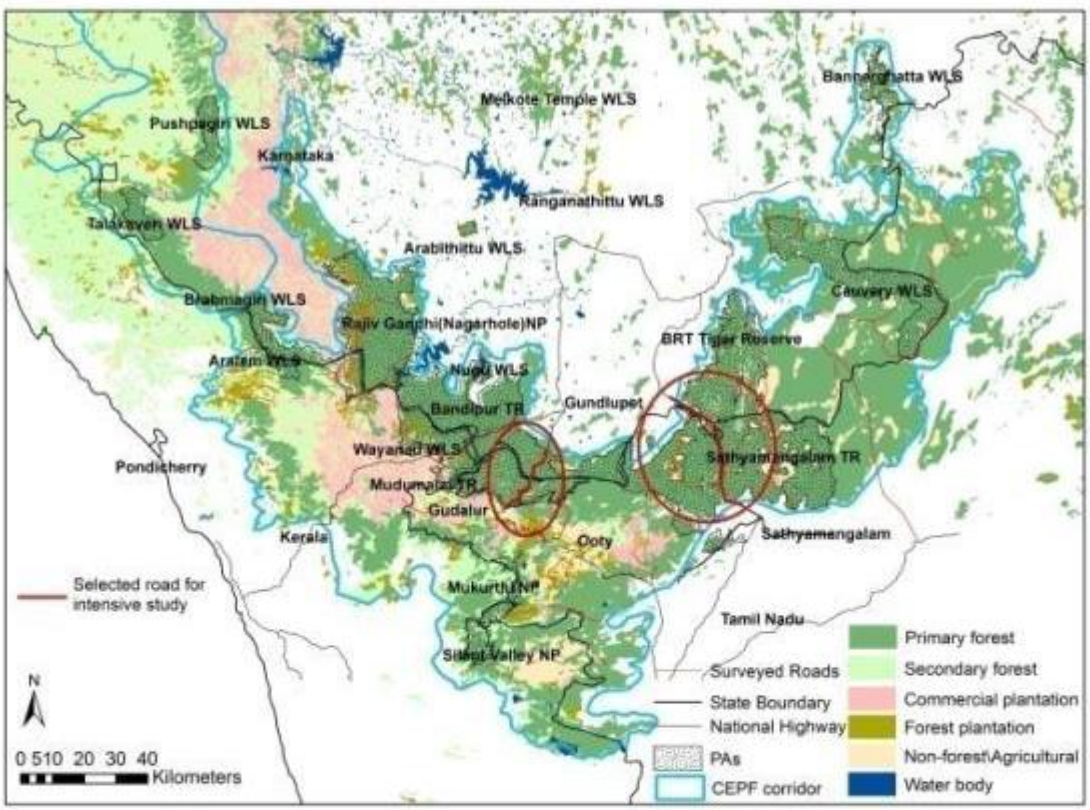
a) **Sathyamangalam to Mysore road (NH209)**

The NH209 connects Bengaluru, Karnataka with Dindigul, Tamil Nadu. The road from Bannari Temple to Swarnavahini dam passes through Sathyamangalam Tiger Reserve and BRT Tiger Reserve for a length of around 45.3 km was selected for the intensive study to assess the impact of road on wildlife in Thorn forest. The dominant forest type along the road stretch is Tropical thorn forest. The vehicular traffic intensity in the road stretch is high at over 3000 vehicles per day. Also this road passes through three elephant corridors namely, Talamalai- Guttiyalathur, Chamrajnagar- Talamali at Puninjur, Chamrajnagar- Talamalai at Muddallai (Varma *et al.*, 2005).

b) Gudalur to Mysore road (NH67)

The NH67 connects Nagapattinam, Tamil Nadu with Gundlupet, Karnataka. The road from Thorapalli to Bandipur passes through Mudumalai Tiger Reserve and Bandipur Tiger Reserve for a length of around 27km was selected for intensive study to assess the impact of road on wildlife in Deciduous forest. The dominant forest type along the road stretch is tropical dry deciduous. The vehicular traffic intensity in the stretch is high at around 3500 vehicles per day. Few studies has been carried out on impact of this road on vertebrates (Boominathan *et al.*, 2008, Baskaran & Boominathan, 2010, Selvan *et al.*, 2012), snakes, (Gokula, 1997) and insects (Rao & Girish, 2007).

Fig 1.4b. Map showing roads selected for detailed study



Canals/Flume channel

There are only two canals in the study area. They were mapped and information on the dimensions of the structures was noted along with habitat type, protected area status etc. Both the canals/flume channels were selected for the intensive study and preparation of mitigation plan.

Maravakandy to Moyar flume channel

This canal carries water from Singara Power house to Moyar Power house in Mudumalai Tiger Reserve. The flume channel runs as a non- cemented structure from Singara to Maravakandy for a length of 8.63 km and through a largely cemented structure for 6.81 km from Maravakandy to Moyar power house. The stretch between Maravakandy to Moyar flume channel was taken up for detailed study. The width of the channel varies from 11- 13m and passes through the Moyar-Avarahalla elephant corridor (Varma *et al.,* 2005). Tyagi (1995) and Daniels *et al.,* (2008) have recommended to install bridges across this canal to mitigate the impact on the movement of wildlife especially elephants.

Parali canal

This flume channel of length around one km carries water from Parali power house to Bhavani River in Coimbatore Forest Division. The width of the canal is around 9m and the depth is around 7m. The canal does not allow movement of any wildlife throughout its length except at a bridge on a road crossing the channel.

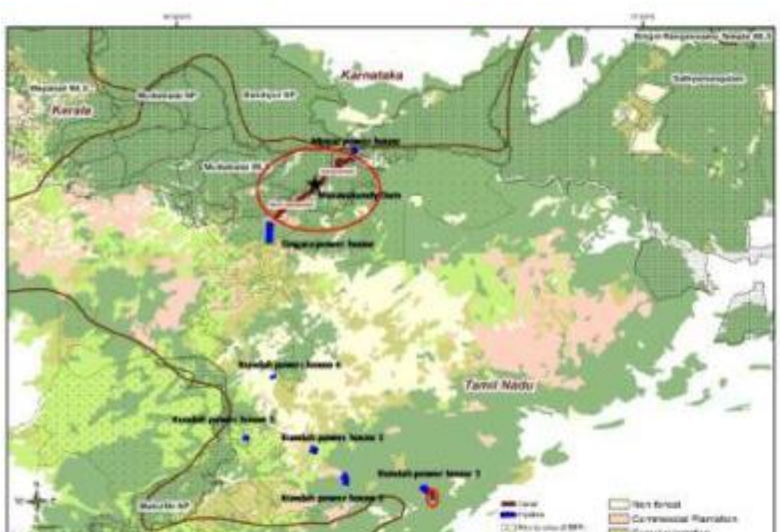


Fig 1.4 Map showing location of flume channels selected for study

Pipelines

The pipelines were marked and information on the dimensions of the structures, habitat type, Protected Area status etc was noted.

There are seven pipelines in the study area (Table 1.4) collectively passing through a length of around 8.63km through forests. Among this, we have selected two pipelines for the pilot studies based on elephant corridor and being part of important wildlife habitat and also due to the fact that they were close to the canals selected for detailed study.

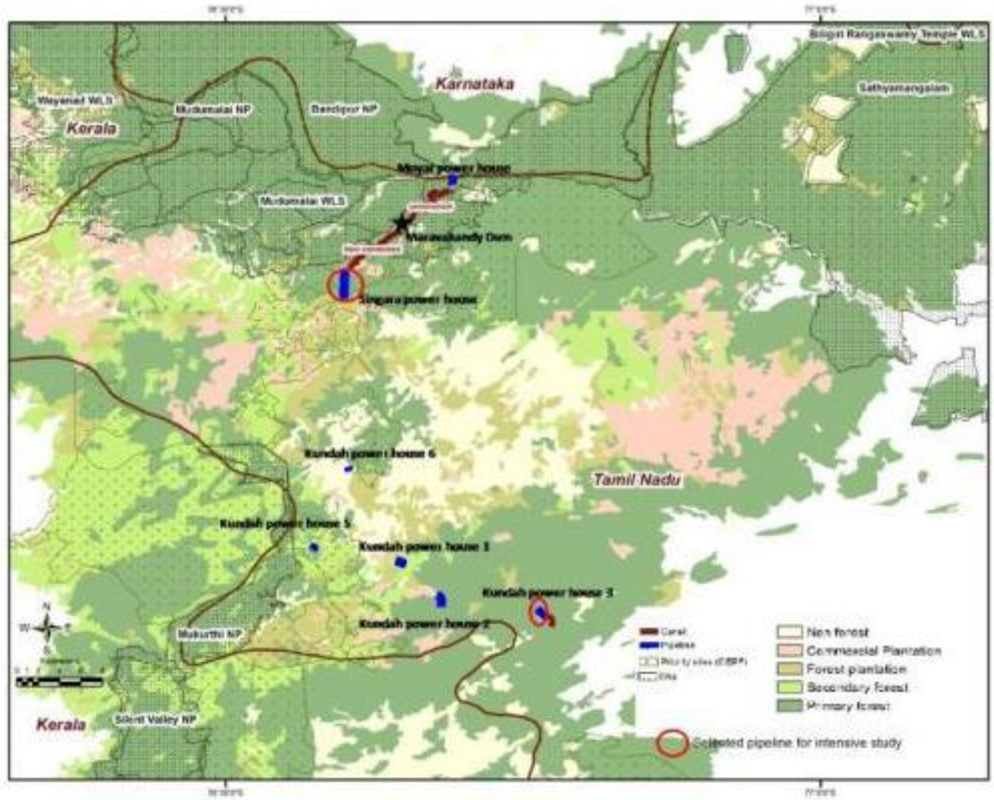
a) **Glenmorgan to Singara:** The pipelines run through the Mudumalai Tiger Reserve for around 2.8km with a diameter of around 2m. The pipeline carries water to Singara power house from Glenmorgan. This pipeline obstructs movement of elephants (Sukumar & Easa, 2006).

b) **Parali :** The penstock pipe carries water to the Kundah power house III at Parali. The pipeline is a vertical obstruction in the movement of elephants between Geddai and Kallar in the southern slopes of the Nilgiri Mountains. This penstock measures around 1km in length and around 2.44m in diameter. The penstock carries water from underground penstock to Parali power house.

Table 1.4 List of Pipelines in project site

Name of the pipeline	Major Forest type	Length (km)	Height (m)	PA/Non PA	Elephant corridor
Kundah PH1 at Kundah	Deciduous	0.93	2	Non PA	No
Kundah PH2 at Geddai	Deciduous	1.4	2	Non PA	No
Kundah PH3 at Parali	Deciduous	1	2.5	Non PA	No but good wildlife habitat
Kundah PH5 at Avalanche	Shola grasslands	0.6	2	Non PA	No
Kundah PH6 at Kattukuppam	Evergreen	0.4	2	Non PA	No
Glenmorgan- Singara PH	Deciduous	2.8	2	PA	Yes
Moyar PH at Moyar	Scrub	1.5	2	PA	No

Fig 1.5: Pipelines selected in study site



Power lines

The major impact of power lines is due to electrocution and due to vegetation clearance (Raman, 2011 and Raman and Madhusudha, 2015). For studying electrocution, secondary information from forest divisions of the study area was collected.

For intensive pilot studies, power lines with ground vegetation clearance were selected. Power lines with ground vegetation clearance were mapped and information on voltage of the line, habitat type, width of the vegetation clearance, etc was collected. These power lines were ranked based on 5 factors- voltage, width of the vegetation clearance, Protected Area status, vegetation type and length of the line through forests.

Ranks for voltage was determined as follows, medium voltage, (250V-650V) =1, high voltage, (651V-33kV) =2, ultra-high voltage, (34kV-800kV) =3.

Ranks for the length of the line through forests was calculated as follows, 0-5km=0.5, 5.1-10km=1, 10.1-15km=1.5, 15.1-20km=2, 20.1-25km=2.5, 25-30km=3.

Ranks for the width of the vegetation clearance was calculated as follows, 0-5m=0.5, 5.1-10m=1, 10.1-15m=1.5, 15.1-20m=2, 20.1-25m=2.5, 25-30m=3.

Lines running through protected areas were assigned 1 mark against '0' for non-protected areas.

Ranks for vegetation type was determined in the same way as was done for the roads.

The integrated rank for each power line was then calculated adding ranks for these parameters- voltage (1- 3), length of the vegetation clearance (0.5- 3), width of the vegetation clearance (0.5-3), protected area status (0 & 1), vegetation type (0-3)- as described above. Thus the maximum rank for power line was 13.

In total 31 power lines run through the various forests for the length of 208.16 km in Nilgiri-Mysore landscape Table 1.5 and Figure 1.6. Most of these lines are running through tropical deciduous forests (122km, 58.61%), followed by tropical thorn forests (63.46km, 29.70%) and Evergreen/semi evergreen forest (22.7km, 10.91%).

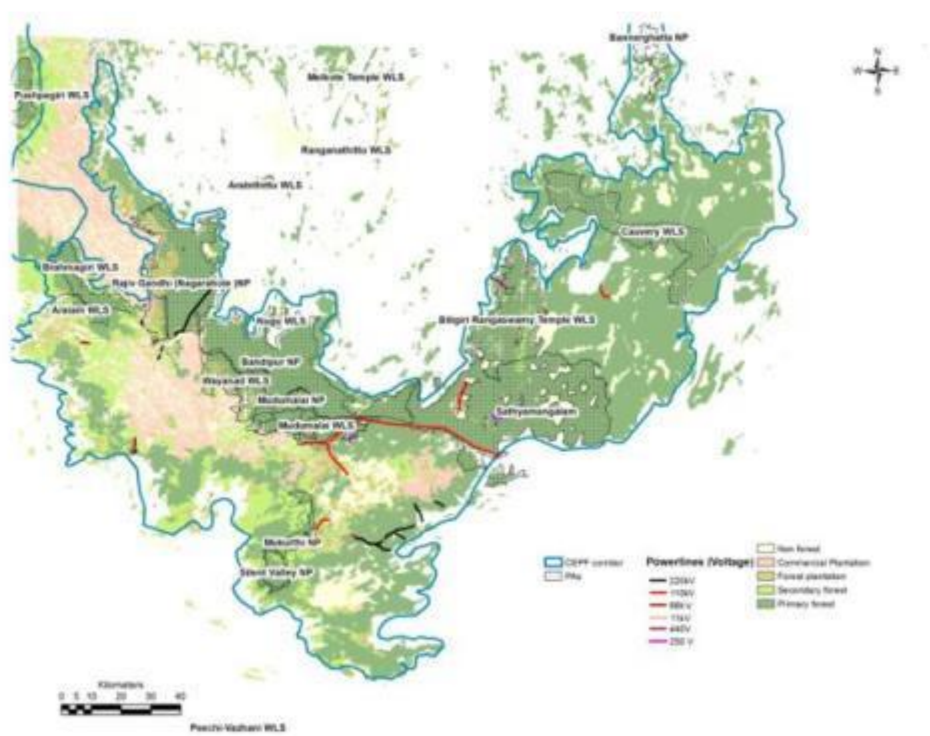
Table 1.5. Power lines with ground vegetation clearance in the study area with ranks for the selection of pilot study sites

SL No	Name	Habitat	Voltage	Voltage rank, **A**	Length of the line through forest, (km)	Rank for length, **B**	Width of the vegetation clearance (m)	Rank for the width of the vegetation clearance, **C**	Protected area status, **D**	Total rank, **E= A+B+C +D**
1	Bavali-Manchegowdanahalli	Deciduous	220 kV	3	20.6	2.5	30	3.0	1	9.5
2	Gudalur to Singara	Deciduous	110kV	3	13	1.5	13	2.0	1	7.5
3	Geddai to Kaaramadai	Deciduous	220kV	3	13.3	1.5	25	2.5	0	7.0

4	Geddai to Parali(Kundah PH-2 to 3)	Deciduous	220kV	3	12	1.5	25	2.5	0	7.0
5	Parali(PH-3) to Nellithurai	Deciduous	220kV	3	11.3	1.5	25	2.5	0	7.0
6	Sandynallah- Singara PH	Deciduous	110kV	3	12	1.5	17	2.0	0	6.5
7	Parali to Pillur Dam(Kundah PH-3 to 4)	Deciduous	220kV	3	5.5	1.00	25	2.5	0	6.5
8	Dasanakkara	Deciduous	220kV	3	2.03	0.5	30	3.0	0	6.5
9	Edayarhalli	Deciduous	66kV	3	1.5	0.5	13	2.0	1	6.5
10	Kuruva	Deciduous	220kV	3	1.66	0.5	30	3.0	0	6.5
11	Parali Dam to Thudialur(PH-4 to Thudialur)	Deciduous	220kV	3	3.6	0.5	25	2.5	0	6.0
12	Appapara	Deciduous	220kV	3	1.65	0.5	25	2.5	0	6.0
13	Kundah Bridge to Geddai(Kundah PH-1 to 2)	Deciduous	110kV	3	2.4	0.5	20	2.0	0	5.5
14	Nellithurai to Burliar	Deciduous	220kV	3	7.23	1.00	9	1.5	0	5.5
15	Valad- Varayal	Deciduous	66kV	3	2.03	0.5	10	1.5	0	5.0
16	Mettupalayam to Kothagiri	Deciduous+scrub	220kV	3	5	0.5	25	2.5	0	6.0
17	Upper Bavani to Kundha PH-5	Evergreen	110kV	3	12	1.5	11	1.5	0	6.0
18	Adivaram-Pozhuthana	Evergreen	66kV	3	3.8	0.5	25	2.5	0	6.0
19	Lakkidi- Adivaram-3	Evergreen	220kV	3	1.88	0.5	20	2.0	0	5.5
20	Kundah Bridge to Avalanche (Kundah PH-1 to 5)	Evergreen	110kV	3	2.8	0.5	5	0.5	0	4.0
21	Singara PH- Moyar PH	Scrub	110kV	3	10.2	1.5	8	1.5	1	7.0

22	Raamarpatham to Thalavadi	Scrub	110kV	3	7.9	1.00	6	1.5	1	6.5
23	Ramapura to 4-Road	Scrub	110kV	3	6	1.00	5	0.5	0	4.5
24	Moyar to Bhavani Sagar	Scrub+ Thorn	110kV	3	28	3	14	2.0	1	9.0
25	Lakkidi- Adivaram 2	Evergreen	11kV	2	1.72	0.5	7	1.5	0	4.0
26	Anappara- Meppadi	Evergreen	11kV	2	0.57	0.5	10	1.5	0	4.0
27	Masinagudi to Moyar	Scrub	11kV	2	4	0.5	5	0.5	1	4.0
28	Thimbham to Paavanatham	Deciduous	250V	1	6	1.00	3	0.5	1	3.5
29	Gumballi to Biligri temple	Deciduous	440V	1	6	1.00	5	0.5	1	3.5
30	Maavalla to Bokkapuram	Scrub	250 V	1	2.6	0.5	6	1.5	1	4.0
31	Raamarpatham to Thalavadi	Scrub	440V	1	4.76	0.5	5	0.5	1	3.0

Fig.1.6. Map showing power lines with ground vegetation clearance in the study area

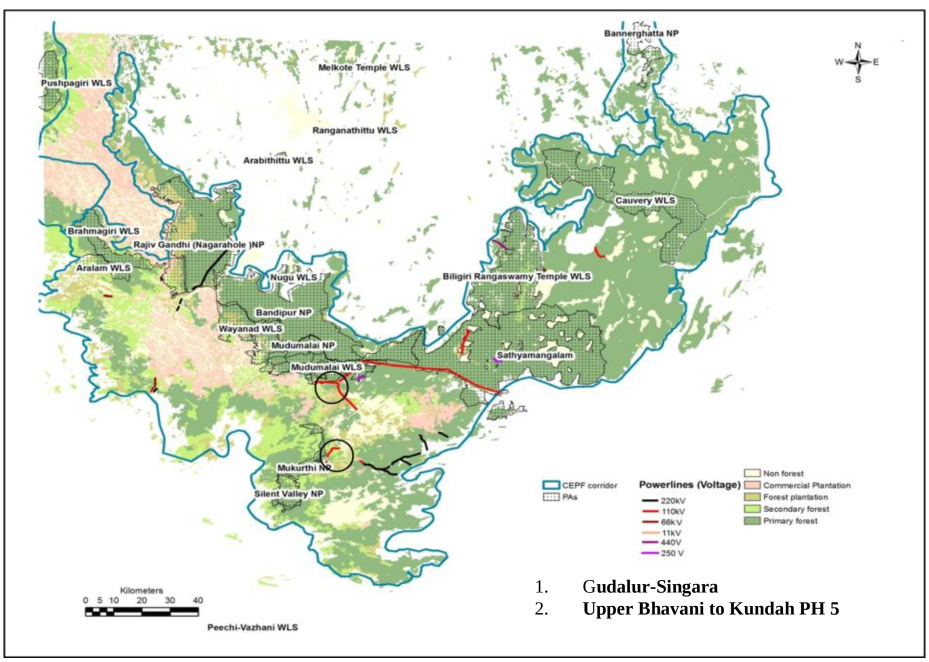


The voltage of the power lines varied from 230V to as high as 220 kV. Of which, there are 11 stretches of 220 kV lines (84 km), 9 stretches of 110 kV lines (89 km) and few 66 kV and 11 kV lines also found in the study area. Totally 12 stretches of power lines with ground clearance are running through the protected area for the length of about 112 km. Particularly a 28 km length of power line passing the Sathyamangalam Tiger Reserve. The width of the ground clearance in the forests is varied from 3 meter to 30 meter based on voltage.

The power lines were categorized based on voltage for intensive study as medium voltage line (MVL) (250V-650V), high voltage line (HVL) (650V-33kV) and ultra-high voltage line (UHVL) (33kV-800kV). Two power lines were selected for the intensive study from three voltage categories as given below.

a) **Gudalur-Singara UHVL:** The 110kV power line passes through deciduous forests in Mudumalai Tiger Reserve for the length of 13km. The width of ground vegetation clearance is 13m.
b) **Upper Bhavani to Kundah Powerhouse 5 UHVL:** The 110kV power line passes through shola forests of Nilgiri South forest division for a length of around 12 km with a ground vegetation clearance of 11m.

Fig.1.7. Map showing power lines selected for study



2. Impact of Roads on forest and wild animals

The expansion of India's economic growth over the last few decades has involved a considerable expansion of road and highway projects. India has the second largest road network across the world at 4.7 million km and transports more than 60 per cent of all goods in the country and 85 per cent of India's total passenger traffic. Keeping pace with increasing road traffic and vehicle growth (10.2% per annum), the Government of India has earmarked 20 per cent of the investment of US$ 1 trillion reserved for infrastructure during the 12th Five-Year Plan (2012–17) to develop the country's roads network. The value of roads and bridges infrastructure in India is projected to grow at a compound annual growth rate (CAGR) of 17.4 per cent over FY12–17. The Indian government plans to develop a total of 66,117 km of roads under different programmes and has set an objective of building 30 km of road a day from 2016 (Ministry of Road Transport and Highway 2015; http://www.ibef.org/industry/roads-india.aspx)

This extensive network of road and vehicular traffic has severely affected the natural areas and wildlife, the most visible effect being habitat loss and their fragmentation into smaller patches and mortality of animals (Andrews 1990, Rebecca *et al*. 1996, Rajvanshi *et al*. 2001, Raman, 2011). However, the area of forest habitat affected by roads (ecological footprints) may be much larger than the actual cleared footprints due to negative effects that penetrate the forest to varying distance (Goosem *et al*. 2010). The response of an ecosystem to impacts is governed by many factors, and different ecosystems can be expected to adapt in different ways to road related impacts (Rajvanshi *et al*. 2011). Broad negative impacts of road could be categorized as follows (Rajvanshi *et al.* 2001; Raman , 2011):

Fig 2.1: Road as trap/ attractants to animals

- Habitat loss and degradation
- Habitat fragmentation and as barriers affecting genetic diversity of animals
- Wildlife mortality and injury
- Conduits for invasive alien species
- Cause for landslide, soil erosion and hydrological alterations
- Effects on arboreal animals and through opening of closed canopy forest
- Roads as ecological traps/ attractants
- Causes pollution of environment- light, noise, air
- Affects animal behavior
- Impacts local and indigenous people

The most significant effect associated with road construction and operation is the fragmentation of large wildlife habitat areas into smaller patches (Andrews 1990, Rebecca *et al*. 1996, Menon *et al*. 2005, Bera *et al*. 2006, Goosem 1997, Prasad 2009, Gubbi 2010) threatening wildlife movement. However, very few study available that has looked at the extent of area lost by roads. About 456 hectares of biodiversity rich forest was lost in Garo Hills, Meghalaya due to roads between 1971 and 1991 (Bera *et al*. 2006). The tourism zone in Bandipur Tiger Reserve has a road density of 2.25 km of road per square kilometer of forest (Prasad 2009) and indicates the loss of habitat. Taking just 800 km of road in Bandipur Tiger Reserve (Gubbi 2010), and assuming an average width of 10 m of the road itself, this translates into 800 hectares (8 km^2) of direct habitat loss (Raman, 2011).

Fig 2.2 : Road and vehicular traffic as barrier to elephant

The impacted area of road is much more than the area it occupies. On an average about 30-40 m of vegetation is cleared as “viewlines” along roads and thus direct loss of habitat along the roads. Prasad (2009) found that tree death is 250% higher along roads than forest interior. Opening a road through forested area may also induce micro-climatic changes, thereby bringing about modification of the ecosystem. Tropical forests within 50-100m of edges experience greater diurnal fluctuations in light, temperature and humidity, being typically drier and hotter than forest interiors, with elevated tree mortality, numerous canopy gaps and a proliferation of disturbance-adapted vines, weeds and pioneer species (Laurance *et al*. 2009).

Injury and mortality of animals is another major consequence of roads through forests. In India, a large number of wild animals are killed annually due to accidents on highways (Gokula, 1997; Rajvansh *et al*. 2001; Singh and Sharma 2001, Vijayakumar *et al.* 2001; Chhangani, 2004, Menon *et al*. 2005; Das *et al*. 2007; Rao and Girish 2007; Seshadri *et al*. 2009; Baskaran and Boominathan, 2010; Selvan *et al*. 2011; Gubbi et al 2012). However, most of the studies have looked at road kill of mammals, amphibians, reptiles and birds with very little study on other lower taxa.

Fig 2.3: Hog deer killed by vehicle on NH-37 near Kaziranga NP

A large number of Protected Areas in India have National and State highways and other roads passing through them being managed by various agencies. Although these roads increases connectivity between key towns/cities and economic centres, the lack of wildlife mitigation plan of the existing and proposed roads and their expansion (high speed highways) poses serious threats to wildlife and this need to be addressed on priority keeping into consideration the huge expansion of road proposed for the economic growth of the country.

In India, the impact of roads or vehicular traffic on wildlife has received less research priority, and most of the studies have looked mainly at road kills. Despite the facts that roads have various impacts on large groups of wildlife and their habitat, there has been hardly any research assessing their impacts based on road's physical structure, location, terrain type and in various forest types. Also only very few studies have assessed the impact of current mitigating measures to reduce road kills. In this study, we tried to assess the impacts of various physical dimensions of road on wildlife and focused on two roads- Sathyamangalam to Mysore road (NH209) and Gudalur to Mysore road (NH67). Both the roads passes through Protected Area and Tiger Reserve with the former has unregulated vehicular traffic where as the later has vehicular traffic ban at night and thus serves as control road. The specific objectives of the study are as follows.

1. Identify the vehicular traffic and wildlife mortality by road kills

2. Identify the main factors responsible for road hit

3.Identify other impacts of road on wildlife and its habitat

4. Suggest site specific mitigation plans

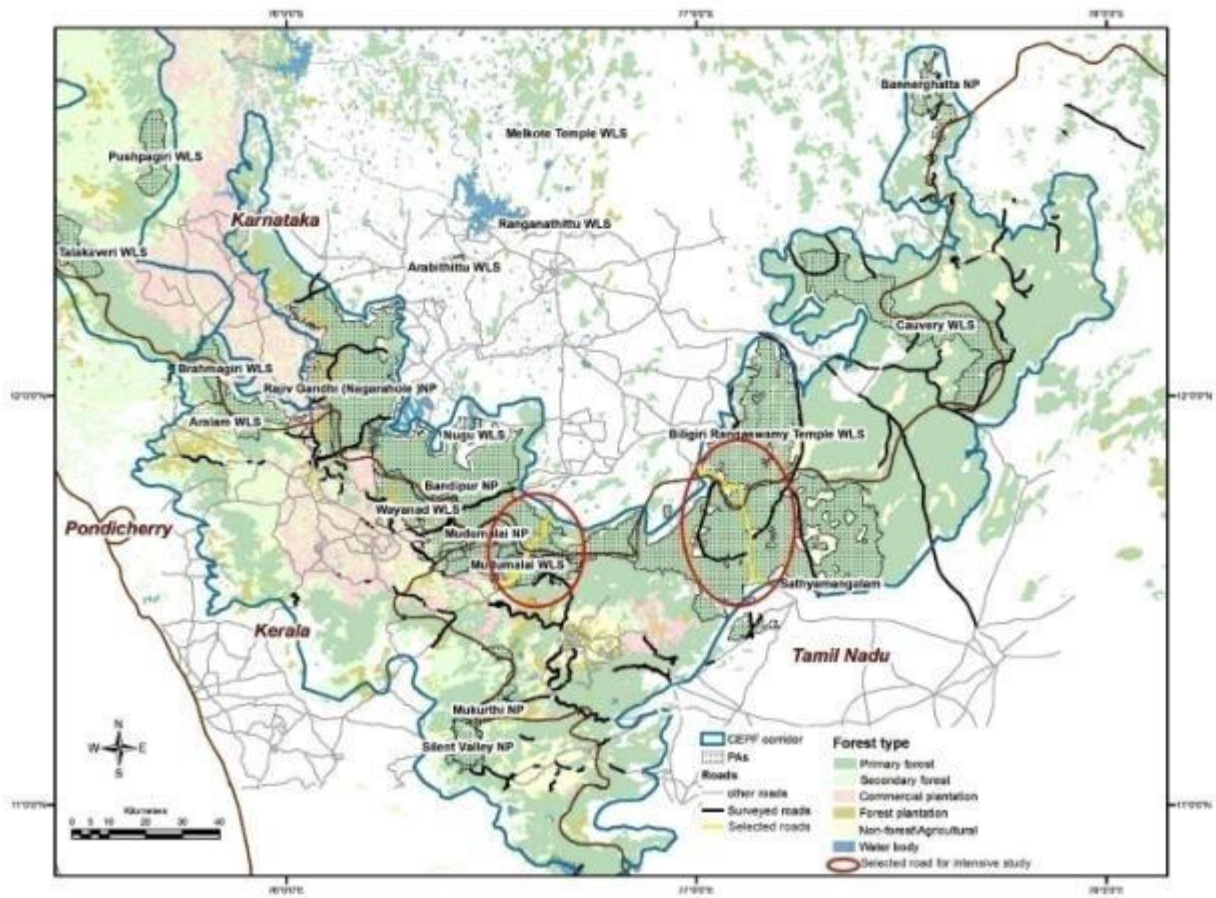


Fig2.4: Map of Nilgiri – Mysore landscape showing road network and the two highways taken up for detailed study

Impact of Sathyamangalam to Mysore road (NH-209) on wildlife

The NH-209 connects Bengaluru, Karnataka with Dindigul, Tamil Nadu. The road from Bannari Temple to Suvarnavathi dam passes through Sathyamangalam Tiger Reserve and BRT Tiger Reserve for a length of around 45.3 km and was selected for the detailed study. The dominant forest type along the road stretch is Tropical thorn and Semi-evergreen forest. The vehicular traffic intensity on the road stretch is high as this road is one of the major connectivity between Tamil Nadu and Karnataka. The road passes through three important elephant corridors namely, Talamalai-Guttiyalathur, Chamrajnagar-Talamali at Punjur, Chamrajnagar-Talamalai at Muddahalli connecting habitats of BRT Tiger Reserve (Chamrajnagar Forest Division) with Sathyamangalam Tiger Reserve (Varma *et al.*, 2005).

Fig2.5: Map of Nilgiri – Mysore landscape showing NH 209

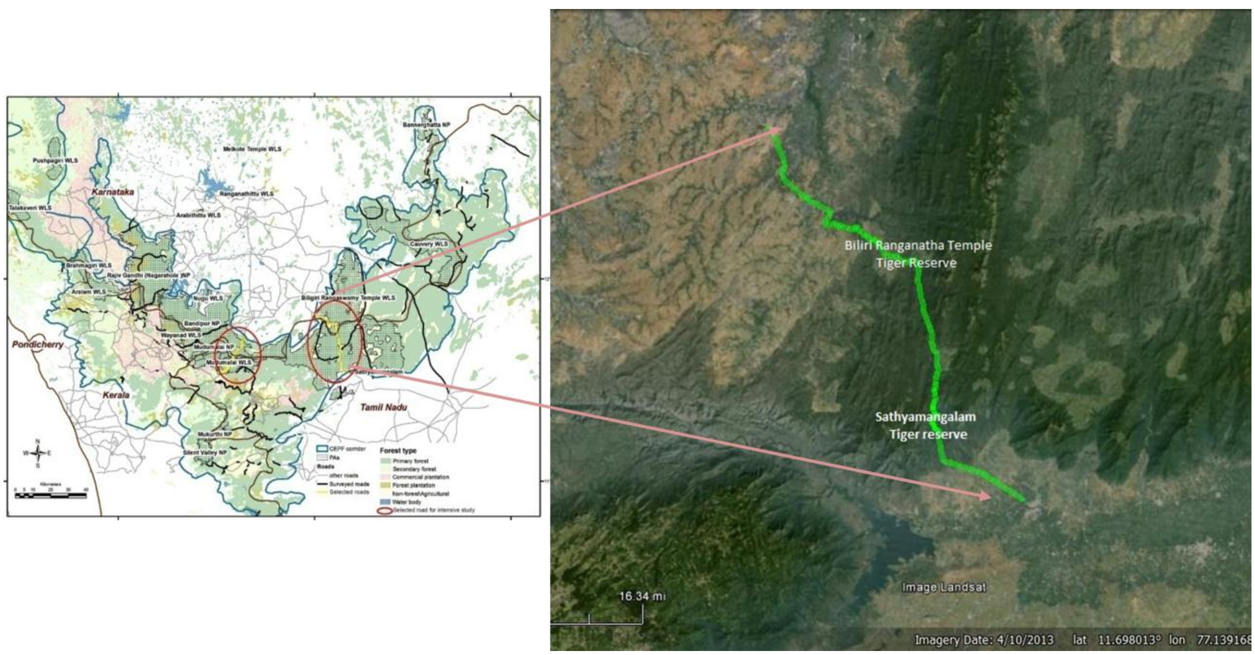


Fig2.6: View of NH 209 passing through Sathyamangalam Tiger Reserve

Sathyamangalam Tiger Reserve connects the habitats of Western Ghats and Eastern ghats acting as an important link for gene flow between diverse populations of the two landscapes. It is contiguous with Bilgiri Rangaswamy Temple Tiger Reserve, Mudumalai Tiger Reserve, Bandipur Tiger Reserve and Sigur plateau. The Sathyamangalam Tiger Reserve covers an area of 1411 km^2. The forest type is mostly tropical dry forest followed by tropical evergreen, semi evergreen, mixed deciduous and thorn forests. The major mammals in the tiger reserve are Asian elephants, tiger, leopard, sloth bear, wild dog, Indian gaur, wild boar, sambar deer, spotted deer, barking deer, mouse deer, four horned antelope, blackbuck, striped hyenas etc. Sathyamangalam has elephant population of 877 (648-1174) (2012 synchronized population estimation) and tiger population of about 51 individuals.

Bilgiri Rangaswamy Temple Tiger Reserve (BRT) is located in south- eastern part of Karnataka spread over an area of 539 km^2. The tiger reserve is contiguous with Sathyamangalam Tiger Reserve and Kollegal Forest Division. The BR hills links the Eastern Ghats and the Western Ghats allowing animals to move between them and facilitating gene flow between populations of species in these areas. The Sanctuary serves as an important biological bridge for the biota of the entire Deccan plateau. The annual rainfall varies from 600mm at the base of the hills and 3000mm at the top of the hills. The altitude varies from 600m to 1800m. The major vegetation types of the Tiger Reserve are scrub, deciduous, evergreen, savanna and shola. The BRT is rich in biodiversity with 776 species of higher plants, more than 36 mammals, 245 species of birds and 145 species of butterflies. The major mammals in the reserve are Asian elephants, tiger, leopard, wild dog, Indian gaur, wild boar, sambar deer, spotted deer, barking deer, four horned antelope, mouse deer, lesser cats, civets etc. The elephant population is about 617 (335-976) (2012 synchronized population estimation) and tiger population of about 50 individuals.

Methodology:

Road kills of various species such as amphibians, birds, reptiles and mammals were collected thrice a month from August to December 2014 for NH 209 and October 2014 to March 2015 for NH 67. This data was collected by walking along the road and travel by motor bike with minimum speed of 10-20 kmph. Variables such as species name of the road kill, location of road kills (Middle/Edge/Outside of road), forest type, physical structure of road (Blind curve/Minor curve/ Straight road) and terrain type (Ghats/Gentle slope/ Plain road) collected. The location of each kill with GPS location recorded.

Edge effect of road on animals and vegetation: To assess the edge effect of road on movement of wild animals and abundance of vegetation, 20 x 20 m plots were laid at an interval of 200m along the one km line transect from the road. The line transects were laid radially in both side of road in all major vegetation types. In each plot variables such as name of the animal, number of animal dung, name of the tree and number of trees were recorded. Two 5m x 5m sub plots were laid in the corner of 20x20 m plot to record shrubs and herbs. Also two 1x1 m sub plots were laid in the alternative corner of plots for weeds and invasive species.

Traffic Intensity: The selected roads were monitored round the clock (6 am – 6 am) in three week days and three weekends to assess the traffic intensity. Vehicles were divided into three categories such as two wheeler, four wheeler and six wheeler.

Usage of under passage by wild animals: A total of four under passages with various dimension were selected to assess the usage by wild animals on NH-209. These under passages were monitored thrice a month for five months and variables such as species name and number of animal droppings were recorded.

Impact of physical structure of road: GPS coordinates of starting and end point of all blind curves, minor curves, straight road, ghat road, gentle slope, plain road and different forest types were recorded. These coordinates were superimposed in google earth and distance of each physical structure was calculated. These distances were correlated with the road kills and assessed the influence of different dimension of road on animal kills.

Impact of mitigating measures: GPS coordinates of all speed breakers were recorded. These coordinates were superimposed in google earth and distance between two speed breakers was calculated. The inter speed breaker distance was correlated with the road kills and effectiveness of speed breakers were assessed.

Results and Discussion

The stretch of road from Bannari Temple to Suvarnavathi dam passing through Sathyamangalam Tiger Reserve and Biligiri Rangaswamy Temple (BRT) Tiger Reserve covering a length of around 45.3 kms was selected. The overall vegetation of the area consists of dry deciduous forest, semi-evergreen forest, scrub and Eucalyptus plantation. Major part of the road is level (plain road) measuring about 28 kms, Ghat road is about 10.8 kms and gentle slope is about 6.5 kms.

Table 2.1: Major forest type along the NH-209

S.No	Major forest type	Terrain	Forest on both side(km)	Forest on one side(km)	Total Km
1	Eucalyptus plantation	Plain	4	4.5	8.5
2	Scrub	Plain	3.9	1.7	5.6
3	Semi evergreen	Plain	13	0	13
4	DDF	Ghats section	10.9	0	10.9
5	Thorn	Plain	5.2	2.1	7.3
			Total length km:	45.3	

Traffic intensity on the highway: The vehicular traffic on this stretch of the road was about 116.8 vehicles per hour with almost 2800-3000 vehicles plying on the road every day. This is an increase by about 30% compared to traffic volume on the same stretch in 2010. The vehicular traffic increases drastically during festival times at Bannari Amman temple during Kundam festival (March-April). Most of the vehicles on plain and straight road moves at a speed of 80-90 kmph and this increase the probability of road hit.

Fig 2.7: Vehicular traffic on NH 209
(at Bannari Check Gate)

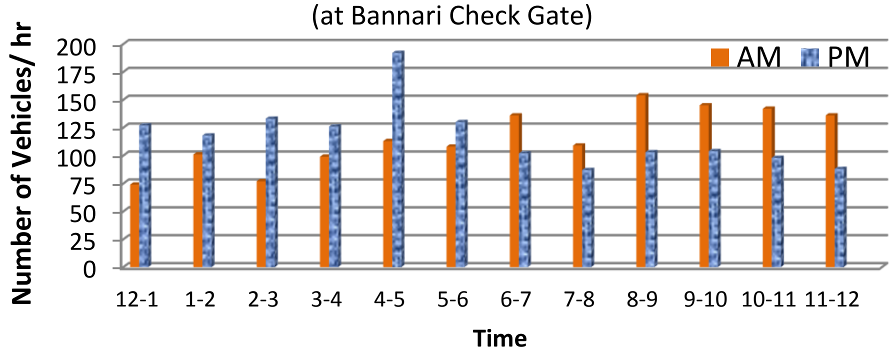
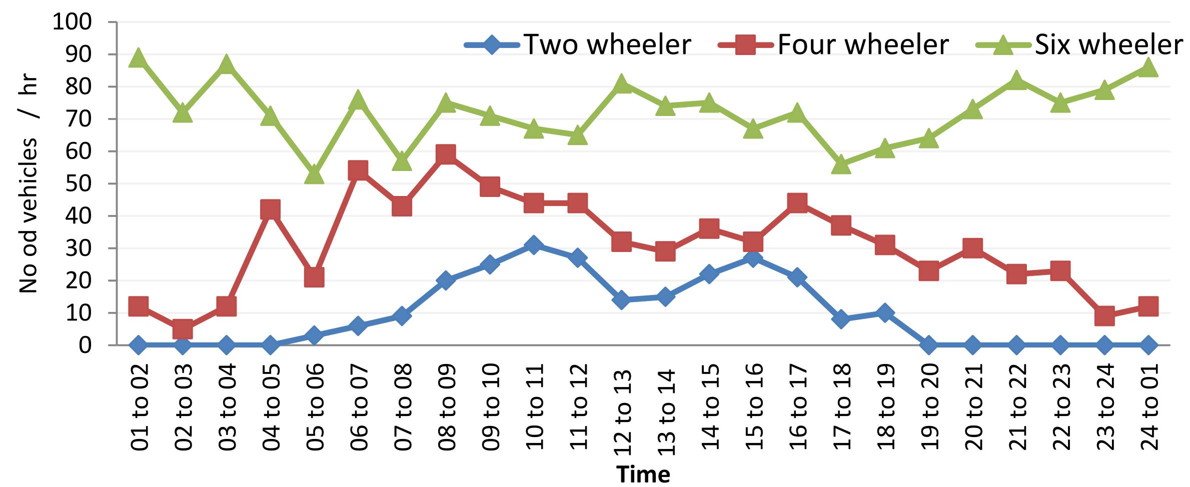


Fig 2.8: Vehicle intensity



Most of the six wheelers (bus and truck) ply during mid night to avoid traffic during day time when four wheelers (car, small goods vehicle, Jeep) traffic increases. Most of the goods vehicles carry vegetable from Chamrajnagar to take them to Sathyamanagalam town during early morning hours (04-09 AM) and returns during evening (04-07 PM). The late night and early morning traffic hinders animal movements and at time the animals have to wait for long time to cross the road.

Fig 3.8: movement of elephant obstructed by vehicular movement

Road Kill

Traffic volume and vehicular speed are the important determinant of road kills. Four different taxa (Amphibians, Birds, Mammals, reptiles) were monitored for road kills and total of 31 species were found to be killed by vehicle hit (Table.2.2.). Relative percentage of overall road kills from different taxa revealed that birds were highly affected (38.95%) followed by reptiles (29.38%) and mammals (21.71%). On the contrary, highest individuals of road kills recorded were Common Indian toad (*Duttaphrynus melanostictus)* (0.017 road kills/km). Bhaskaran and Boominathan (2010) reported similar observation in Mudumalai TR where they reported that among the road kills, the Common Indian toad was the most susceptible species for the vehicular traffic and accounted for over 50% of the road kills. Apart from common Indian toad, mouse also similary affected followed by Green keel back (0.015 road kills/km), Calotes (0.013 road kills/km), Red-vented bulbul (0.013 road kills/km) and Spotted dove (0.011 road kills/km). Relative percentage of overall road kills from different taxa revealed that birds were highly affected (38.95%) followed by reptiles (29.38%) and mammals (21.71%). The least affected taxa due to road kill were amphibians (8.3%).

Table 2.2 Encounter rate of road kills in Sathyamangalam road

Taxa	Vernacular name	Scientific name	Road kill/km	Relative %
Amphibians	Common Indian toad	*Duttaphrynus melanostictus*	0.017	8.301
Birds	Coucal	*Centropus sinensis*	0.008	3.831
	Drongo	*Dicrurus macrocercus*	0.003	1.277
	Indian jungle crow	*Corvusculminatus*	0.001	0.639
	Indian Myna	*Acridotherestristis*	0.009	4.47
	Jungle babbler	*Turdoidesstriata*	0.006	3.193
	Magpie Robin	*Capsychussaularis*	0.003	1.277
	Purple-rumped sunbird	*Leptocomazeylonica*	0.003	1.277
	Red-breasted flycatcher	*Ficedulaparva*	0.003	1.277
	Red-vented bulbul	*Pycnonotuscafer*	0.013	6.386
	Red-whiskered Bulbul	*Pycnonotusjocosusfuscicaudatus*	0.001	0.639
	Spotted dove	*Spilopeliachinensis*	0.011	5.747
	Tailor bird	*Orthotomussutorius*	0.01	5.109
	Yellow-throated Sparrow	*Petroniaxanthocollis*	0.008	3.831
Mammals	Bandicoot	*Bandicota sp.*	0.009	4.47
	Bonnet macaque	*Macaca radiate*	0.001	0.639
	Common palm civet	*Paradoxurushermaphroditus*	0.001	0.639
	Mouse	*Mus sp.*	0.017	8.301
	Sambar deer	*Rusa unicolor*	0.001	0.639
	Three stripe squirrel	*Funambulus palmarum*	0.013	6.386
Reptiles	Garden lizard	*Calotes versicolor*	0.013	6.386

	Chameleon	*Chamaeleo zeylanicus*	0.006	3.193
	Common krait	*Bungaruscaeruleus*	0.001	0.639
	Dumerill's Black headed snake	*Sibynophissubpunctatus*	0.001	0.639
	Elliot's Shieldtail	*Uropeltisellioti Gray*	0.003	1.277
	Green keel back	*Macropisthodonplumbicolor*	0.015	7.663
	Green vine snake	*Oxybelisfulgidus*	0.011	5.747
	Indian flapshell turtle	Lissemyspunctate	0.001	0.639
	Rat snake	*Ptyas mucosa*	0.001	0.639
	Russell's viper	*Daboiarusselii*	0.005	2.554
	Saw-scaled Viper	*Echiscarinatus*	0.001	0.639

Encounter rate of road kills were also analysed in three different terrains (plain road, gentle slope and ghat road). A total of 31 species were affected due to road kills. Among the terrain types, the highest number of species were killed in plain road (30 species) followed by ghat road (11 species) and gentle slope (8 species) (Tab.2.3 & Fig.2.9). Among the species, road kills of Red-vented bulbul, Bandicoot, mouse, Chameleon and Green vine snake were recorded in all terrain types (Fig.2.10). Overall the road kills were considerably high in plain road (0.281 road kills/km) compared to gentle slopes (0.063 road kills/km) and ghat road (0.06 road kills/km) (Table.2.3 & Fig.2.9).

Table.2.3 Encounter rate of road kills in different terrain types

	Vernacular name	Scientific name	Road kills / km		
			Plain road (total surveyed 444.6km)	Gentle slope (total surveyed 138 km)	Ghat road (total surveyed 199.8 km)
Amphibians	Common Indian toad	*Duttaphrynus melanostictus*	0.029	0.000	0.000
Birds	Drongo	*Dicrurus macrocercus*	0.004	0.000	0.000
	Indian jungle crow	*Corvus culminatus*	0.000	0.000	0.005
	Indian Myna	*Acridotheres tristis*	0.013	0.000	0.005
	Jungle babbler	*Turdoides striata*	0.009	0.007	0.000
	Magpie robin	*Capsychus saularis*	0.004	0.000	0.000
	Purple-rumped sunbird	*Leptocoma zeylonica*	0.002	0.000	0.000
	Red-breasted flycatcher	*Ficedula parva*	0.002	0.000	0.005
	Red-vented bulbul	*Pycnonotu scafer*	0.018	0.007	0.005
	Red-whiskered Bulbul	*Pycnonotus jocosus*	0.004	0.000	0.000

		fuscicaudatus			
	Spotted dove	*Spilopeliachinensis*	0.020	0.000	0.000
	Tailor bird	*Orthotomussutorius*	0.013	0.014	0.000
	Yellow-throated Sparrow	*Petroniaxanthocollis*	0.007	0.000	0.005
	Greater Coucal	*Centropus sinensis*	0.013	0.000	0.000
Mammals	Bandicoot	*Bandicota sp.*	0.002	0.007	0.005
	Bonnet macaque	*Macaca radiata*	0.002	0.000	0.000
	Common palm civet	*Paradoxurus hermaphroditus*	0.002	0.000	0.000
	Mouse	*Mus sp.*	0.022	0.007	0.010
	Porcupine	*Hystrix indica*	0.002	0.000	0.000
	Sambar	*Rusa unicolor*	0.002	0.000	0.000
	Three striped palm squirrel	*Funambulus palmarum*	0.020	0.000	0.005
Reptiles	Garden lizard	*Calotes versicolor*	0.020	0.007	0.000
	Indian Chameleon	*Chamaeleozeylanicus*	0.007	0.007	0.005
	Common krait	*Bungarus caeruleus*	0.002	0.000	0.000
	Dumerill's Black headed snake	*Sibynophissubpunctatus*	0.002	0.000	0.000
	Elliot's Shieldtail	*Uropeltisellioti Gray*	0.004	0.000	0.000
	Green keel back	*Macropisthodonplumbicolor*	0.027	0.000	0.000
	Green vine snake	*Oxybelis fulgidus*	0.016	0.007	0.005
	Rat snake	*Ptyas mucosa*	0.002	0.000	0.000
	Russell's viper	*Daboia russelii*	0.007	0.000	0.005
	Saw-scaled Viper	*Echiscarinatus*	0.002	0.000	0.000
	Indian flapshell turtle	Lissemys punctate	0.002	0.000	0.000

Fig 2.9 Overall encounter rate of road kills in different terrain type

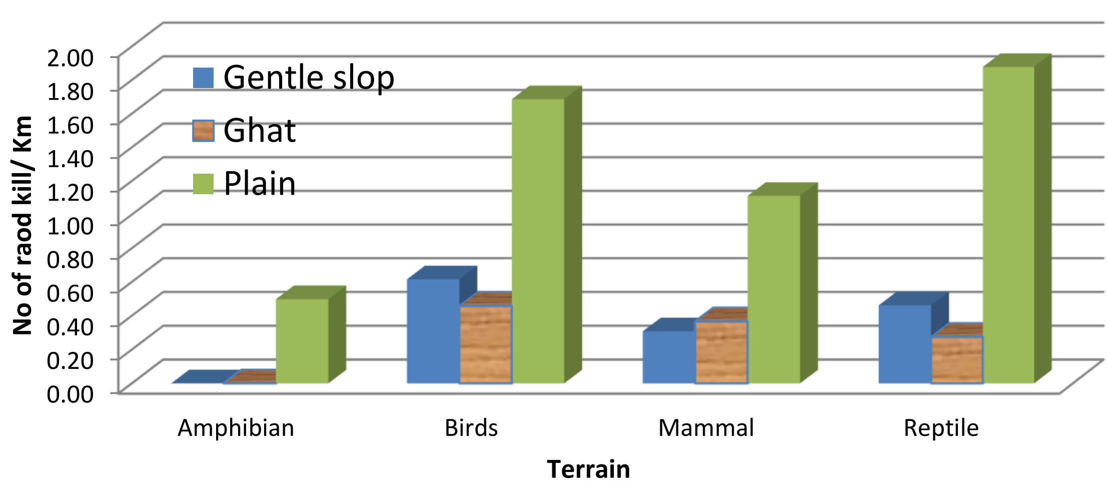


Fig.2.10 Relative percentage of road kills of different taxa in different terrain type

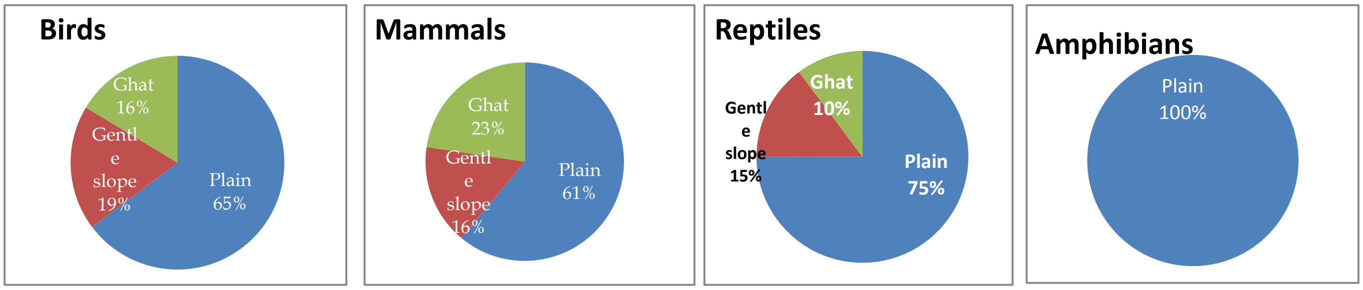
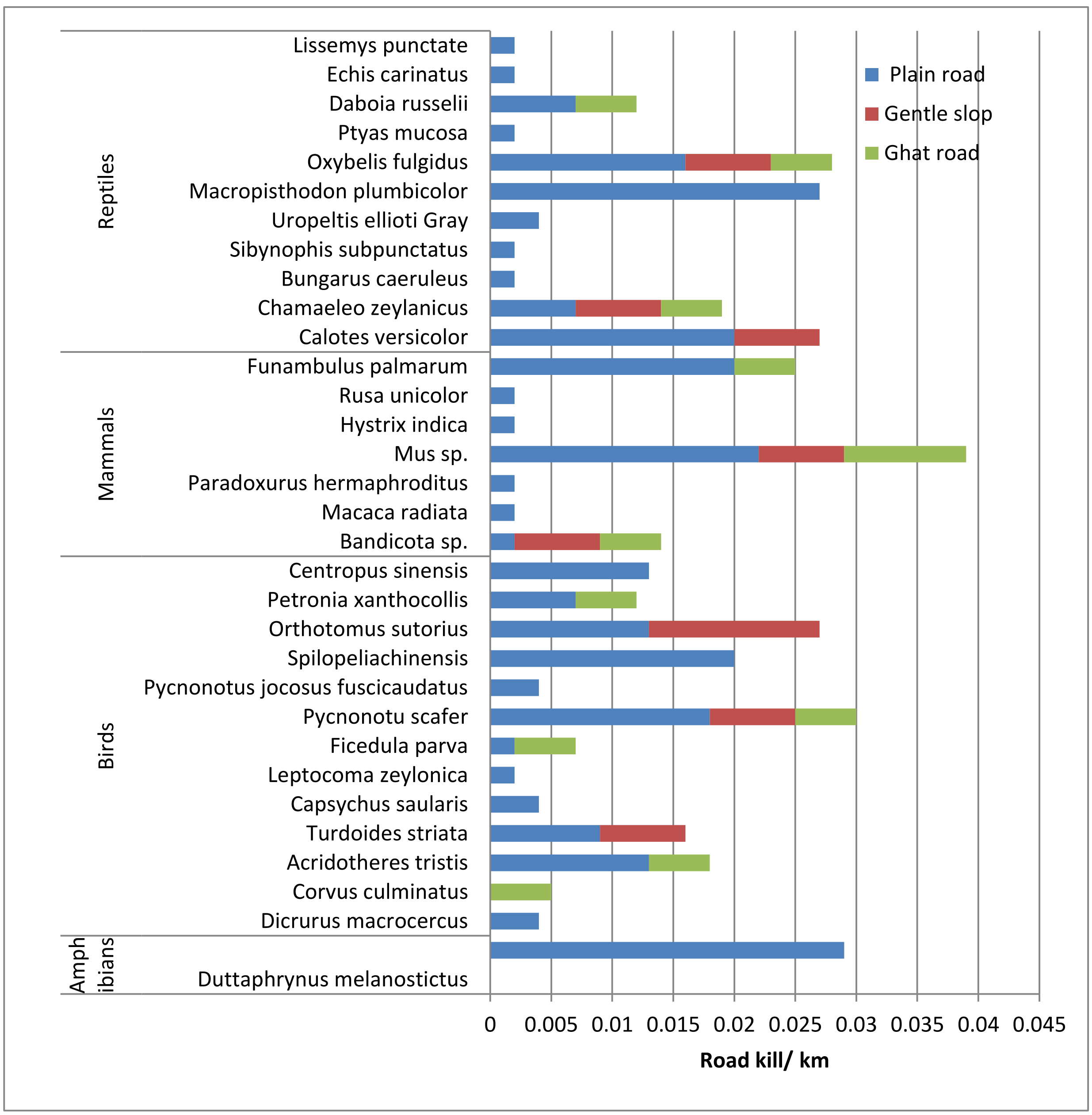


Fig.2.11 Pictorial representation of road kills in different terrain types



To catch up for the time lost on ghat roads, most vehicles speed off on the plain (level) and gentle slopes (80-90 kmph). Hence, the reaction time for the driver as well as the animals on road is very less causing more accidents. There are hardly any physical barriers such as barry guards on the road or speed breakers to prohibit speeding of vehicles. The speed vehicles should also be supplemented with signboards to sensitize vehicle drivers. This part of the road also has three elephant corridors and it is important to impose speed restriction and physical barrier to avert road kills of animals. The feeding of primates on the road has further aggravated the situation and attracts animals on road increasing probability of accidents. Similarly the leakage of grains from lorries are highly responsible for the kills of more birds.

The study also looked at the different portion of the road where most of the accidents occurred. Relative percentage of road kills in various portions of the road revealed that mortality on road edge was high (49%) followed by Middle part of the road (29%) and the least was outside the road (22%).

Table 2.4. Relative percentage of road kills in different portions on road

	Vernacular name	Scientific name	Middle	Edge	Out
Amphibian	Common Indian toad	*Duttaphrynus melanostictus*	0.22	0.44	0.06
Birds	Greater Coucal	*Centropus sinensis*	0.11	0.06	0.17
	Drongo	*Dicrurus macrocercus*	0.06	0	0.06
	Indian jungle crow	*Corvus culminatus*	0.06	0	0
	Indian myna	*Acridotheres tristis*	0	0.28	0.11
	Jungle babbler	*Turdoides striata*	0.11	0.11	0.06
	Magpie robin	*Capsychus saularis*	0.06	0.06	0
	Purple-rumped sunbird	*Leptocoma zeylonica*	0	0	0.06
	Red-breasted flycatcher	*Ficedula parva*	0.06	0	0.06
	Red-vented bulbul	*Pycnonotu scafer*	0.17	0.33	0.06
	Red-whiskered Bulbul	*Pycnonotus jocosus fuscicaudatus*	0	0.11	0
	Spotted dove	*Spilopelia chinensis*	0.11	0.28	0.11
	Tailor bird	*Orthotomus sutorius*	0.11	0.22	0.11
	Yellow-throated sparrow	*Petronia xanthocollis*	0	0.17	0.06
Mammal	Bandicoot	*Bandicota sp.*	0.11	0.17	0.17
	Bonnet macaque	*Macaca radiata*	0	0.06	0
	Common palm civet	*Paradoxurus hermaphroditus*	0	0.06	0
	Mouse	*Mus sp.*	0.28	0.33	0.11

	Porcupine	*Hystrix indica*	0	0.06	0
	Sambar	*Rusa unicolor*	0	0	0.06
	Three stripe squirrel	*Funambulus palmarum*	0.17	0.33	0.06
Reptiles	Garden lizard	*Calotes versicolor*	0.06	0.22	0.28
	Chameleon	*Chamaeleozeylanicus*	0.06	0.17	0.06
	Common krait	*Bungaruscaeruleus*	0.06	0	0
	Dumerill's Black headed snake	*Sibynophissubpunctatus*	0.06	0	0
	Elliot's Shield tail	*Uropeltis ellioti*	0	0.06	0.06
	Green keel back	*Macropisthodon plumbicolor*	0.28	0.28	0.06
	Green vine snake	*Oxybelis fulgidus*	0.28	0.11	0.11
	Rat snake	*Ptyas mucosa*	0	0.06	0
	Russell's viper	*Daboia russelii*	0.06	0.17	0
	Saw-scaled Viper	*Echis carinatus*	0	0.06	0
	Indian flap-shelled Turtle	*Lissemys punctata*	0.06	0	0

Road kills in different physical structures of road (Blind curve, Minor curve, Straight)

The study also looked at the occurrence of road kill on different physical structures of road (Blind curve, Minor curve, Straight). Relative occurrence of road kills in different physical structures of road revealed that minor curve was more responsible for road kills followed by blind curve and straight road (Fig.2.12). The intensity of road kills in different physical structures of road varied among taxa. Amphibians (65%) and birds (38%) were killed more in straight road (Fig.2.13). Whereas reptiles and mammals were killed more in minor curve (41%) and blind curve (39%).

Fig 2.12 :Relative percentage of road kills in different physical structures of road

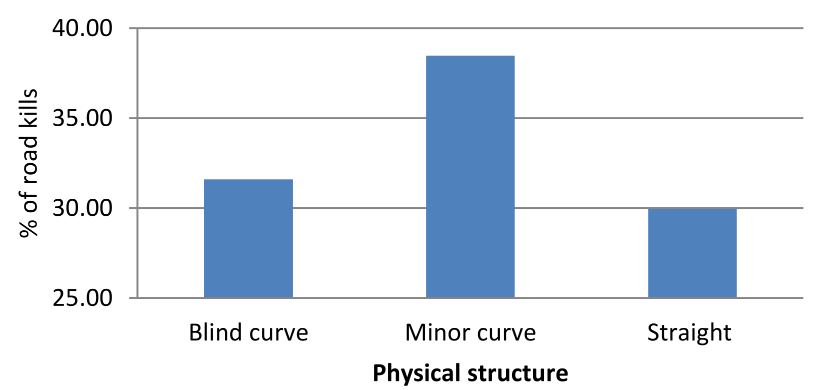
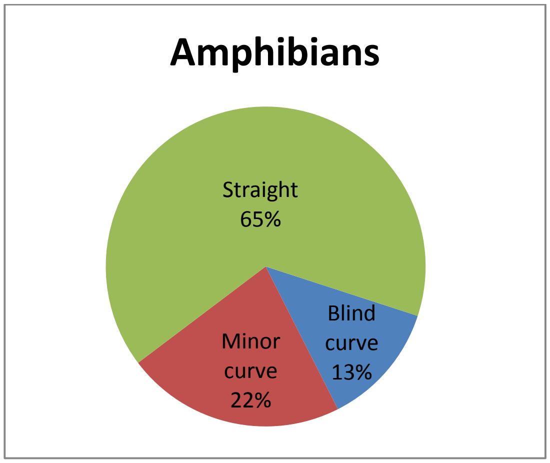
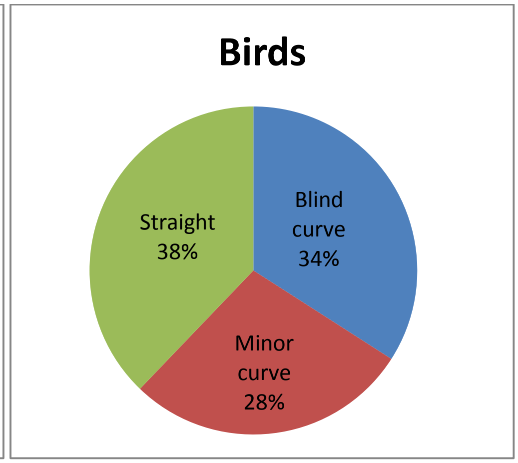
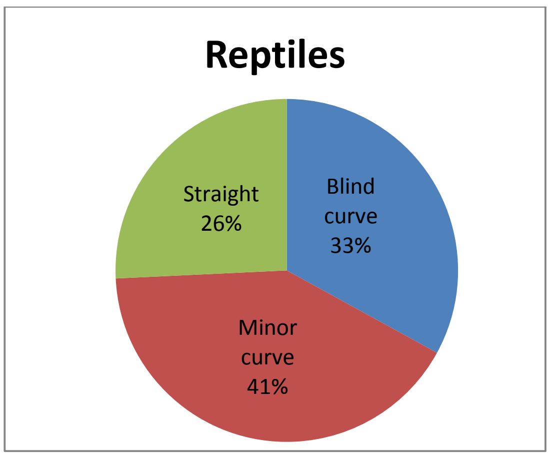


Fig.2.13 Relative occurrence of road kills of different taxa in different physical structures of road (Blind curve / Minor curve / Straight road)







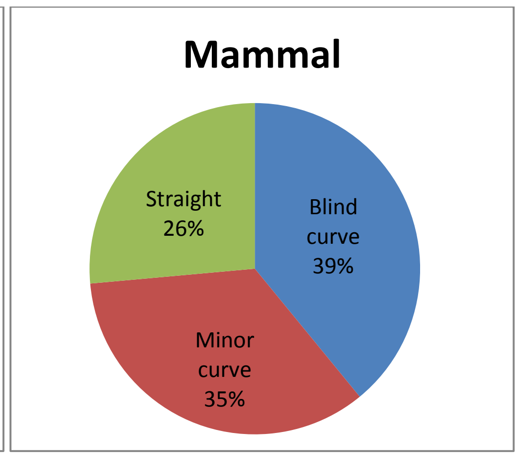


Table.2.5 Occurrence of road kills of different taxa in different physical structures of road

	Blind curve		Minor curve		Straight road	
	Road kills/km	Relative %	Road kills/km	Relative %	Road kills/km	Relative %
Mammal	0.05	26.32	0.05	23.26	0.03	17.81
Birds	0.08	39.47	0.08	32.56	0.08	43.84
Reptiles	0.06	31.58	0.09	39.53	0.04	24.66
Amphibians	0.01	2.63	0.01	4.65	0.02	13.70
		100%		100%		100%

Road kills in different forest type: The study also looked at road kills in different vegetation types along the road. It revealed that birds mortality was high in Eucalyptus forest (ECA) followed by Scrub forest (SF), semi-evergreen forest (SEG) and dry deciduous forest (DDF). High mammal mortaility recorded in semi-evergreen forest. In general, road kills were very less in dry deciduous forest compare to other vegetation types. This is due to the fact that only the ghat section of this road has dry deciduous forest and vehicular speed will be very low due to slopes and hairpin bends. On the other hand, mortality of animals higher in semi-evergreen forest and scrub forest and this could probably be due to larger animal abundance and availability of perennial and seasonal water bodies on both sides of the road.

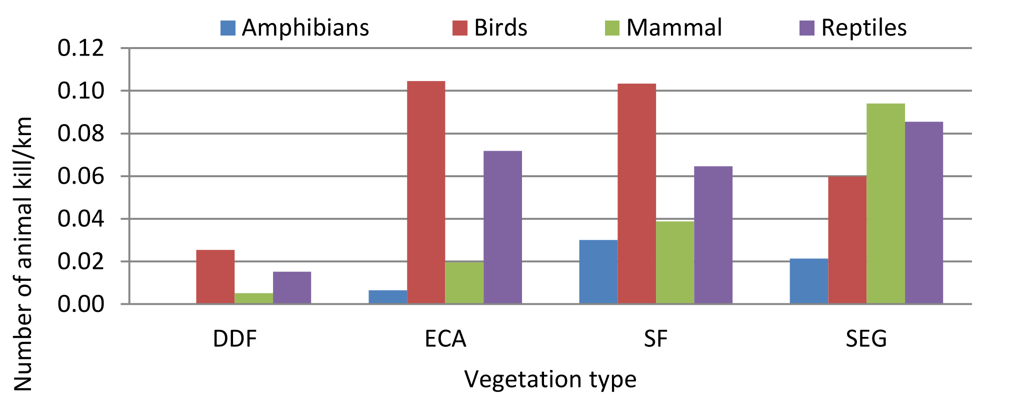


Fig 2.14: Encounter rate of road kills in different vegetation type

Edge effect of road on vegetation and habitat usage by animals

Abundance of trees with respect to proximity of road

Data on distribution of various plant species radially along the roads were assessed to look at the impacts of road. Due to various level of clearance along the road, the distribution of different plant types also varied. A total of 36 tree species were found upto 1000 meter from the proximity of the road . Tree species diversity was recorded high and almost similar between 200 and 800m (Annexure.1) with least diversity recorded in 0m. A Total of 26 shrub species were found at proximity of the road (Annexure.1). Prasad (2009) found that tree death is 250% higher along roads than forest interior. Shrub species diversity was higher at 1000m followed by 0m, 600m, 200m and 400m. A total of five herb species were also found during the survey (Annexure.1) and was found to be positively correlated with the proximity of the road ($R^2 = 0.942$). It clearly reveals that herbs were high near the road and follows the pattern that abundance decreased with increasing distance from road. This could be due to clearing of road edges that facilitates its growth.

A total of three invasive species were found up to 1000 meter from the road. *Latana camara* showed high density at 600m (452.63/ha) followed by 1000m (442.11/ha) and 800m (400/ha) (Tab.2.6). Lowest density of invasive species was recorded for *Casiasophera* 42.11/ha on road edge. No significant correlation with the proximity of the road was observed (Fig.2.15e).

Apart from this, 20 weed species were also recorded in the study area (Tab.9) and this was positively correlated with the proximity of the road ($R^2 = 0.684$) (Fig.3.15d) and reveals that weeds were high near the road and follows the pattern that abundance decreased with increasing distance from road. This could be attributed to periodic clearing of vegetation along the roads encourages weed colonization (Goosem et al. 2010). The increased light levels, exposure, and microclimatic effects of roads such as heating and drying, produce conditions that favour the establishment of alien (exotic) weed species. A road also provides a movement corridor for the dispersal of weeds. This often results in the development of exotic grasslands or shrubby swathes of woody weeds along verges which enables the penetration of more weeds and animal pests alien to the surrounding forest habitat (Goosem and Turton 2002). Invasive alien weed species may spread into adjoining natural ecosystems and affect the natural recruitment of native plant species (Raman 2011).

A combination of greater road width and higher infestation by invasive alien species (*Lantana camara*) in Bandipur Tiger Reserve has been shown to have an impact both on tree death as well as tree community composition (Prasad 2009). Road 'improvements' such as widening, improved surface, paving, and grading, carried out without attention to ecological aspects, often result in greater invasion by alien species and declines in native vegetation in a range of ecosystems from grasslands and semi-arid habitats to forest (Gelbard and Belnap 2003, Prasad 2009).

Table. 2.6. Abundance of Invasive species

Sl.No	Species Name	Density/ha					
		Distance from road					
		0m	200m	400m	600m	800m	1000m
1	*Bidenapilosa*	252.63	326.32	294.74	63.16	231.58	126.32
2	*Lantana camara*	326.32	189.47	400.00	452.63	400.00	442.11
3	*Casiasophera*	42.11	136.84	168.42	157.89	147.37	63.16

Table. 2.7 Abundance of Weeds

Sl.No	Species name	Density/ha					
		Distance from road					
		0m	200m	400m	600m	800m	1000m
1	*Abutilaon indicum*	231.58	263.16	63.16	73.68	147.37	73.68
2	*Acalypha indica*	105.26	73.68	73.68	52.63	73.68	115.79
3	*Alternathera sessilis*	52.63	94.74	52.63	157.89	105.26	73.68
4	*Argemone mexicana*	115.79	178.95	242.11	189.47	94.74	42.11
5	*Blepharismader aspatensis*	663.16	494.74	515.79	357.89	305.26	147.37
6	*Boerhavia diffusa*	42.11	94.74	63.16	31.58	94.74	126.32
7	*Cassia didymobotrya*	21.05	126.32	178.95	115.79	42.11	42.11
8	*Cassia tora*	52.63	105.26	10.53	178.95	73.68	63.16
9	*Croton banplandianus*	126.32	42.11	21.05	73.68	52.63	52.63
10	*Desmodium triquetrum*	42.11	21.05	63.16	0.00	31.58	0.00
11	*Euphorbia hitra*	115.79	126.32	136.84	252.63	73.68	157.89
12	*Leucas aspera*	263.16	231.58	168.42	263.16	210.53	84.21
13	*Mimosa pudica*	389.47	357.89	452.63	589.47	452.63	210.53
14	*Oxalis corniculata*	189.47	221.05	210.53	221.05	94.74	73.68
15	*Phylanthus sp*	84.21	147.37	63.16	136.84	94.74	63.16
16	*Pyllanthus amarus*	347.37	126.32	147.37	189.47	84.21	115.79
17	*Sida cordifolia*	0.00	84.21	0.00	21.05	63.16	52.63
18	*Tephrosia purpurea*	105.26	63.16	157.89	31.58	147.37	31.58
19	*Tribulusterrestris*	305.26	200.00	147.37	84.21	63.16	315.79
20	*Triumfetta annua*	221.05	294.74	389.47	252.63	126.32	115.79

Fig 2.15 Relative abundance of vegetation at different distance from road

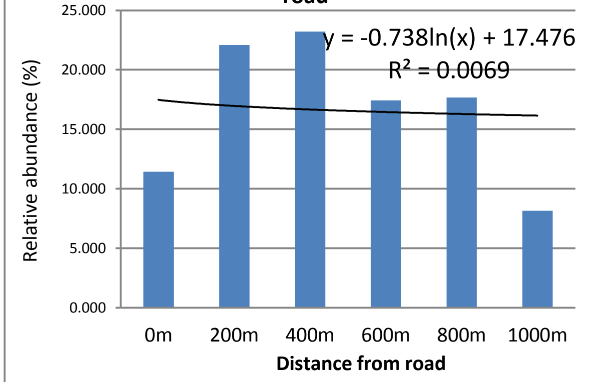


Fig 3.15a Relative percentage of Trees from road

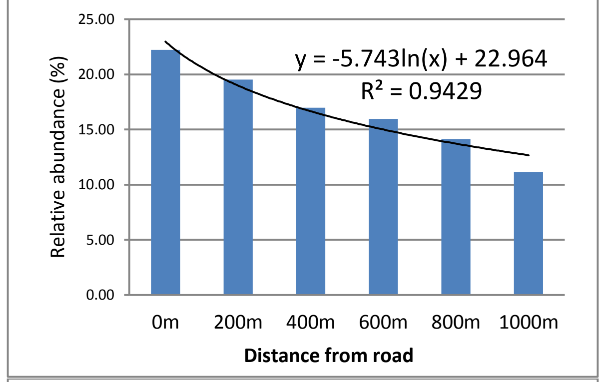


Fig 3.15b Relative percentage of Herbs from road

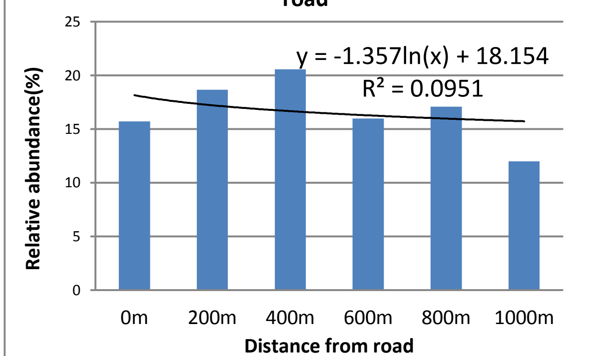


Fig 3.15c Relative percentage of Shrubs from road

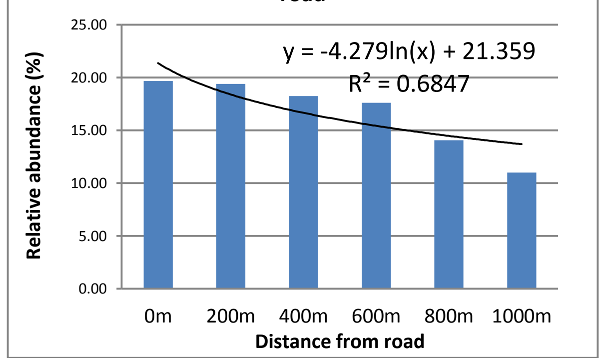


Fig 3.15d Relative percentage of Weeds from road

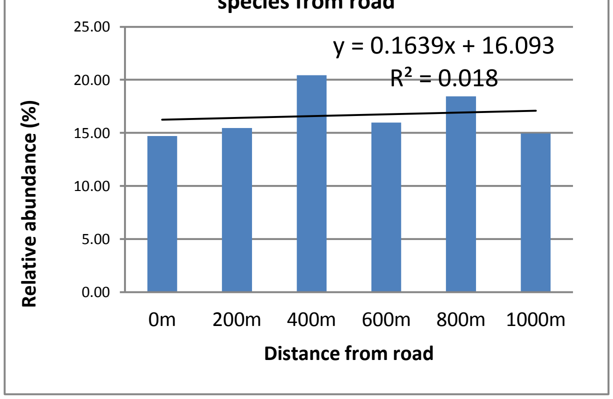


Fig 3.15e Relative percentage of Invasive species from road

Road as barrier or attractants to animals were investigated by assessing the indirect occurrence of various species at different distances from the road. Vehicular traffic on roads may repeal some species, it has also been seen that clearing of vegetation along road edges also creates micro-habitat that attracts animals. The spill from of food and vegetable being carried by vehicles also attracts many species on road, especially the primates and birds. In current study, chitals, barking deers and sambar deers were seen more on road edge and this could be attributed to the abundance of grass along the highway edges due to clearing of vegetation by forest and Highway authorities to increase visibility. This also increases their probability and risk of being hit by vehicles. Interestingly the occurrence of elephants was also more on road edges. One reason could be perennial stream running along road side as well as bamboo patches on either side of the road in semi-evergreen forest areas. Dhole was also seen to use road edges, probably to feed on road kills. Taylor et al. (1985) conducted a mammal survey along roads in Tasmania and concluded that roads increase the ease with which large carnivorous mammals can move into roadside habitats and prey on the fauna living there. In this study area four people were killed and partially eaten by leopard along the road between Bannari Check post and Dimbam during last two years.

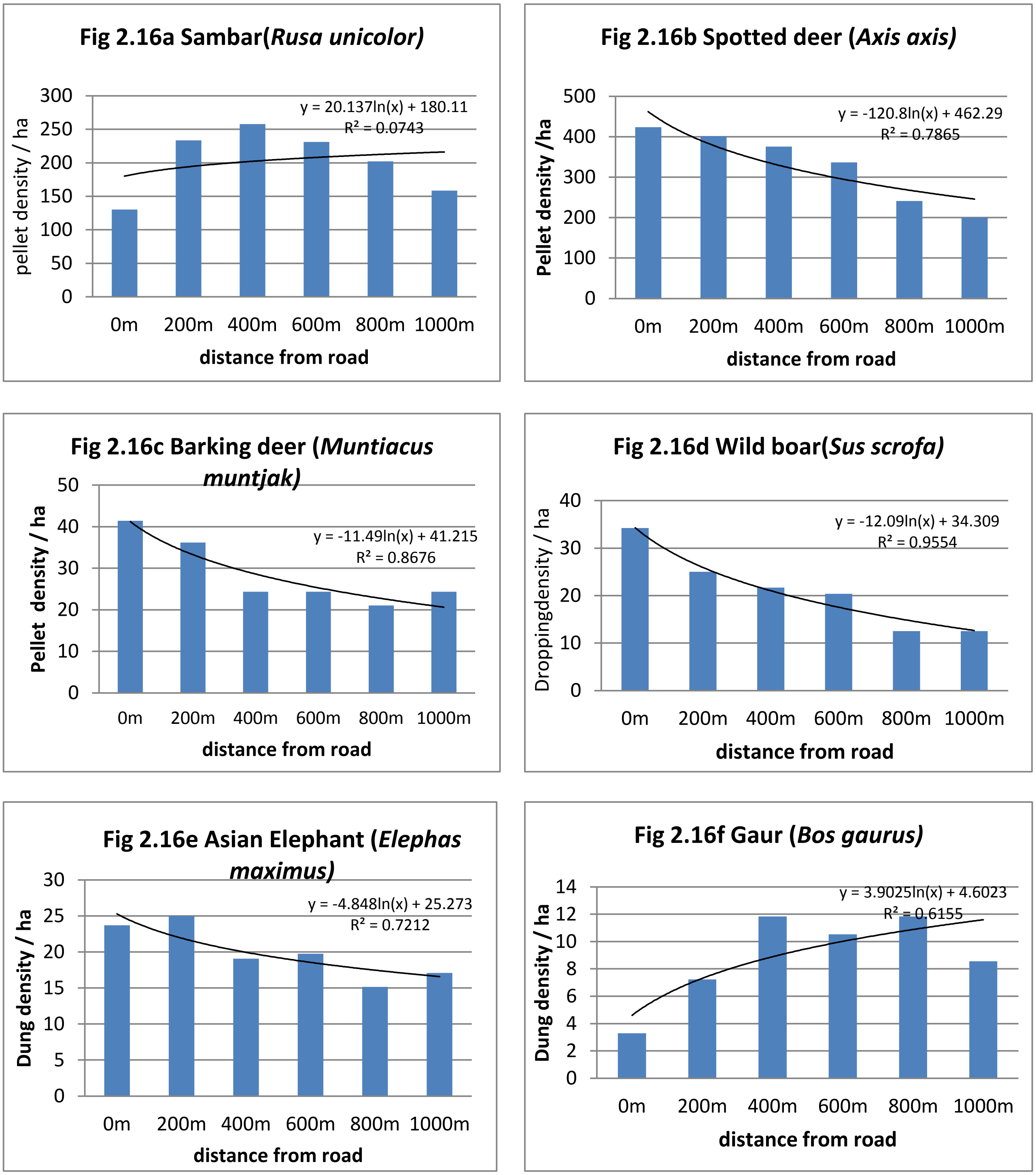
Table 2.8 Habitat preference of mammals at different distance from road

S.no	Vernacular Name	Scientific Name	Dropping density / ha from proximity of the road					
			0m	200m	400m	600m	800m	1000m
1	Asian Elephant	*Elephas maximus*	23.68	25	19.08	19.74	15.13	17.11
2	Barking deer	*Muntiacus muntjak*	41.45	36.18	24.34	24.34	21.05	24.34
3	Civet	*Viverricula indica*	9.868	8.553	14.47	11.84	5.921	11.18
4	Dhole	*Cuon alpinus*	5.263	7.237	7.895	7.895	5.921	5.921
5	Gaur	*Bos gaurus*	3.289	7.237	11.84	10.53	11.84	8.553
6	Leopard	*Panthera pardus*	1.316	1.316	1.974	1.316	2.632	1.316
7	Mouse deer	*Moschiola meminna*	0	0	7.237	12.5	13.82	17.76
8	Sambar	*Rusa unicolor*	130.3	233.6	257.9	230.9	202	158.6
9	Sloth bear	*Melursus ursinus*	4.605	5.921	7.895	9.211	6.579	10.53
10	Spotted	*Axis axis*	423.7	401.3	375.7	336.8	241.4	200
11	Wild boar	*Sus scrofa*	34.21	25	21.71	20.39	12.5	12.5

Table 2.9 Habitat preference of mammals in different forest type

S.no	Vernacular name	Scientific name	Animal dropping density/ha in different forest type		
			Scrub forest (SF)	Semi-evergreen forest (SEG)	Eucalyptus forest (ECA)
1	Barking deer	*Muntiacus muntjak*	109.72	237.50	212.50
2	Civet	*Viverricula indica*	30.56	131.30	28.10
3	Dhole	*Cuon alpinus*	45.83	27.10	46.90
4	Elephant	*Elephas maximus*	131.94	112.50	103.10
5	Indian Gaur	*Bos gaurus*	27.78	75.00	78.10
6	Leopard	*Panthera pardus*	8.33	12.50	9.40
7	Mouse deer	*Moschiola indica*	38.89	104.20	0.00
8	Sambar deer	*Rusa unicolor*	997.22	1402.10	1415.60
9	Sloth bear	*Melursus ursinus*	56.94	6.30	75.00
10	Spotted deer	*Axis axis*	1969.44	1962.50	2025.00
11	Wild boar	*Sus scrofa*	143.06	114.60	106.30

Fig 2.16 Habitat preference of mammals at different distance from road



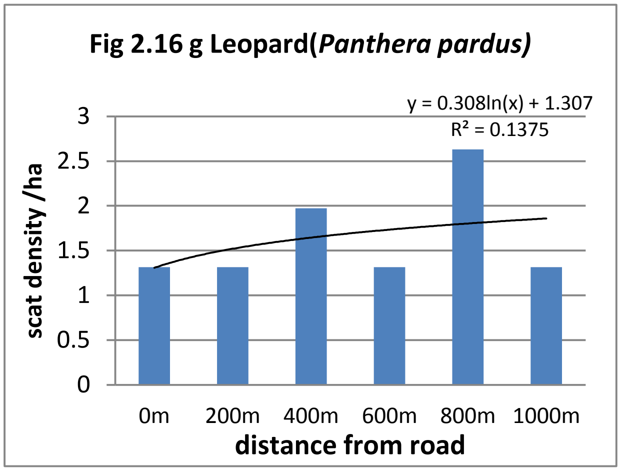


Fig 2.16 g Leopard(*Panthera pardus)*

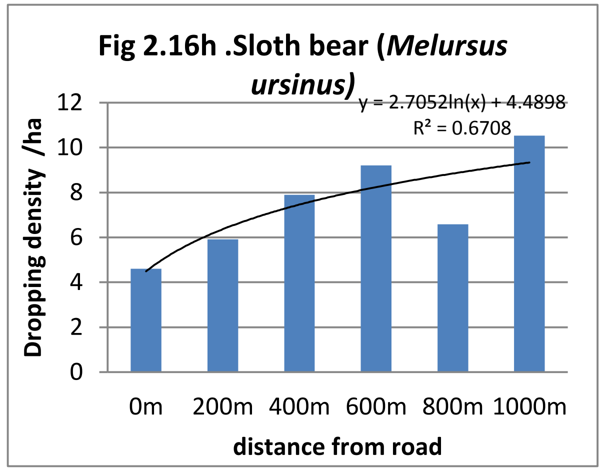


Fig 2.16h .Sloth bear (*Melursus ursinus)*

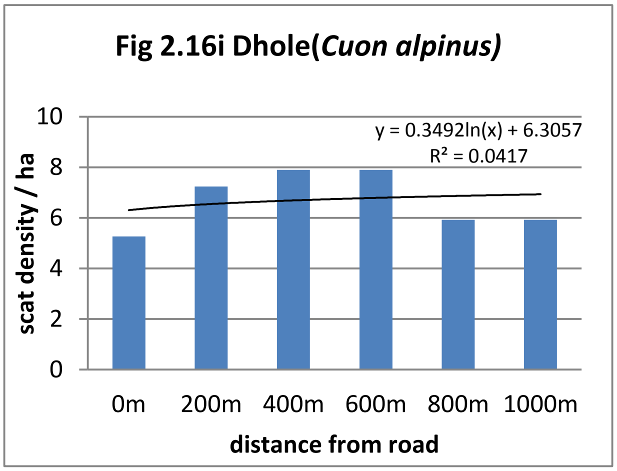


Fig 2.16i Dhole(*Cuon alpinus)*

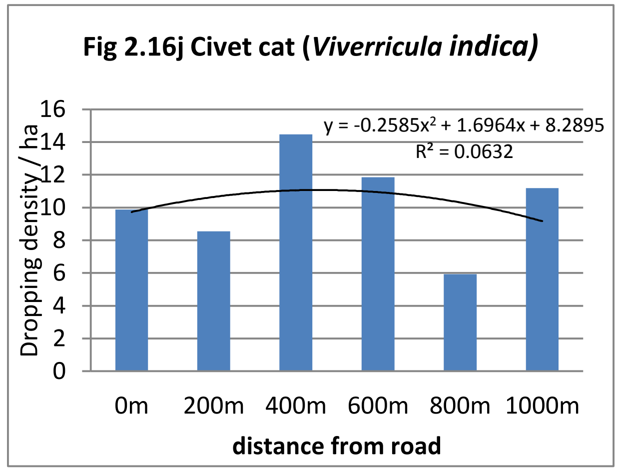


Fig 2.16j Civet cat (*Viverricula indica)*

Underpassage for animal movement

Well-designed tunnels, culverts, pipes and other structures can function as underpass below road and bridges, for a wide range of terrestrial and aquatic species, especially frogs, fish, reptiles, etc (Raman, 2011). The entire stretch of surveyed road patch has about 202 under passes/culverts (cut stone, pipe culvert, RCC pipe, RCC slab culvert, slab/cut stone and steel) contructed mostly for drainage, bridges over streams/rivers and to prevent soil erosin; many of these structures being used by various groups of animals. These includes 135 such structures (cut stone-68, pipe culvert-29, RCC pipe-24, RCC slab culvert-10, slab/cut stone-3 and steel-1) in the State of Tamil Nadu part of road and 67 in the State of Karnataka. These structures/under passes are extremely helpful, especially for smaller groups of animals to move between habitat and without risk of accident by vehicular traffic. The larger ones are being even used by deer and larger carnovores (tigers and leopards). However, as most of these underpasses were not built with the intention to facilitate wildlife movement and being poorly maintained, many of them are not being used by animal. During the survey, we found at least four underpasses being used by wild animals and were taken up for monitoring. In total 18 replicates were undertaken for monitoring each underpass.

Underpass-I (Bridge-I): This underpass is in thorn forest (GPS location 11.54706N 77.15785E) and was constructed over the stream for passage of vehicle. The underpass has three compartments and the width of the underpass is 6 meter and height is 5 meter. The underpass is being used by cattle, wild boar, sambar, chitals, bonnet macaque, etc. No signs of elephant, tiger or leopard were seen during the survey and elephants definitely are not using this passage due to low height of the culvert.

Underpass-II (Bridge-II): This underpass is located in thorn forest close to the starting point of Ghat road from Bannari checkpost (GPS location 11.58227 N 77.13250 E) near Pillayar temple and is part of Talamalai- Guttiyalatur elephant corridor. The underpass has three compartments and the width of the underpass is 4 meter and height is 6 meter. This is being widely used by large number of species. During survey, indirect signs of leopard, dhole, sambar deer, chital, wild boar and bonnet macaque were observed. Elephant foot print was also seen close to the bridge but no evidence of the usage of under pass seen. There is a temple close to the bridge and garbages are thrown that attracts deer and primates.

Underpass-III (Bridge-III): This underpass is located in forest patch dominated by bamboo after Punjur and close to Chamrajnagar-Talamalai at Muddahalli elephant corridor (GPS location 11.80162 N 77.04836 E). The underpass has only one compartment and the width of the underpass is 4 meter and height is 5 meter. During survey, indirect signs of leopard, dhole, sambar deer, chital, wild boar, bonnet macaque and pea fowl were observed. Elephant dung was seen few meters from the underpass but no sign of its usage. .

Underpass-IV (Bridge-IV): This underpass is located at the end of forest patch and close to Eucalyptus plantation (GPS location 11.81117N 77.01727E) over the stream connected with Suvarnavathi dam. The underpass has two compartments and the width of the underpass is 6 meter and height is 7.5 meters. Indirect signs of sloth bear, sambar, chital, wild boar recorded but also heavy use by cattle.

Fig 2.17: Location of the four underpasses studied

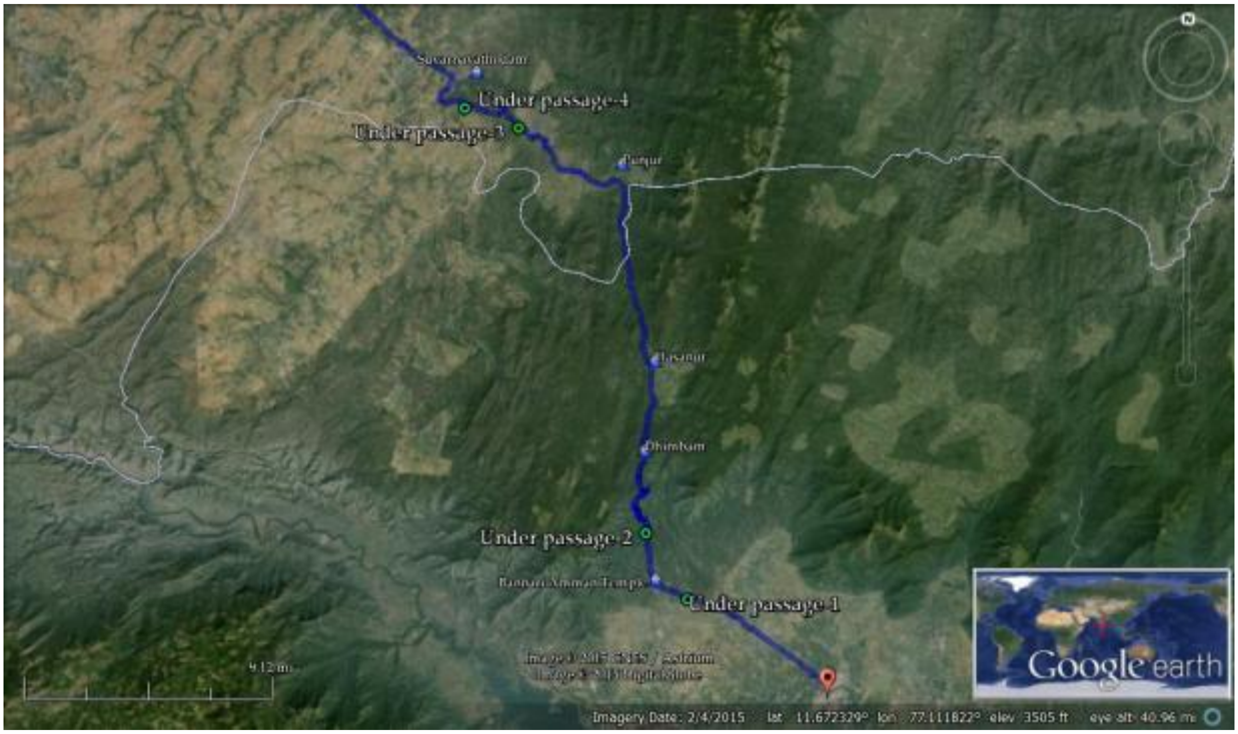


Table 2.10: Mean animal detection of species using the underpass

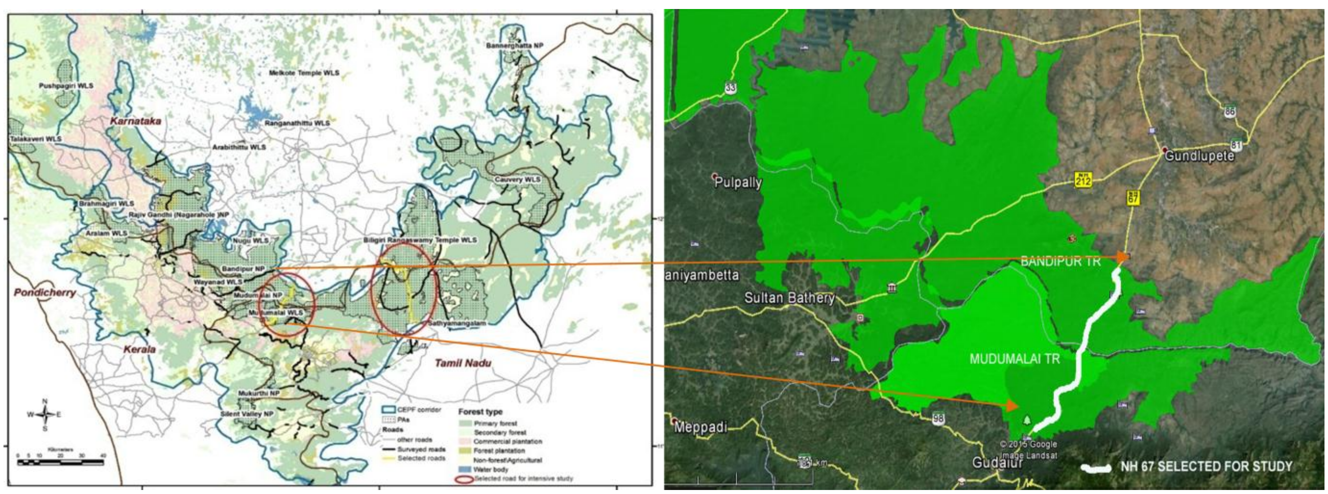
Vernacular name	Scientific Name	Underpass-I		Underpass-II		Underpass-III		Underpass-IV	
		6wx5h(m)		4w/6h(m)		4wx5h(m)		6wx7.5h(m)	
		Average number of dropping per sampling	Relative	Average number of dropping per sampling	Relative	Average number of dropping per sampling	Relative	Average number of dropping per sampling	Relative
		(N=33)	%	(N=48)	%	(N=41)	%	(N=24)	%
Bonnet macaque	*Macaca radiata*	0.61	33.33	0.56	20.97	0.33	14.47	0.17	12.69
Dhole	*Cuon alpinus*	0	0.00	0.17	6.37	0.11	4.82	0	0.00
Leopard	*Panthera pardus*	0	0.00	0.28	10.49	0.06	2.63	0	0.00
Mouse deer	*Moschiola indica*	0	0.00	0	0.00	0.39	17.11	0	0.00
Sambar deer	*Rusa unicolor*	0.39	21.31	0.44	16.48	0.5	21.93	0.17	12.69
Sloth bear	*Melursus ursinus*	0	0.00	0.22	8.24	0	0.00	0.11	8.21
Spotted deer	*Axis axis*	0.44	24.04	0.67	25.09	0.39	17.11	0.5	37.31
Wild boar	*Sus scrofa*	0.39	21.31	0.33	12.36	0.5	21.93	0.39	29.10

Most of these structures could be markedly improved for animal usage with some minor changes and proper maintenance. The height of the passage below the bridge could be increased for all these bridges by digging the under surface and landscaping in a way that would channelize animal flow, especially Underpass-IV whose height could be increased to 8.5meters that may facilitate elephant movement. The sidewalls of the bridge above the underpass should be blind and install screen to a minimum of 3.5 m high so that the moving vehicle on the road is not visible nor the glares of vehicles light passing on the bridge. The sidewalls of the structure should be camouflaged and local vegetation should be planted in the bed of the structure so that it should look like an integral part of the forest. No tree in the alignment of the structure should be cut; rather it should be protected. Both sides of the road near the underpass could be fenced for some distance to channelize and encourage animals use the underpass. Most of the underpasses are not well maintained and is full of bushes and vegetation that hinders animal movement. Animal movement in the under passage could also be facilitated if the bushes are cleared periodically.

Impact of Gudalur to Mysore road (NH67) on wildlife

The NH 67 connects Nagapattinam, Tamil Nadu with Gundlupet, Karnataka. The road from Thorapalli to Bandipur passes through Mudumalai Tiger Reserve and Bandipur Tiger Reserve for a length of around 27km and was selected for intensive study to assess the impact of road on wildlife in Deciduous forest. The dominant forest type along the road stretch is tropical dry deciduous. The vehicular traffic intensity in the stretch is high at around 3500 vehicles per day. Few studies has been carried out on impact of this road on vertebrates (Boominathan *et al.*, 2008, Baskaran & Boominathan, 2010, Selvan *et al.*, 2012), snakes, (Gokula, 1997) and insects (Rao & Girish, 2007).

Fig 2.19 Map of Nilgiri- Mysore landscape showing Bandipur TR and Mudumalai TR with NH 67



Bandipur Tiger Reserve

Bandipur Tiger Reserve covering an area of around 874 km^2 is contiguous with large natural habitats in the Nilgiri Biosphere Reserve and Mysore plateau including Mudumalai Tiger Reserve, Nagarhole Tiger Reserve, Sathyamangalam Tiger Reserve, Nilgiri North Forest Division and Wayanad Wildlife Sanctuary forming an important wildlife haven for a wide range of animals including long ranging mammals like elephant, tiger and Indian gaur. The terrain is undulating with low hills, and the altitude varies from 800m to 1500m. The highest peak is at

1450m (Gopalaswamy Betta). The Nugu and Kabini rivers flow through the northern portions of the reserve and are the main sources of water during the dry season. The reserve is dominated by mixed dry deciduous forest type. The forest type changes from dense mixed deciduous forest type in the western side of the reserve to open dry deciduous forest in the middle to the tropical dry thorn forest in the eastern side. The major mammalian species in the reserve are Asian elephants, tiger, wild dog, leopard, sloth bear, Indian gaur, sambar deer, spotted deer, mouse deer, langur, bonnet macaque, four horned antelope, etc.

There are two national highways running through the tiger reserve- NH 67 and NH212. The NH67 connects Nagapattinam in Tamil Nadu with Gundlupet in Karnataka. The NH 212 connects Calicut in Kerala with Kollegal in Karnataka. The night traffic is closed between 9 pm and 6am in the Tiger Reserve through these roads to reduce road kills.

Mudumalai Tiger Reserve

The Mudumalai Tiger Reserve in the Nilgiri Biosphere Reserve is situated in the state of Tamil Nadu. It covers an area of 321 km^2 and is contiguous with Bandipur Tiger Reserve, Wayanad Wildlife sanctuary and Nilgiri North Forest Division forming an important habitat for large mammals like elephants and tiger. Rainfall ranges from 800-2000m and the forest types vary from moist deciduous forest in the western side to the dry deciduous and thorn- scrub to the eastern side of the reserve. The major mammals in the reserve includes Asian elephants, tiger, wild dog, leopard, sloth bear, Indian gaur, sambar deer, spotted deer, mouse deer, langur, bonnet macaque, four horned antelope, stripped hyena, blackbuck, wild boar, jackal, porcupine, common mongoose, stripe necked mongoose, ruddy mongoose, common palm civet, small Indian civet, jungle cat, leopard cat, rusty spotted cat, Indian giant squirrel etc.

There is one national highway (NH67) and one interstate highway passing through the reserve. The vehicular traffic is banned on these roads between 8.30 pm to 6.00am to reduce the road kills.

Results and Observations

The stretch of NH 67 from Thorapalli to Bandipur passing through Mudumalai Tiger Reserve and Bandipur Tiger Reserve for a length of around 27 km was select for study.

The vehicular traffic density in the stretch is high at around 3500 vehicles per day between 6.00 AM and 9.00 PM. As soon as the traffic opens in morning at 6.00AM, there is high flow of traffic and increases to about 500 vehicles per hour between 6-7 AM and then after average of about 200 vehicles per hour. There is a slight increase of traffic between 5-6 PM to ensure that the vehicle is out of the Tiger reserve by 9 PM. The movement of four wheelers and six wheelers are high with very little movement of two wheelers and heavy vehicles. The drop in heavy vehicles could be attributed to night ban when most of the tourist bushes and other heavy vehicles carrying good move.

Fig 2.20 Traffic volume on NH 67 from 6 AM to 9 pm

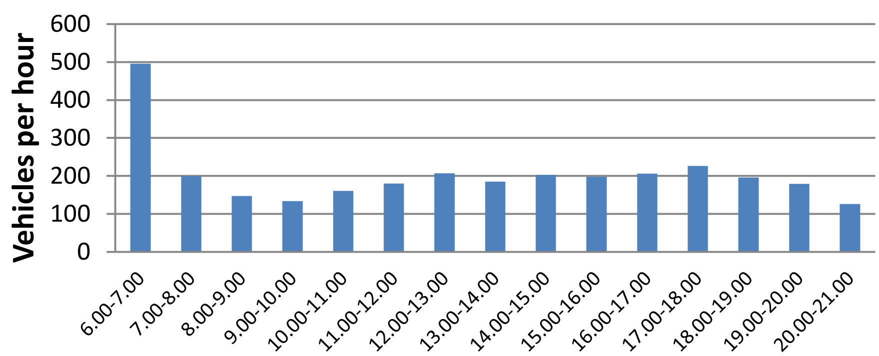
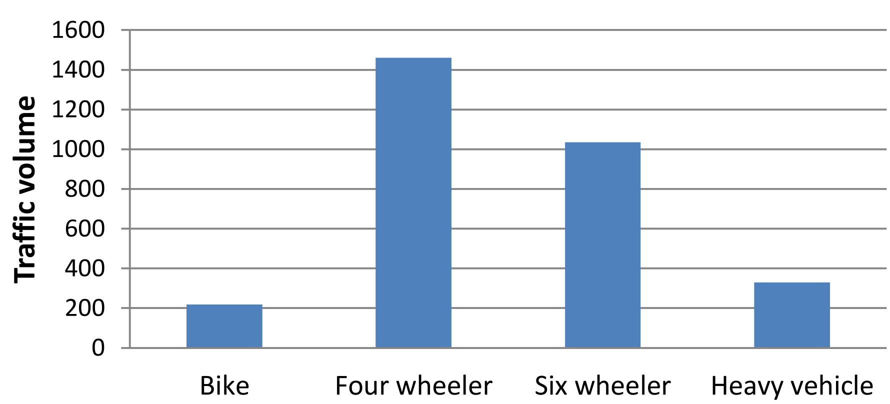


Fig 2.21 Daily traffic volume and vehicle type



Road kill

Data on road kill was collected from October 2014 to March 2015. A total of 75 roads kills belong to 22 species recorded through vehicle transects replicated 38 times between October 2014 and March 2015. The study collected data on road kill of four taxa (mammals, birds, reptiles and amphibians). A total of 22 species were found affected by road kill (table 2.11). Among the taxa, large number of reptiles (10 species) were killed on the roads followed by Birds (6 species) and mammals (5 species). Only two species of amphibians were found killed on road which could be due to season of survey. However almost 24% of the road kill was on Common Indian toad (*Duttaphrynus melanostictus)* at rate of 0.017 individuals/km. Bhaskaran and Boominathan (2010) reported similar observation in Mudumalai TR where they reported that among the road kills, the Common Indian toad was the most susceptible species for the vehicular traffic and accounted for over 50% of the road kills.

Baskaran and Booiminathan (2010) study on this road also revealed that most of the species killed were reptiles (16), followed by mammals (13), birds (8) and amphibians (3). However, the study was carried when there was neither night traffic regulation nor the speed breakers and hence large number of individuals and species killed. The present study did not report death of any large species.

The study revealed an average of 0.073 road kills per km. This is very less compared to 0.42 kills per km reported by Selvan et al. 2011 who conducted the study prior to the night traffic ban. Thus the night ban has significantly contributed to reducing the road kill apart from other management interventions like speed breakers and sensitization of public.

Table.2.11 Encounter rate of road kills in Bandipur – Thorappalli road

Common name	**Scientific name**	**Road kill/km**	**Relative % of road kills**
Mammals			
Bat species		0.001	1.33
Black-naped hare	*Lepus nigricollis*	0.001	1.33
Grey mongoose	*Herpestes edwardsii*	0.001	1.33
Rat species		0.012	17.33
Three-striped palm squirrel	*Funambulus palmarum*	0.004	5.33
Birds			

Bird sp		0.004	5.33
Chestnut- shouldered petronia	*Gymnoris xanthocollis*	0.001	1.33
Southern Coucal	*Centropus (sinensis) parroti*	0.001	1.33
Indian robin	*Saxicoloides fulicatus*	0.001	1.33
Jungle babbler	*Turdoides striata*	0.001	1.33
Oriental magpie robin	*Copsychus saularis*	0.003	4.00
Red-whiskered bulbul	*Pycnonotus jocosus*	0.001	1.33
Reptiles			
Bibroni coral snake	*Calliophis bibroni*	0.002	2.67
Buff-striped keelback	*Amphiesma stolatum*	0.001	1.33
Common krait	*Bungarus caeruleus*	0.001	1.33
Common trinket snake	*Coelognathus helena helena*	0.004	5.33
Common vine snake	*Ahaetulla nasuta*	0.001	1.33
Common wolf snake	*Lycodon aulicus*	0.002	2.67
Elliot's shieldtail	*Uropeltis ellioti*	0.001	1.33
Green keelback	*Macropisthodon plumbicolor*	0.001	1.33
Mabuya sp	*Mabuya sp*	0.007	9.33
Ornate flying snake	*Chrysopelea ornata*	0.001	1.33
Snake unidentified		0.002	2.67
Amphibians			
Common Indian toad	*Duttaphrynus melanostictus*	0.017	24.00
Frog unidentified		0.002	2.67

Road kills in different physical structures of road (straight and curved road)

The study also looked at which part of the road most of the accidents happened and their physical features. Occurrence of road kills in different physical structures of road revealed that highest numbers of individuals were killed on straight road irrespective of the taxa with very less number of individuals killed in the curves (table 2.12.) Road kills within straight road revealed that the highest percentage were recorded in reptiles 31.90% followed by mammals (27.11%), Amphibian (25.52%) and birds (15,95%). It is interesting to note that none of the bird species were killed on curves. On straight roads, vehicle drivers tend to speed and in spite of

Fig 2.22 Animals being feed on curve

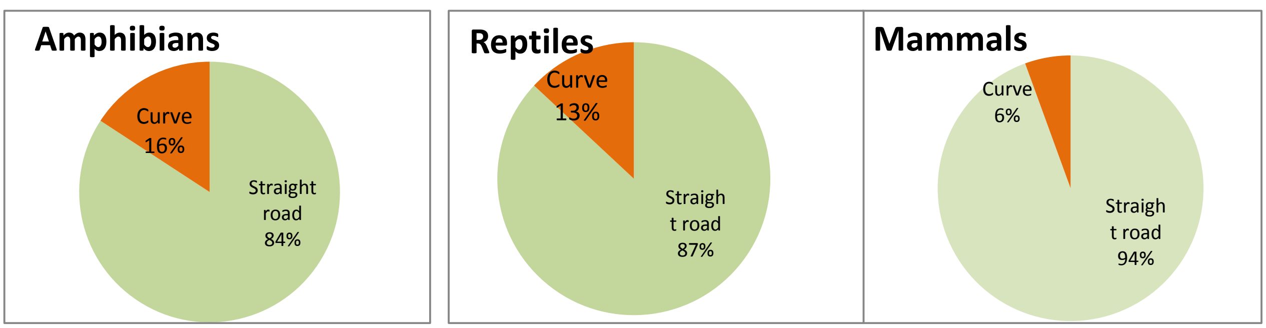
speed breakers results in accident and death of animals at certain places where inter speed breaker distance not effective.

Table. 2.12 Encounter rate of road kills in different physical structures of road

Species	Road kills/km on straight road (Distance surveyed-920km)	Relative %	Road kills/km on curves (Distance surveyed-125km)	Relative %
Amphibians	0.015	25.52	0.003	41.012
Reptiles	0.019	31.90	0.003	41.012
Birds	0.010	15.95	0.000	0.000
Mammals	0.016	27.11	0.001	13.671

Relative percentage of road kills of indicated that about 94% of mammal, 84% of amphibians, 87% of amphibians and all bird kills occurred on straight road. Overall 89.5% of road kills was reported from straight road.

Fig.2.23 Relative percentage of road kills of different species in different physical structures of road



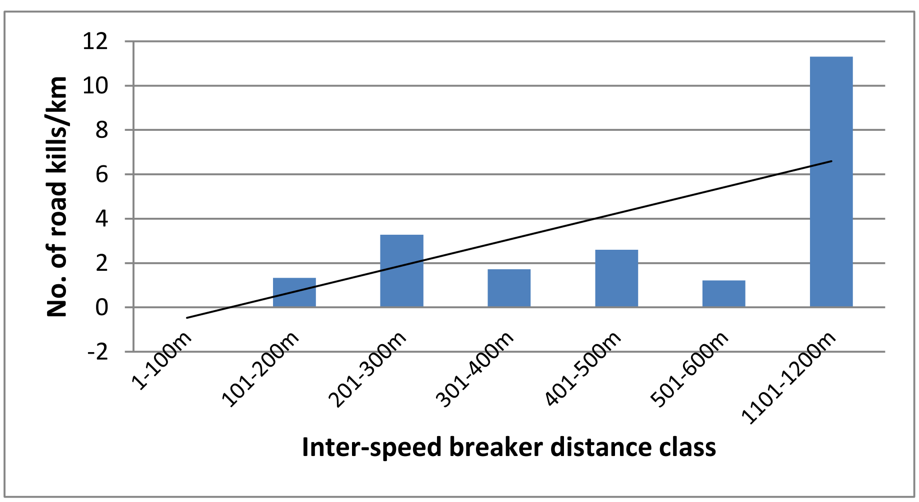
Road kills and speed breakers

Vehicular speed is a major reason of road kill is most part of the world. Hence, it is important to regulate vehicular speed through appropriate barricades and speed breakers/ speed humps. We investigated the encounter rate of road kills with respect to inter-speed breaker distance (Table 2.13). The stretch under study has 75 speed breakers of which 38 were in Bandipur section. The study revealed that road kills were recorded high in 1101-1200m distance class (11.3 road kills/km) followed by 201-300m (15.27 road kills/km) and 401-500m (12.10 road kills/km) (Tab.2.13 & Fig.2.24). Pearson correlation shows significant correlation between the inter speed breaker distance and corresponding road kills in Bandipur Tiger Reserve (r=0.746, p=0.01). The present study shows that with speed breaker distance of maximum 600m, the vertebrate road kills did not show significant difference, but when the inter speed breaker distance was at 1100-1200m, there was a significant increase in the road kills. This shows that increase of inter speed breaker distance beyond 600m increased the probability of accident. Detailed studies with more distance categories of inter speed breaker regions would help in understanding the effective inter speed breaker distance to reduce the road kills as well as in optimizing the frequency of speed breakers. However, the speed breakers have significantly contributed in reducing road kills and almost no incidence of road kill of larger mammals reported during the study period.

Table.2.13 Encounter rate of road kills between inter- speed breakers

Inter-speed breaker distance class	No of road stretches	No of road kills/km	Relative % of road kills
1-100m	4	0.00	0.00
101-200m	5	1.33	6.22
201-300m	11	3.27	15.27
301-400m	5	1.71	8.00
401-500m	6	2.59	12.10
501-600m	3	1.21	5.66
1101-1200m	1	11.30	52.75

Fig. 2.24 Pictorial representation of encounter rate of road kills between inter- speed breakers



Road kills in different forest type

There are only two forest types found along the Bandipur – Thorappalli road. In deciduous forest, encounter rate of road kills of all taxa was more or less similar except birds (Fig.4). In teak plantation, encounter rate of road kills of reptiles were high and remaining three taxa had very low mortality.

Overall Occurrence of road kills were high in deciduous forest (63%) compared to teak plantation (27%) and showed significant correlation to the number of road kills. High mortality in deciduous forest compared to teak plantation is attributed to both larger abundance of animals in deciduous forest and probably also due to better visibility in teak plantation areas.

Fig 2.25 Encounter rate of road kills in diffrent vegetation types

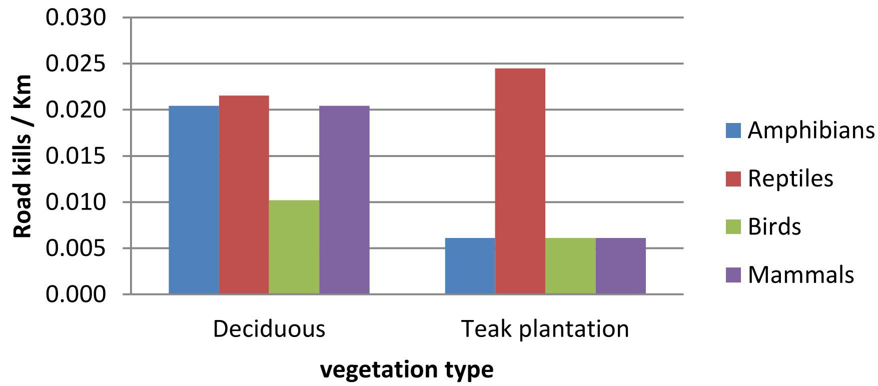
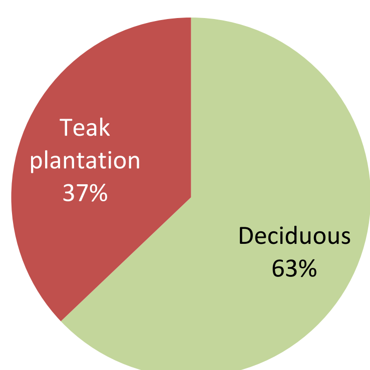
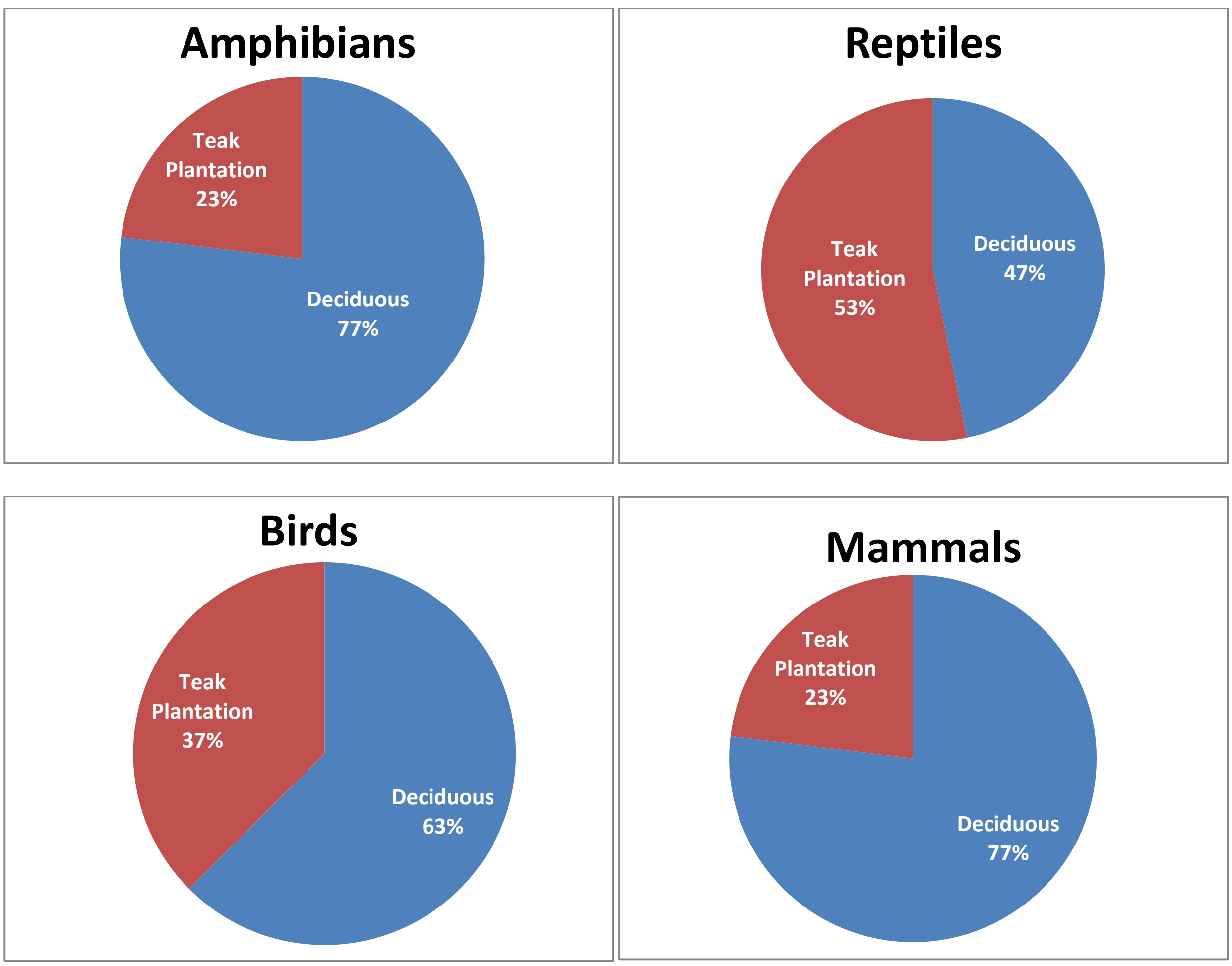


Fig 2.26 Relative percentage of road kills in diffrent forest types



Relative percentage of road kills from different categories of species in different forest types revealed maximum death of mammals, amphibians and birds in deciduous forest. Reptile mortality was evenly placed in both forest types.

Fig. 2.21 Relative percentage of road kills from different categories of species in different forest types



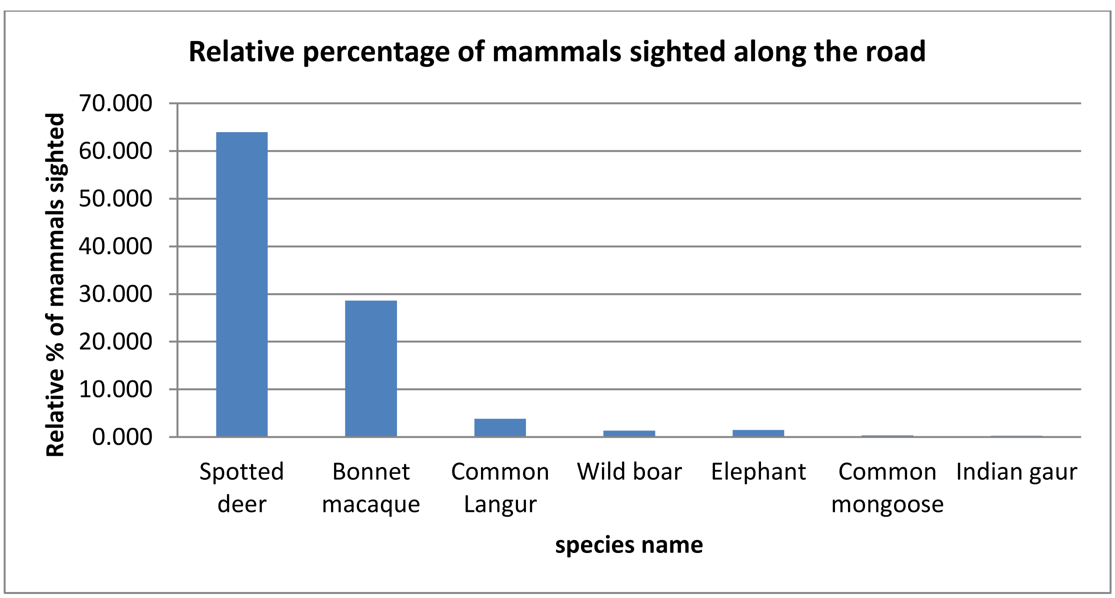
Encounter rate of mammals on the road

The encounter rate of mammals sighted during vehicular transects replicated 36 times between 6.30 AM to 9.30 AM were recorded. A total of seven mammal species were sighted along the road during the survey. Of these spotted deer sighting attributed was high at 2.47/km followed by Bonnet macaque (1.1/km), Common langur (0.15/km) and elephant (0.06/km) (Tab.2.14). Relative percentage of mammal sighting along the road revealed that spotted deer alone attributed for 64% and remaining 36% of sighting contributed by six species (Fig.2.28). The presence of bonnet macaque and common langur on the road was mostly due to the availability of food thrown by passengers.

Table. 2.14. Encounter rate of mammals along the road

Sl.No	Species	No. of animals sighted/ km (N= 383)	No. of groups sighted /km
1	Spotted deer	2.47	0.15
2	Bonnet macaque	1.10	0.14
3	Common Langur	0.15	0.04
4	Wild boar	0.05	0.03
5	Elephant	0.06	0.02
6	Common mongoose	0.01	0.01
7	Indian gaur	0.01	0.01

Fig.2.28. Relative percentage of mammals sighted along the road



Recommendations to minimize road kill and facilitate animal movement on NH 209

One of the major impacts of roads apart from habitat loss and fragmentation is road kills. Irrespective of whether road mortality is significant to the survival of a species or not, there is economical and ethical concern that demands for the construction of mitigation measures. To minimize the negative impact of NH-209 of forest and wildlife and to facilitate movement of animals, the following measures are highly recommended

1. **Vegetation clearance**: Vegetation on both sides of the road minimizes visibility of drivers and it is important to clean them periodically. However, this should not be done randomly and care should be taken to retain the native species, else it will proliferate growth of weeds and invasive (Raman, 2011). In stretch of roads with curves, vegetation clearance should be not more than three meters and in other areas, it should not be more than two meters.

2. **Speed breakers**; Most of the accidents have been reported from areas with minor curves and in plains (level) with straight road. Speed breakers should be installed in these areas to regulate speed and avoid accidents. Based on locations of minor curves, straight roads, road kills, connecting forests and wildlife movement, especially elephant corridors, it is suggested to install speed breakers between Bannari Check gate to Pillayar temple, Dhimbam to Hasanur, Hasanur to Punjur and Punjur to Suvarnavathi dam. The locations of the speed breakers have been shown with GPS locations in the maps below (fig 2.18a-2.18d).

3. **Underpasses**: Many of the underpasses, essentially meant for drainage and vehicular movement are not being maintained properly. Many of the speed breakers being suggested above could be avoided if these underpasses are maintained and some of them modified to facilitate animal movement including elephants as the road passes through three elephant corridor. It is suggested to

    a. Proper maintenance and clearing of all the structures to facilitate animal movement, especially amphibians and reptiles.
    b. The height of the passage below the bridge could be increased for all these bridges by digging the under surface and landscaping in a way that would

channelize animal flow. The usage could be further increased by creating barriers along the road and channelizing the animals to use the under passage.

c. The sidewalls of the bridge above the underpass should be blind and install screen to a minimum of 3.5 m high so that the moving vehicle on the road is not visible nor the glares of vehicles light passing on the bridge. The sidewalls of the structure should be camouflaged and local vegetation should be planted in the bed of the structure so that it should look like an integral part of the forest. Both sides of the road near the underpass could be fenced for some distance to channelsie and encourage animals use the underpass. Most of the underpasses are not well maintained and is full of bushes and vegetation that hinders animal movement.

4. **Scientifically designed Sign boards**: Along with speed breakers, scientifically designed sign boards (for quick information/message) depicting wildlife safety to sensitize vehicle drivers should be installed, especially on minor curves and straight road. Most of the sign boards along the road are so poorly designed that it does not convey the message to the driver moving in high speed.

5. **Speed regulation**: Impose speed restriction (40 kmph) on vehicle passing through this road after 9 PM. Install speed detection devices and speed cameras at sensitive stretches (SEG/Scrub forest) and at identified wildlife corridors to monitor and regulate speed in night and early morning (9 PM-6AM).

6. **Restrict vehicle movement**: Since night ban may not be a feasible option on this stretch, it is advised to have convoy systems (every 30 mins) with regulated speed and timing with dual check points to restrict frequent movement of vehicles. To minimize influx of private and tourist vehicles, high toll during late evening to early morning (9 PM-6AM) be imposed. However, night ban should be imposed on all commercial vehicles. The toll collected could be used for wildlife conservation.

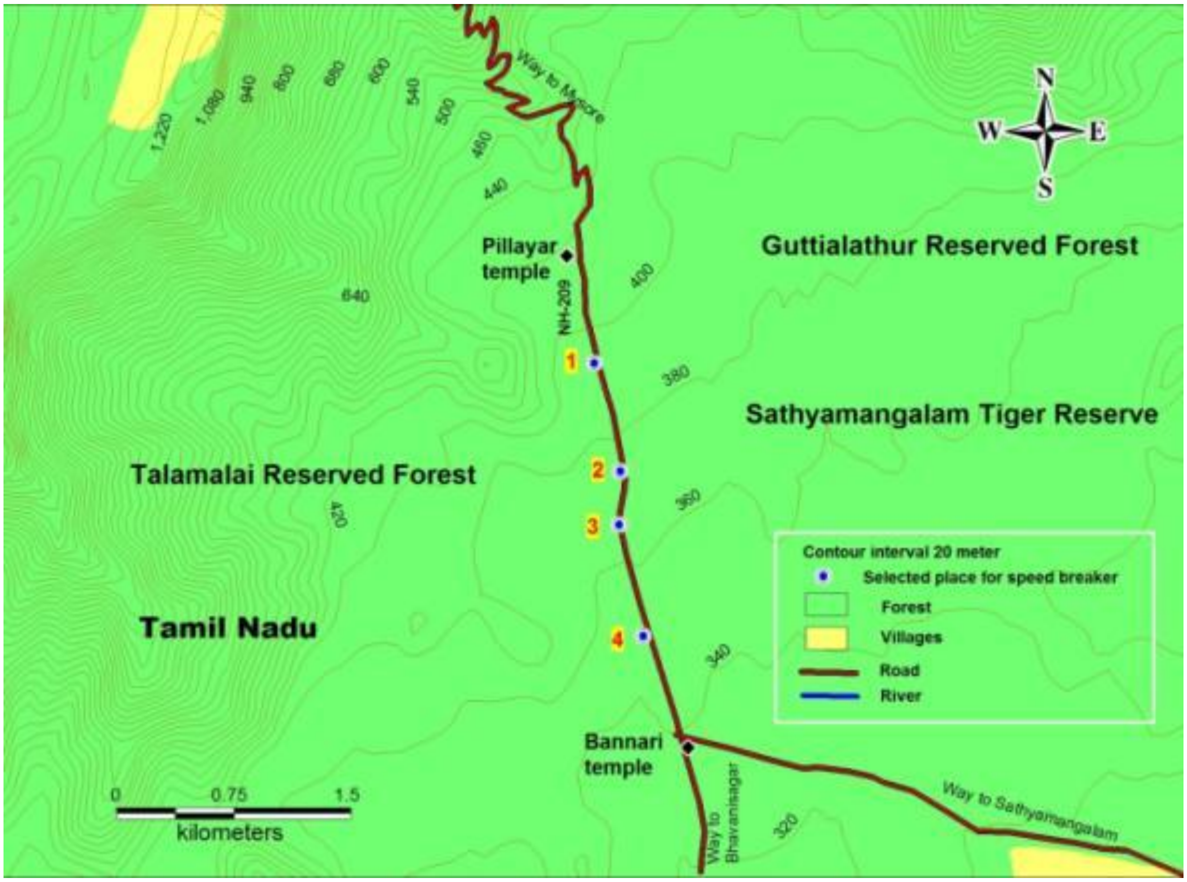
7. **No dumping of food waste**: Large number of vehicles carrying vegetables ply on the road every day. No dumping or off loading of these food and vegetable be allowed along the road as they attracts animals. This should be made a punishable offence and fine imposed.

8. **Prohibit feeding of animals**: strict enforcement to prohibit feeding of animals, especially primates. This should be supplemented with proper education of people using the road.

9. **Make NH 209 litter free**: prohibit dumping of litters and garbage along the road and make it a punishable offence. Strict enforcement especially during festivals as there is large numbers of temples along the road.

10. **Sensitizing drivers and people using the road**: This should be undertaken periodically, especially during festival times with scientifically designed sign boards at critical locations.

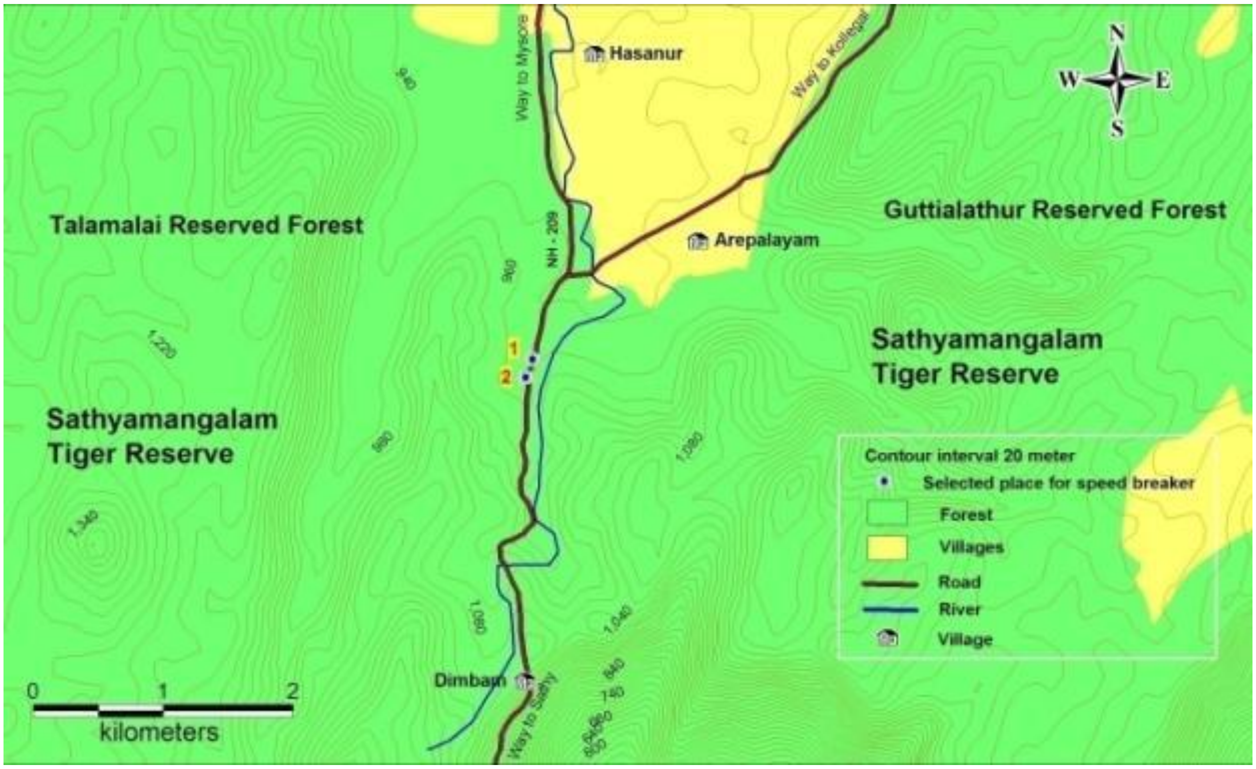
Fig 2.18a Location of speed breakers between Bannari Check Gate and Pillayar temple



Coordinates of speed breakers – Dimbam - Bannari road

Sl.No	Latitude	Longitude
1	11.574269	77.133547
2	11.567910	77.135070
3	11.564770	77.135000
4	11.558212	77.136410

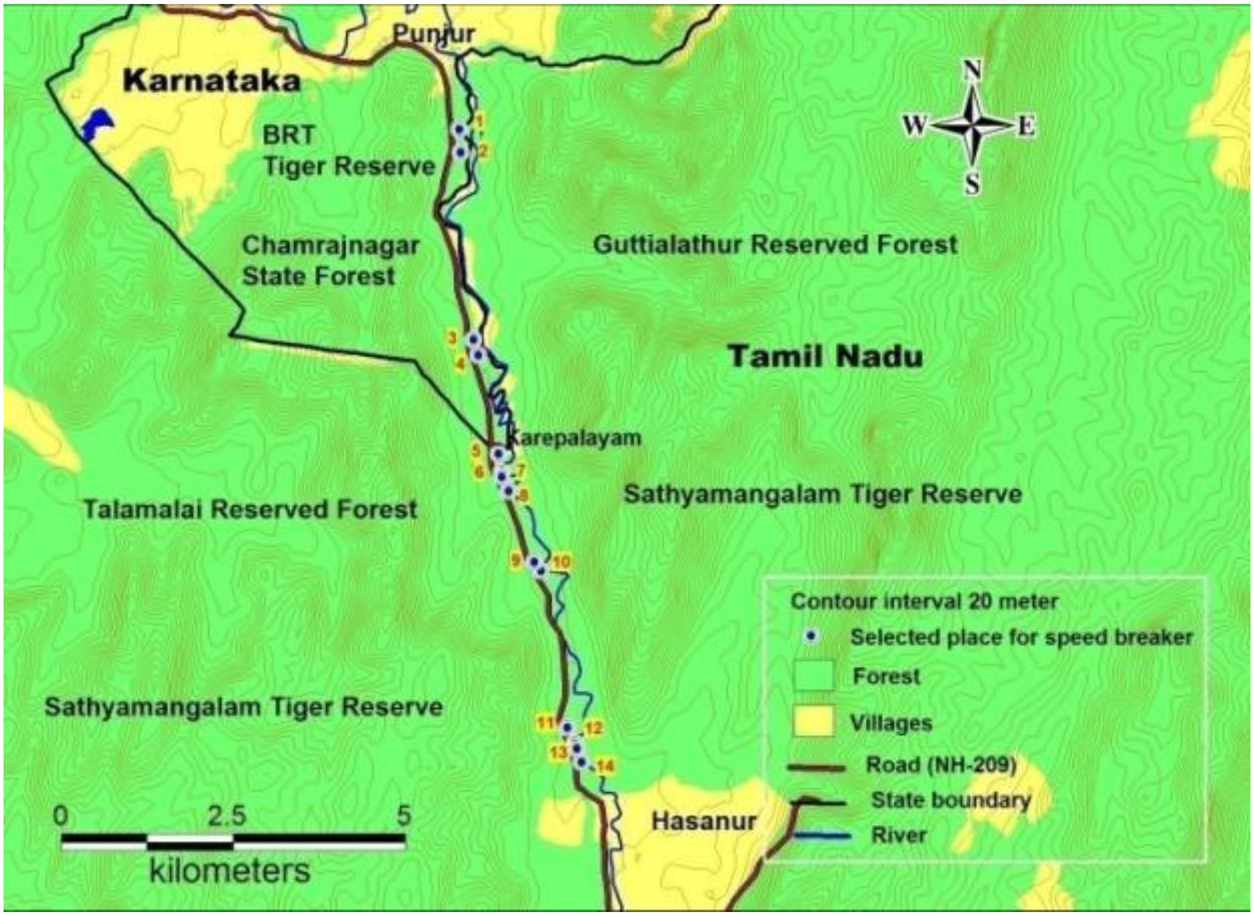
Fig 2.18b Location of speed breakers between Dimbam and Hasanur



Coordinates of speed breakers –Hasanur – Dimbam road

Sl.No	Latitude	Longitude
1	11.645710	77.129830
2	11.644420	77.129350

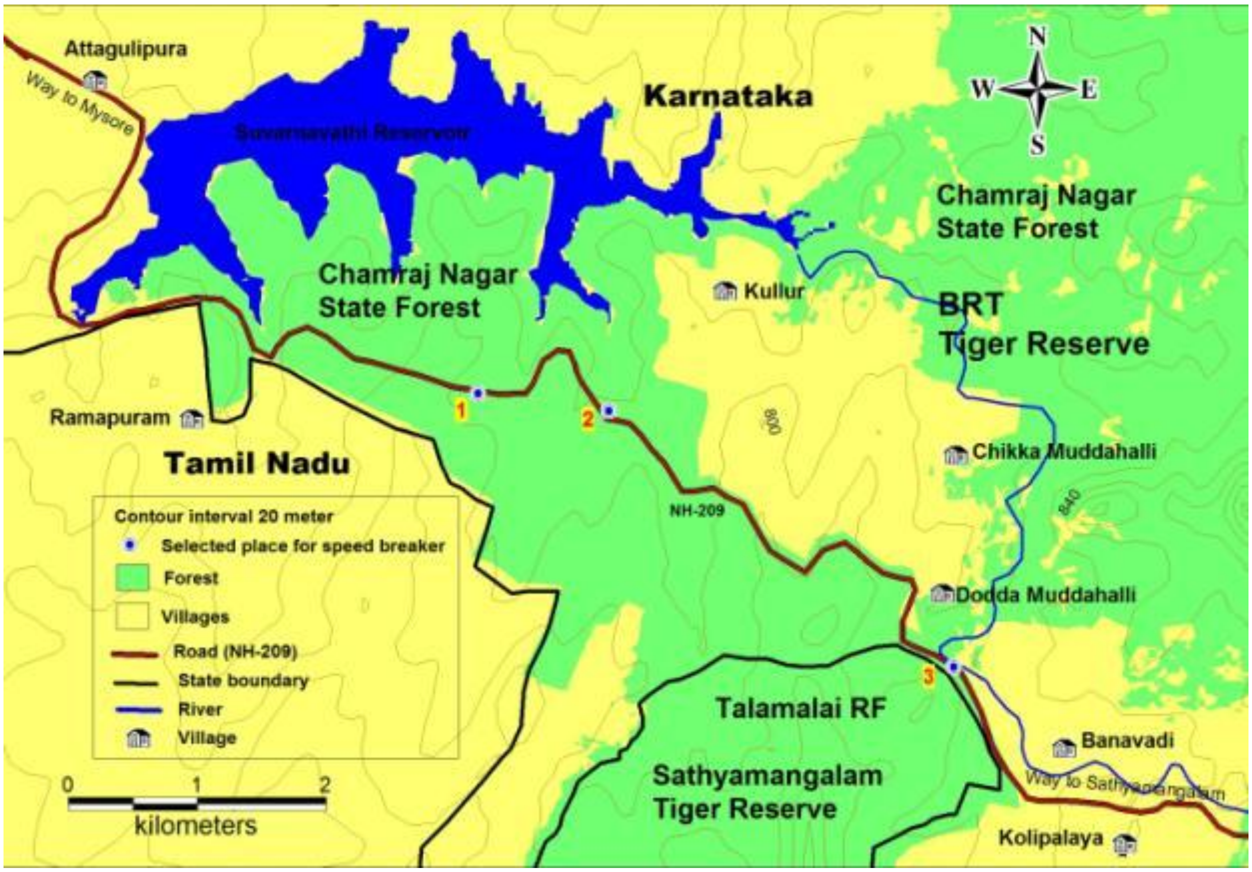
Fig 2.18c Location of speed breakers between Hasanur and Punjur



Coordinates of speed breakers – Punjur – Hasanur road

Sl.No	latitude	Longitude
1	11.76353	77.10997
2	11.76078	77.10994
3	11.73557	77.11192
4	11.73376	77.11230
5	11.72037	77.11522
6	11.71821	77.11544
7	11.71733	77.11567
8	11.71564	77.11639
9	11.70599	77.11998
10	11.70501	77.12071
11	11.68387	77.12443
12	11.68209	77.12520
13	11.68108	77.12565
14	11.67953	77.12608

Fig 2.18d Location of speed breakers between Punjur and Suvarnavathi dam



Coordinates of speed breakers from Punjur to Suvarnavathi dam

Sl.No	Latitude	Longitude
1	11.808068	77.032645
2	11.806820	77.041950
3	11.788640	77.066508

Broad recommendations to minimize road kill and facilitate animal movement on NH 67

1. Install new speed breakers in road through Bandipur where the inter speed breaker distance is more than 600m. Also install new speed breaker between speed breakers at GPS location 11.629410° 76.595590° and 11.638800° 76.597050° where there is a significantly high accumulation of vertebrate road kills.

2. Enforce highway patrolling to reduce littering, parking (stopping of vehicles), over-speeding and feeding of animals by tourists.

3. Night traffic has significantly reduced road kills. Although there are request from various agencies to minimize night ban time, we strongly advocate continuing the night traffic ban between 9.00 Pm to 6.00 AM.

4. The vehicular traffic suddenly increases between 6.00-7.00 AM and this have to be regulated through appropriate means.

5. Fix better reflective signages that are scientifically designed for greater awareness of public and vehicle drivers.

Road kills in most of the existing roads could be drastically reduced and animal movement across the road facilitated for animals by scientific assessment of the wildlife movement and factors contributing to mortality. Underpasses or Overpasses for vehicle or animals could be planned that will not only address above issues but will provide safety of passengers and motorists and well as help in rapid movement. These are cost intensive measures but the structures will prevent many of the negative impacts of linear intrusions including high human wildlife conflict due to habitat fragmentation for which the Government spends large sum of money for mitigation with limited success. A part of the cost could be borne by Forest Department from funds available under various compensatory schemes/plans.

Photo : NH 209



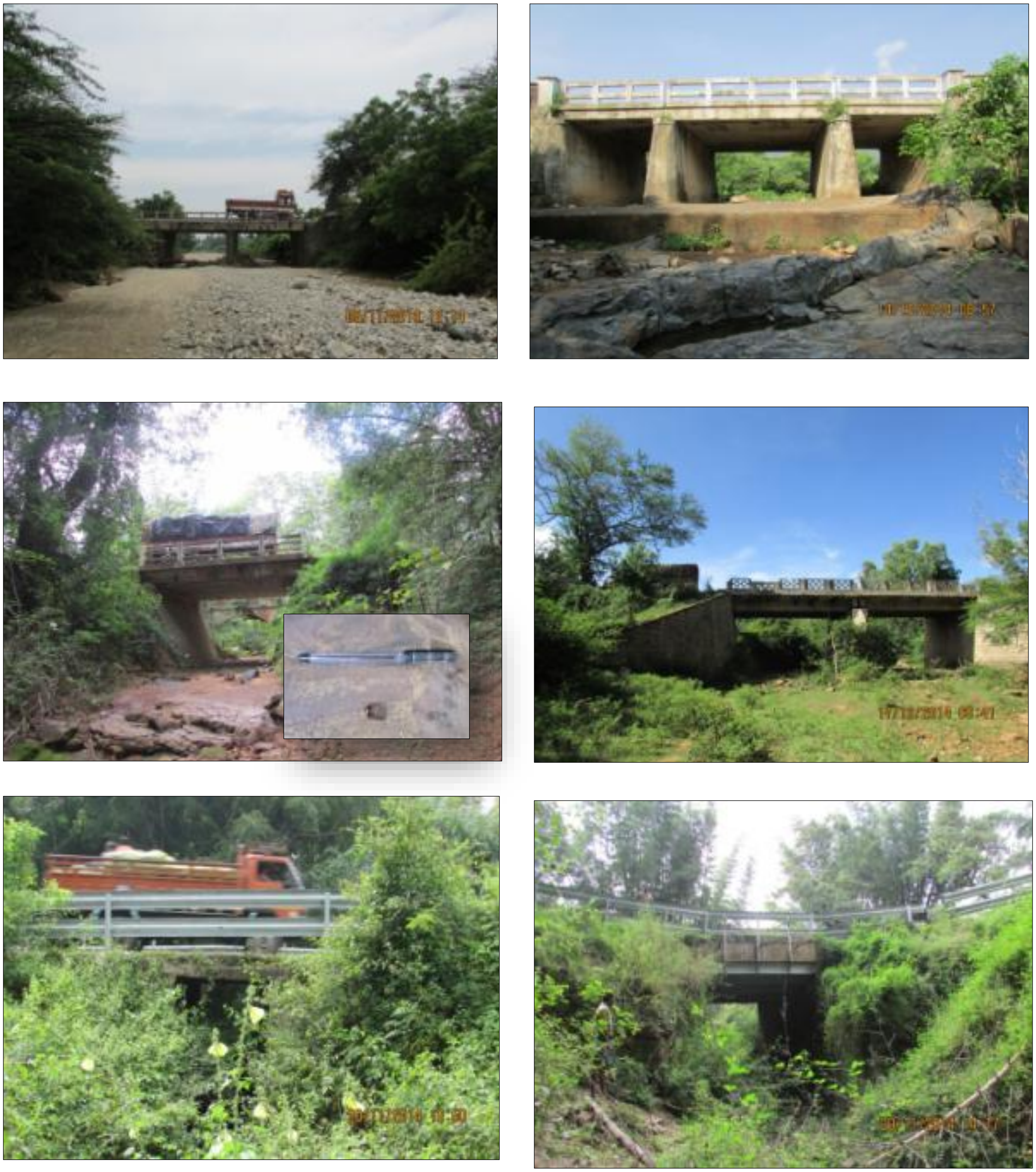



Top left & right: Vehicular traffic on NH 209, Middle left & right: Different barricades placed in the road to prevent vehicular speed, Bottom left: Sign board warning that not to feed animals on road side, Bottom right: Sign board erected by WTI indicating elephant corridor

Photo : Sathyamangalam-Mysore road (NH-209)

Top left: Elephant waits to cross the highway, Top right: Elephants grazing near the highway, Middle left: Spoiled vegetables dumped along the road, Middle right: Bonnet macaque feeding spoiled vegetables dumped road side, Bottom left: Open forest near highway, Bottom right: Bamboo patches located in both side of road

Photo: Under passage on Sathyamangalam to Mysore road – NH209



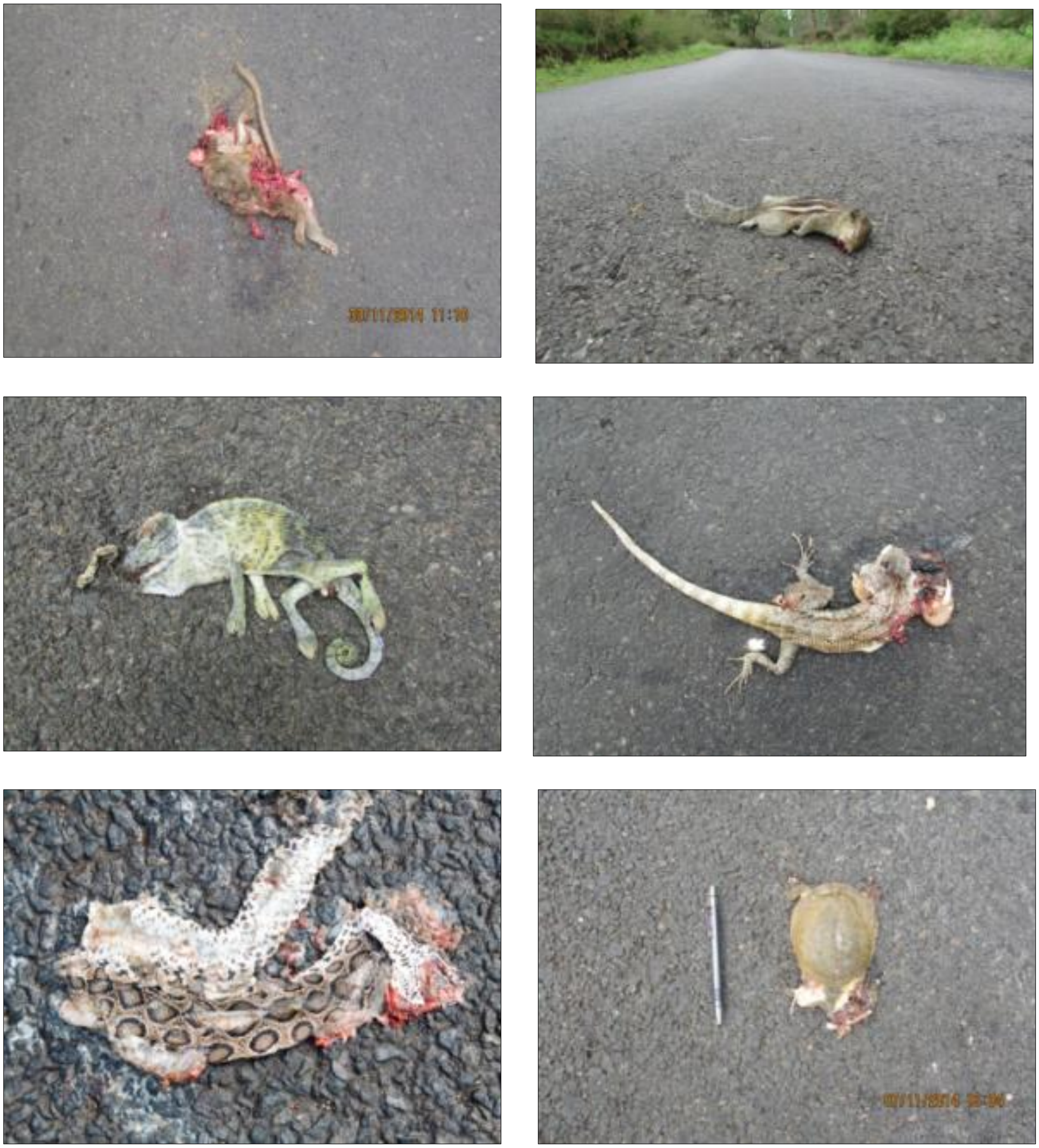
Top left: Under passage-1, Top right: Under passage -2(leopard pugmark), Middle left: Underpassa passage-3(mouse deer foot print),Middle right: Under passage-4. Last left & Right: Un maintain under passage

Photo : Road kill on Sathyamangalam-Mysore road (NH-209)

Top: Mother and un born Spotted deer carcass found very close to the road

Bottom: Bonnet macaque carcass found very close to the road

Photo plate: Road kill on Sathyamangalam-Mysore road (NH-209)

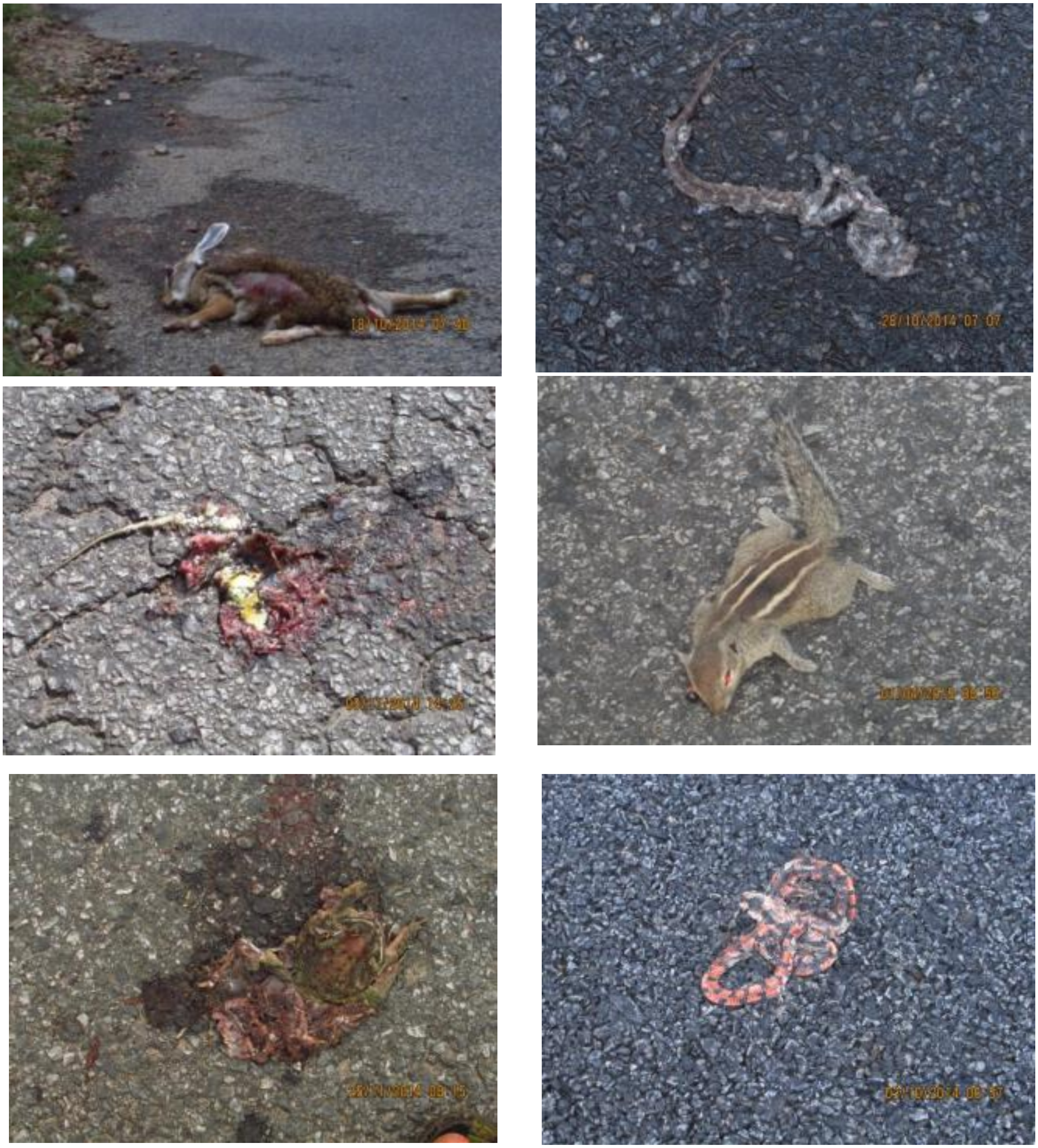


Top left: Bonnet macaque, Top right: Three striped palm squirrel, Middle left: Chameleon, Middle right: Common garden lizard, Bottom left: Russell's viper, Bottom right: Indian flapshell turtle

Photo: NH-67 Gudalur-Bandipur Road

Top left: Herd of spotted deer crossing road in Bandipur tiger reserve, Top right: Hanuman langur on road waiting for food thrown by passengers, Middle left: Common mynas feeding on food thrown by passengers, Middle right: Passengers trying to get out of the vehicle when a wild elephant is around, Bottom left: Wild boar on the road edge in Bandipur TR, Bottom right: Peafowls pecking on Mudumalai road

Photo: Road kill on NH 67



Top left: Black naped hare, Top right: Common wolf snake, Middle left: Mabuya species, Middle right:Three striped palm squirrel, Bottom left: Shield tail snake, Bottom right: Common Indian toad

3. Impact of Railway lines on forest and wild animals

1. Introduction

India with rail route of 66,000 kms (2014-15) has the world's third largest railway network carrying more than more than 23 million passengers and transporting three million tonnes of freight a day and runs 21,000 passenger and freight trains daily (Anon, 2015). Although the growth of Indian railway in terms of route km expansion has been slow (only 10,000 kms of railway network added between 1947 and 2010), this is poised to expand rapidly due to the targets of the Ministry of Railways that proposes to add 25,000 kms of new lines by 2020, about 30,000 km of route would be of double/multiple lines (currently around 18,000 km in 2009-10) and electrifying 33,000 kms of route (that is an addition of 14,000 kms in 10 years). The aim is to expand the network, increase speed of both passengers (110-130kmph to 160-200kmph) and freight (60-70kmph to 100 kmph) trains (Indian Railway Vision 2020). This extensive network of tracks impacts the natural area and wildlife species and large number of elephants and other animals are killed due to train hit every year.

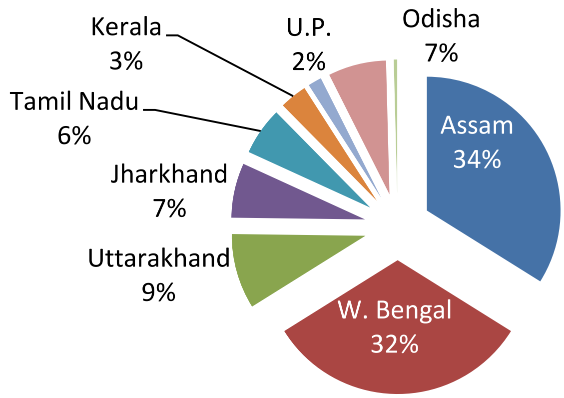
The physical presence of the railway lines and roads in the habitat creates new habitat edges and alters the hydrological dynamics (Seiler, 2001), creates a barrier to the movement of elephants and other wild animals (Gibeau and Heuer, 1996; Menon *et al.*,2005), leads to habitat fragmentation and loss (Andrews 1990, Rebecca *et al*. 1996, Menon *et al*. 2005, Bera *et al*. 2006, Goosem 1997, Prasad 2009, Gubbi 2010, Raman 2011), apart from death due to train hits. This causes not only an overall loss and isolation of wildlife habitat, but also splits up the landscape. Various developmental activities also come up on either side of railway lines and highways thereby further fragmenting the habitat and increasing biotic pressure and human-wildlife conflict (Rangarajan *et al*, 2010). Railways and highways have been recorded to be major sources of wildlife mortality (Clevenger, 1997; Buckingham, 1997; Van der Grift 1999; Jackson, 1999, Singh et al., 2001, Menon *et al*. 2003, Sarma *et al*, 2006, Ritesh, 2010, Rangarajan *et al*, 2010, Raman 2011), threatening wildlife populations throughout the world.

Several ecological drivers have been identified as a source of wildlife mortalities on the railway and highways. Biologists studying road-related black bear mortality in Canada have concluded that the growth along highway and railway right-of-ways of plant species that are attractive to bears contributes significantly to this mortality (Munro 1999, Gibeau and Heuer 1996). In the Bow River Valley (Canada), grain spilled from rail cars have been found as the primary attractant on the railway track. Seven radio-collared bears in the Bow River Valley who came into contact with the rail line, were found feeding at one time or another on spilled grain (Gibeau and Heuer 1996). In Rajaji National Park (Uttarakhand), perennial water sources near the railway track and eatable wastes thrown by the train passengers were found as one of the major attractants for the wild animals (Singh *et al.*, 2001, Menon *et al.*, 2003). Dussault *et al.* (2006) also noticed an increased rate of moose-vehicle accidents (by 80%) with moose density, in the presence of at least one brackish pool.

Various factors contribute to elephant mortality by train hits. These include ecological (food, water, shelter, vegetation and movement of elephants), physical factors (steep embankments and turning), technical (speed of train, frequency and time, unmanaged disposal of the edible waste and garbage) and lack of awareness of among drivers, passengers and planners (Singh *et al*., 2001, Menon *et al*. 2003, sarma *et al.*, 2006). A general lack of coordination between the railways and the forest department is the reason for lack of any sustained mitigation measure.

In India, a large number of wild animals including elephants (*Elephas maximus*), tigers (*Panthera tigris*), leopards (*Panthera pardus*) and gaur (*Bos gaurus*) are being killed annually due to accidents on the railway tracks (Kumar, 1995; Johnsingh and Williams, 1999; Singh and Sharma 2001, Singh *et al*., 2001, Sarma *et al*, 2006). Railways alone have been responsible for death of over 250 elephants since 1987. Majority (89%) of the cases have been recorded from in the States of Assam, West Bengal, Uttarakhand, Jharkhand and Odisha (fig 3.1). In a developing country like India, where expansion of railways and roadways is inevitable, such accidents pose an additional threat to elephant and other wildlife populations especially in the wake of already existing threats like large scale habitat degradation, loss of habitat quality, fragmentation, and conflict with humans. These accidents are also a major cause of worry for passenger safety and a drain on the resources of the Railways.

Fig 3.1 Elephant mortality due to train in India (1987- July 2015)



In Uttarakhand, since 1987 till date Rajaji National Park (RNP) alone has lost 22 elephants due to train hits, which is about 9 % of the total recorded elephant mortality by train hit. Until the year 2001, elephant mortalities in Uttarakhand were high, almost similar to those in Assam. Considering the magnitude of the problem in Rajaji National Park, the Wildlife Trust of India conducted a scientific study and later followed up with implementation of mitigation measures in collaboration with the Forest Department and Railways between 2002 and 2007 to try and reduce the rate of mortality due to such reasons (Singh *et al*, 2001, Menon *et al*., 2003).

The study revealed that elephants were crossing the railway track in search of water and agricultural farmland. In addition, steep embankments, sharp turnings, unmanaged disposal of edible waste and garbage along the track by the train caterers and passengers, increased speed of trains and higher frequency of trains contributed to the cause. Most of the accidents (80%) happened in summer between January and June by night bound trains (Singh *et al*, 2001, Menon *et al*, 2003). The Uttarakhand Forest Department, Indian Railways and Wildlife Trust of India jointly implemented the above recommendations that have resulted in almost zero mortality of elephants by train hit since 2002.

Coimbatore to Palakkad (Podanur to Kottekad) Railway track

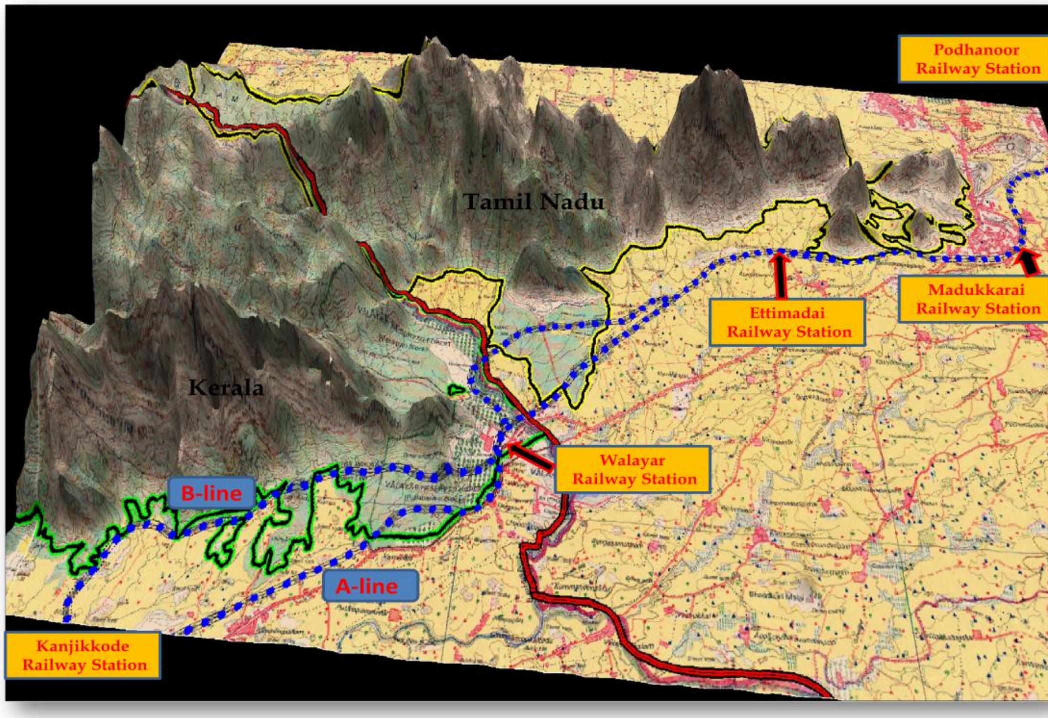
The rail line passes through forests of Coimbatore Forest Division (Tamil Nadu) and Palakkad Forest Division (Kerala) through the Palakkad Gap of the Western Ghats for a length of around 31.7 km. There were 15 elephant mortalities in nine accidents between 1978 and 2010 of which 13 elephants have died on the railway track between 2002 and 2010 alone. In the year 2009, three accidents took place in which four elephants lost their life. These accidents have occurred between Podnaur and Kanjikode railway stations of this section.

Between Podnaur and Kanjikode, there are three railway stations namely, Madukkarai, Ettimadai and Walayar. Podnaur, Madukkarai and Ettimadai railway stations are in Tamil Nadu and Walayar and Kanjikode are in Kerala. The Coimbatore-Palakkad section has busy train traffic and a double line to cater for it. After Ettimadai, both the tracks diverge. The A line passes through 6.5 kms of forests between Kanjikode and Walayar and two kms between Walayar and Ettimadai. Between Ettimadai and Podnaur the track goes completely outside the forests. The B line mostly runs through the forests between Ettimadai, Walayar and Kanjikode. The length of the track of the B line passing through forests between Kanjikode and Walayar is approximately 11.5 Km and between Walayar and Ettimadai is five Km (fig 3.2).

The gradient on the B line is less as compared to the A line. The B line was constructed by the Railways in 1974 to cater to the need of growing traffic of passenger and goods trains. The A line is a very old establishment in existence since 1861. Since the B line passes mostly through forests, most of the accidents have taken place on this line.

Train frequency per day is about 75 to 80 in day time 35-40 trains at night time. Average train speed is about 75 to 100km/hr. Speed restriction imposed in accident zones in Ghats section and is 40 to 45km/hr between Walayar to Kanjokode and Podanur to Madukatai.

Fig. 3.2 : Map of the critical section of the track showing A and B lines



The study aimed at

- To identify the critical and accident prone area along the railway track and the ecological, physical and man-made factors contributing to elephant mortality
- To develop short-term and long- term mitigation plan to address the issue

Methodology

For long-term mitigation plan, it is important to know the elephant movement in this area at a landscape level in relation to habitat availability and other ecological parameters. The mitigation measures and its effectiveness will be based on the knowledge of habitat availability, its utilization by the animal, other ecological attractants and disturbances. These information were collected using the following approach

1. Indirect evidence & Vegetation by plot: The data was collected through temporarily marked transects in the habitat available between A and B lines and in the region. On each transect, circular plots of 10 m radius were laid after every 250 m to assess and measure presence of tree and shrub species, indirect evidence of wild animals, and disturbances (human presence, cattle presence, cattle dung). Records were also collected on the broad vegetation type, canopy cover and availability of water.
2. Secondary information on human-elephant conflict: In order to get information on land use changes, elephant movements, seasonality, influence of crops available in the fringe area on elephant movement a questionnaire survey was conducted in more than 41 villages.
3. Monitoring wildlife movements on railway track: Information was collected to identify critical areas prone to accidents, elephant movement zones along the railway tracks, bridges used by elephants and physical features responsible for accidents. GPS locations of the important landmarks were collected and transferred in a GIS domain to prepare maps.
4. Indirect evidence on railway track: To identify the elephant movement zones and critical areas, encounter rate from direct sightings and elephant dung along the railway track was collected. Records were also made on the presence of other elephant signs (feeding and tracks). Habitat and landscape attributes like availability of water bodies along the track, sharp curves, and steep cuttings on the sides have also been recorded. Data was also collected on attractants like crops and plantations along the track in conflict prone areas. Elephant mortality record, seasonality and accident locations have been collected from the Railway and Forest Departments.

Results and discussion

Pattern of animal mortality

Till date 15 elephants have died in nine accidents on both the lines, of which eight were killed in Kerala and seven in Tamil Nadu. On the B line, six accidents have taken place in which 11 elephants have died and on the A line, three accidents have taken place in which four elephants have died. Out of nine accidents, six have taken place between Kanjikode and Walayar railway section.

In the Walayar Range of Palakkad Forest Division 40% of the total elephant mortality has happened due to train accidents. In addition to elephant death, a few chital and wild boar have also died due to train accidents in this area.

In most of the cases animals from a herd have died. Out of 15 elephant deaths, four were adult male, four adult female, two juvenile (one male and one female), three calves and two animals are unsexed (fig 3.3b).

Fig 3.3a: Elephant mortality in diffent section and line

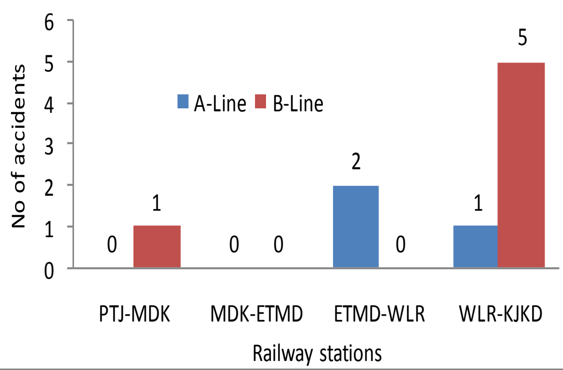
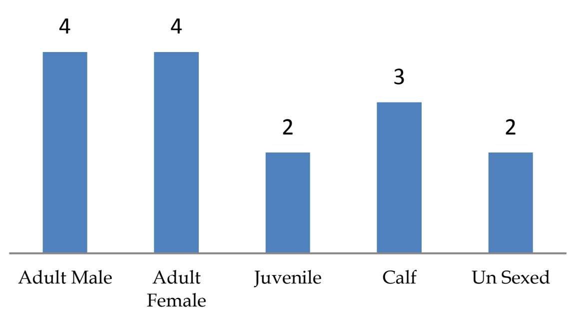


Fig 3.3b : Elephant mortality pattern in age and sex class of elephant



Seasonality of Accidents:

Seasonal mortality data show that most of the accidents have taken place during monsoon and the agricultural season between the months of June and November. All accidents have taken place by night bound passenger trains between 21:00 and 02:15 hours (fig 3.4 and 3.5).

Fig 3.4 : Time of early elephant mortality

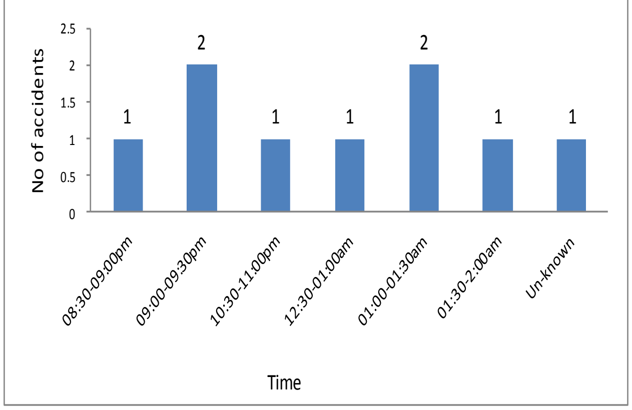


Fig 3.5 : Elephant mortality: seasonal pattern of accidents

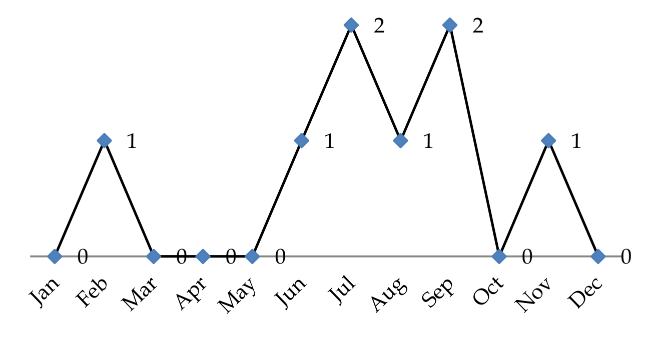
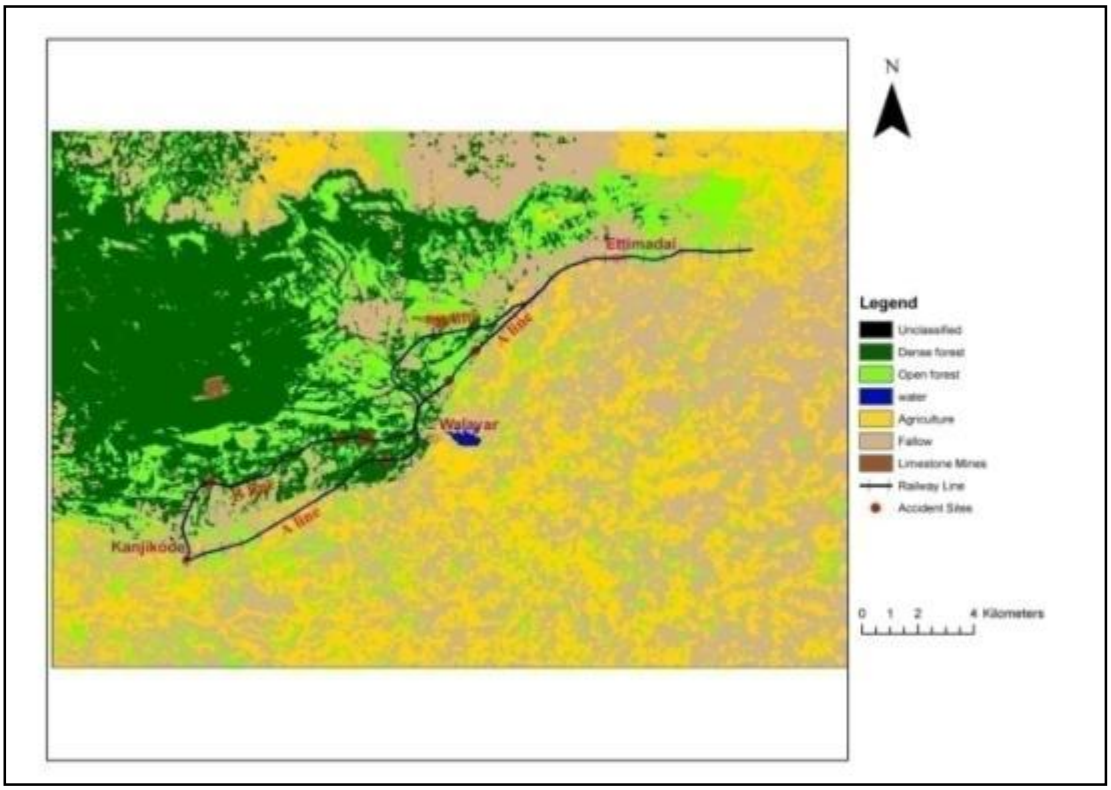


Fig. 3.6: Locations of the past accidents



Wild animal movement on track

Track attracting wild animals:

The frequency of wildlife crossing railway lines is influenced by a number of factors, the most significant of them are: (i) character of the surrounding landscape and concentration of mammals in the vicinity, (ii) grade level (height) of the railway in relation to the geomorphology of the surrounding terrain (large mammals run onto the railway particularly in those places where the grade level of the railroad is at the level of the surrounding terrain), (iii) food and migration needs of mammals.

Frequent elephant movement along the railway track were recorded both on A and B line between Kanjikode-Walayar and Walayar – Ettimadai stations. Between Walayar and Kanjikode, frequencies of elephant signs were recorded from Km 510 to 513 on B line and from Km 511 to 513 on A line. Elephant movement signs were also noticed between Km 505A-508 on B line and Km 506 – 508 on A line between Walayar and Ettimadai. Between Ettimadai-Madukarai and Madukarai-Podnaur (fig 3.7 and 3.8) stations elephant movement is occasional.

During the whole study period elephant groups or loners were sighted on 15 occasions close to the railway track and in nearby areas. The largest group sighted was of 15 animals. The area between Walayar-Kanjikode stations is being used by a family herd of approximately 15-20 elephants and a few small groups and loners. The area between Walayar-Ettimadai stations is mainly used by loners but at times small family groups also visit this area.

The area between Walayar and Kanjikode where elephant movement has been recorded has a good forest patch between A and B line extended between Km 510 and 513. Though this is a small patch of forest this is the only flat land available for the elephant in that area. Most of the forests of the Walayar range are hilly. Another important reason is that this is the only area where elephant can negotiate the hill range between Walayar and Kanjikode stations.

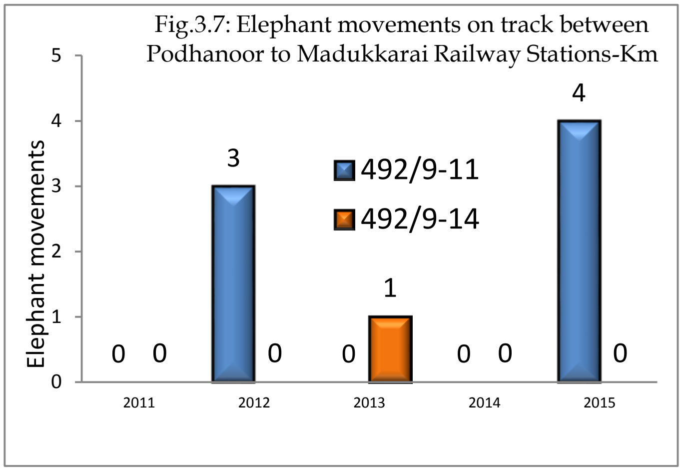
Similarly the area between Walayar and Ettimadai where elephant movement has been recorded has a good forest patch between A and B line. This is also a flat land and has a large patch of bamboo. Other areas close to it is highly fragmented and disturbed.

Identification of critical sections:

Out of six accidents in the Kanjikode-Walayar section, five have taken place on the B line and one on the A line. In all accidents on the B line, members from a family unit have been killed. On the A line one solitary male was killed. On the B line, clearly the most critical section lies between Walayar and Kanjikode. Even in this section, the area between 511 Km to 513 Km is the most crucial as four accidents have taken place in less than a two kilometer stretch. This area is very crucial for elephant movement as one accident has also taken place in the same area on A line between 511-12 Km. Similarly, on the A line the stretch from 505 Km to 508 Km on the Walayar-Ettimadai section is critical as two accidents have taken place in this area too. This result helps in narrowing down of the problem. For implementation of mitigation measures between Walayar and Kanjikode stations, attention should be given in the three Km section on both A and B line from 510 and 513 Km. Similarly between Walayar and Ettimadai stations attention should be given on A and B line from 505 and 508 Km. Between Walayar and Ettimadai stations although no accidents have happened on the B line in the past, the stretch is highly prone to accidents. There is another critical section on B line between Walayar and Kanjikode stations from Km 515 to 517. This is a three Km stretch and elephant movement takes place mostly for crop raiding in the fringe villages. In the past, one accident has taken place in this section

Section 1: Podhanoor to Madukkarai Railway Stations

In a single accident, three elephants were killed (1male/1female/1calf) on 2nd February 2008 by a intercity passenger train at critical cuttings at km 492/9-11. After 3 years elephant begins to cross over this track. Elephants are using a small patch to reach track and crop land over NH-47 (Palakkad to Coimbatore). ACC mining has a big under passage below the Coimbatore to Palakkad NH for carry the lime stone from one side to another side. At night elephant use this under pass to cross the highway without any trouble and use small forest patch to reach cultivation land. Elephant crosses the track between Km 491/19 to 492/21.



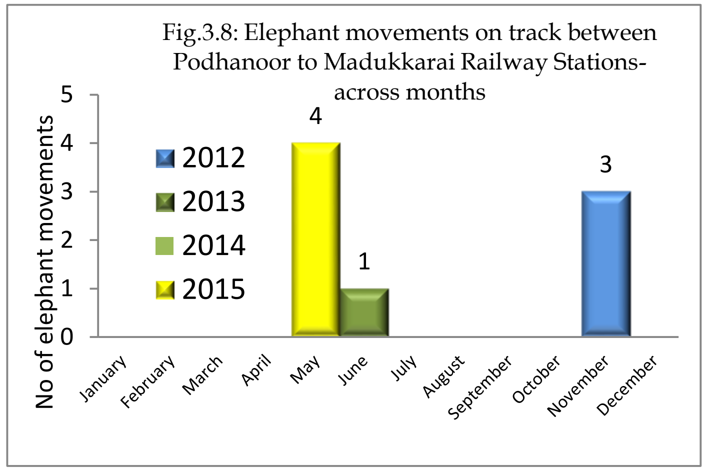


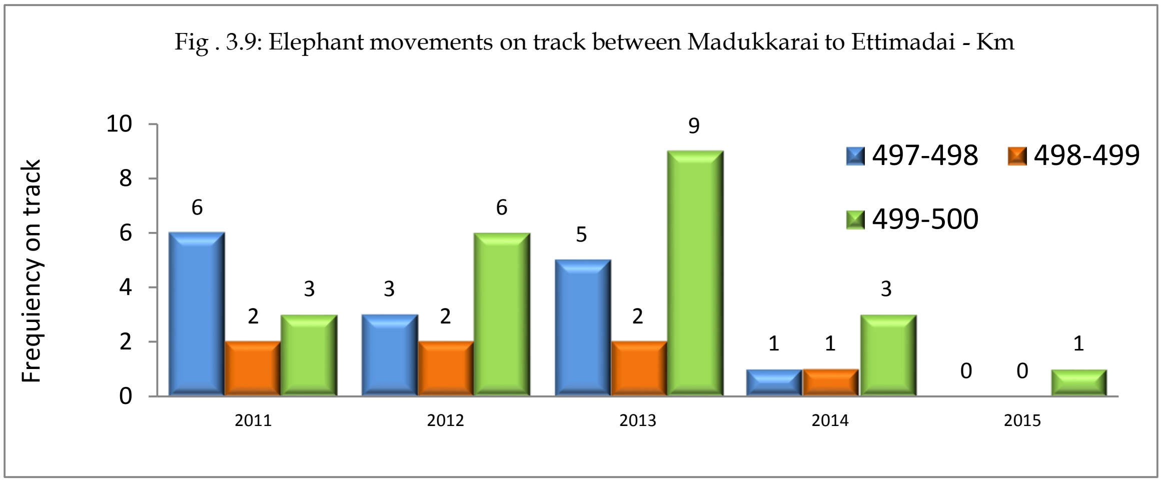
Table 3.1: Critical curves between Madukarai and Podhanoor Railway sections

S.No	From Km to Km	Length
1.	495/4 ½ - 492/32 ½	2.22 Km
2.	492/29-491/29 ½	1.04 Km

Table 3.2 Critical cuttings between Madukarai and Podhanoor Railway sections

S.No	From Km to Km	Status
1.	495/9- 3	Medium
2.	494/14-10	Medium
3	492/25-17	High
4	492/15-1	High

Section 2: Madukkarai to Ettimadai railway Station Track length between this two railway stations is 7 km after Ettimadai railway station to towards Walayar Railway Station both A&B track runs 5km parallel, this section is consider as a low risk for wild animals because both the tracks passes through the edge of dry deciduous & Shrub forest; also there is no blind curve on this track and except one cutting visibility on both side of the track is very clear.



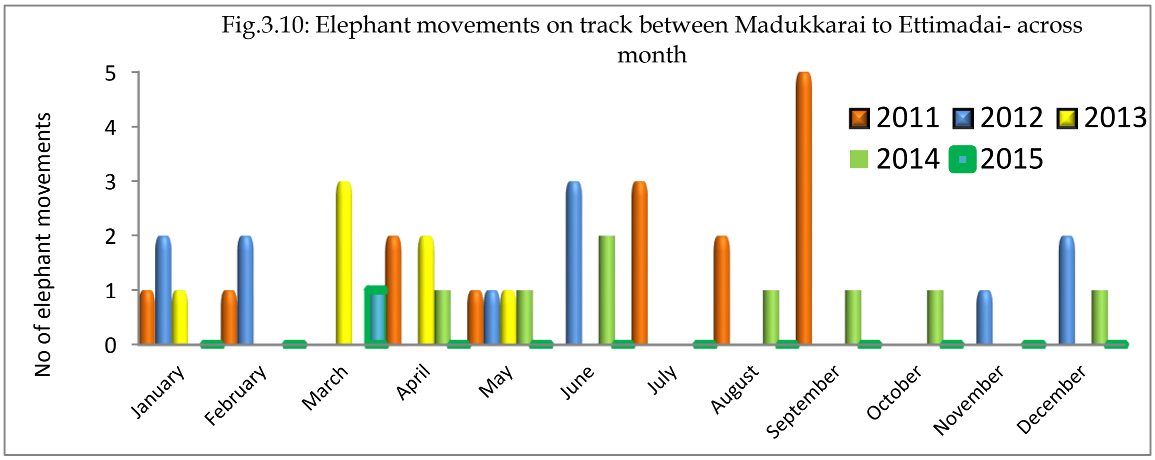


Table 3.3: Critical curves between Madukarai and Ettimadai Railway sections

S.No	From Km to Km	Length
1.	500/21-13	190 m
2.	499/5 ½ - 21 ½	390 m
3.	498/7 ½ - 33 ½	690 m
4.	497/7 ½ - 25 ½	460 m
5.	496/27 ½ - 45	330 m
6.	496/15- 27 ½	260 m

Table 3.4 Critical cuttings between Madukarai and Ettimadai Railway sections

S.No	From Km to Km	Status
1.	500/7-1	Medium
2.	497/20-496/45	Medium

Section 3 :Ettimadai to Walayar Railway Station

This is the most dangerous section and is in the State of Tamil Nadu. Total track length is 11km; 7km from Ettimadai station towards Walayar railway station both A&B track runs parallel and remaining 4 km runs separately through dry deciduous forest patch. About 2 kms before Walayar Railway Station, the track passes through forest patch that is frequently used by elephants to cross the track. Approximately 10-15 times per month, they cross this track. B- track length in forest patch is 4 km and A- track runs only 1.5Km. A track has dangerous cutting 200m before forest starts between Km 505/20-22. On 17th July 2009, one elephant was killed by train hit in this location.

Fig.3.11: Elephant movements on track between Ettimadai to Walayar

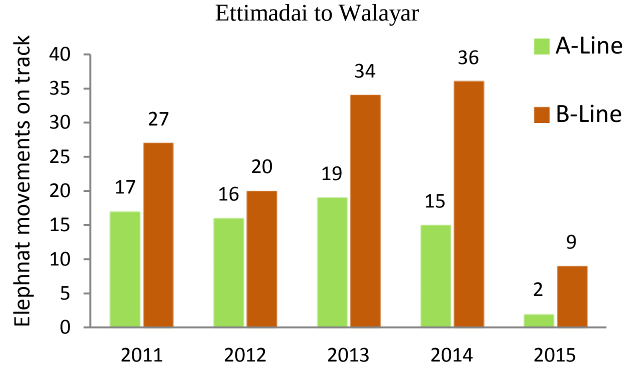


Fig.3.12: Elephant movements on track track between Ettimadai to Walayar - Km

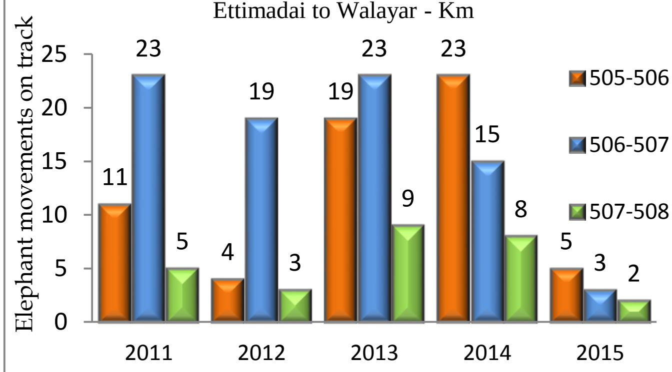


Table 3.5: Critical curves between Ettimadai to Walayar Railway sections

	B line		A line	
S.No	From Km to Km	Length	From Km to Km	Length
1.	509/0-19	370 m	506/22-507/8	406 m
2.	508/1-507/3	1 km	508/30-507/4	260 m
3.	506/37-15 ½	450 m		

Table 3.6 Critical cuttings between Ettimadai to Walayar Railway sections

	B line		A line	
S.No	From Km to Km	Status	From Km to Km	Status
1.	509/10-508/25	High	505/14-506/4	High
2.	507/29-25	Medium		

Section 4 :Walayar to Kanjikode Railway Station

Elephant movement in this section is seasonal between June to December, during this month elephant cross the track only for crop raid and approach plain terrain between A & B track. Wild animal spends time in the forest edge till evening and after 6 pm animals comes out for crop raid.

Fig.3.13: Elephant movements on track between Walayar to Kanjikode -Km

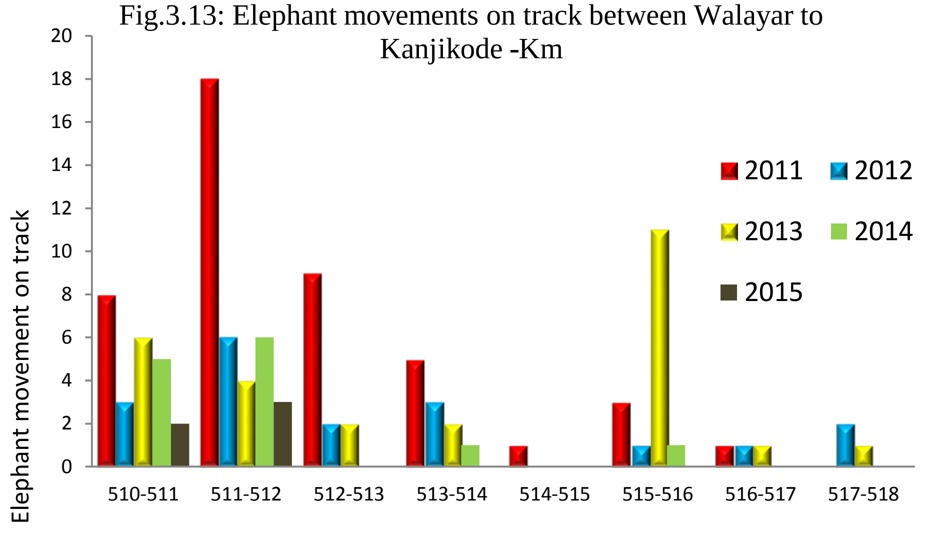


Fig.3.4: Annual elephant movements on track track between Walayar to Kanjikode

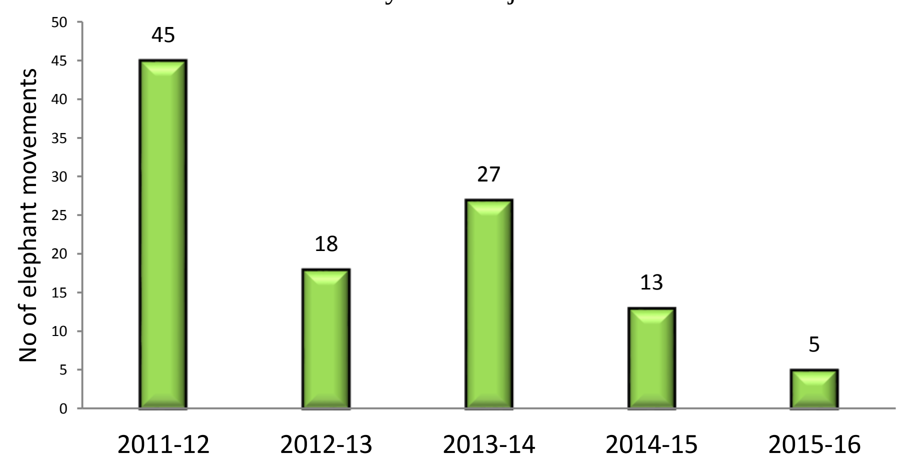


Table 3.7: Critical curves between Walayar and Kanjikode Railway sections

S.No	B line		A line	
	From Km to Km	Length	From Km to Km	Length
1.	509/35 – 510/7	400 m	509/4-48 ½	800 m
2.	510/33-45	230 m	510/2-511/20	670 m
3.	511/1 – 21	440 m	512/8 -513/8	940 m
4.	511/37-512/15	370 m	513/8-514/6	1020 m
5.	512/15-21	180 m		
6.	513/1-11	220 m		
7	513/19-37	380 m		
8.	514/1- 23	470 m		
9.	514/31-49	380 m		
10.	515/11-39	500 m		
11.	515/41- 516/13	290 m		
12.	516/29-516 A/11	590 m		
13.	516A/21-517/11	720 m		
14.	517/15-29	270 m		
15.	517/37-518/5	220 m		
16	518/3-11	190 m		

Table 3.8 Critical cuttings between Walayar and Kanjikode Railway sections

	B line		A line	
S.No	From Km to Km	Length	From Km to Km	Length
1.	510/42-511/9	High	512/10-16	High
2.	511/35-37	Medium	513/6-12	Medium
3.	512/0-7	High		
4.	512/11-19	High		
5.	513/0- 5	Medium		
6.	513/25-514/5	Medium		
7	514/47-515/5	Medium		
8.	517/7-13	High		
9.	517/17-35	Medium		

Section 5 :Kanjikode to Kottekad Railway Station

After Kanjikkode railway station to Kottekkad railway stations (towards Palakkad railway Junction) both tracks A&B runs parallel. The distance comes between these two stations is 7.2Km. The track runs through limited cuttings and curves and through agriculture land. After km 524/16 (curve number 11), the track goes straight for exactly 3.1Km track up to 526/28 (curve number 12). Most of the elephant crossing points is between curve 11 and 12.

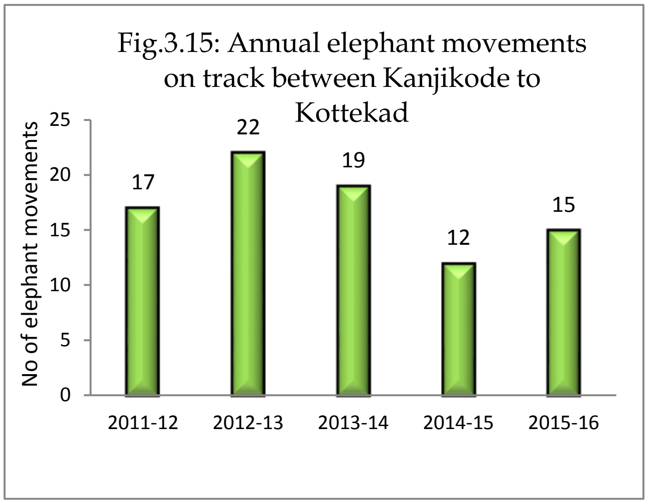


Fig.3.15: Annual elephant movements on track between Kanjikode to Kottekad

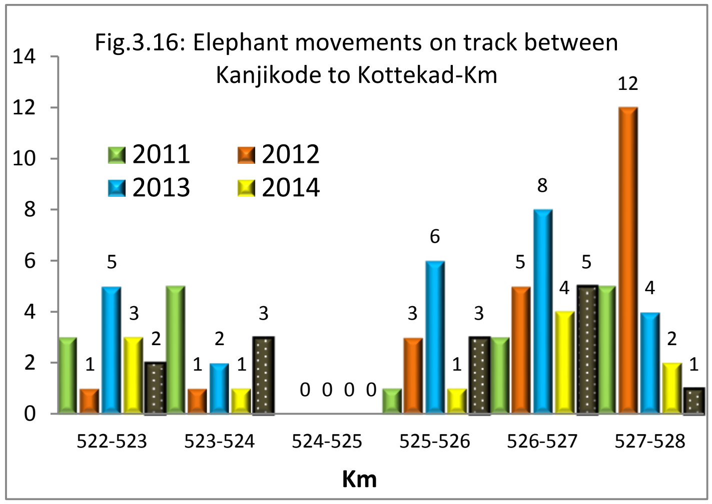


Fig.3.16: Elephant movements on track between Kanjikode to Kottekad-Km

Responsible factors for accidents

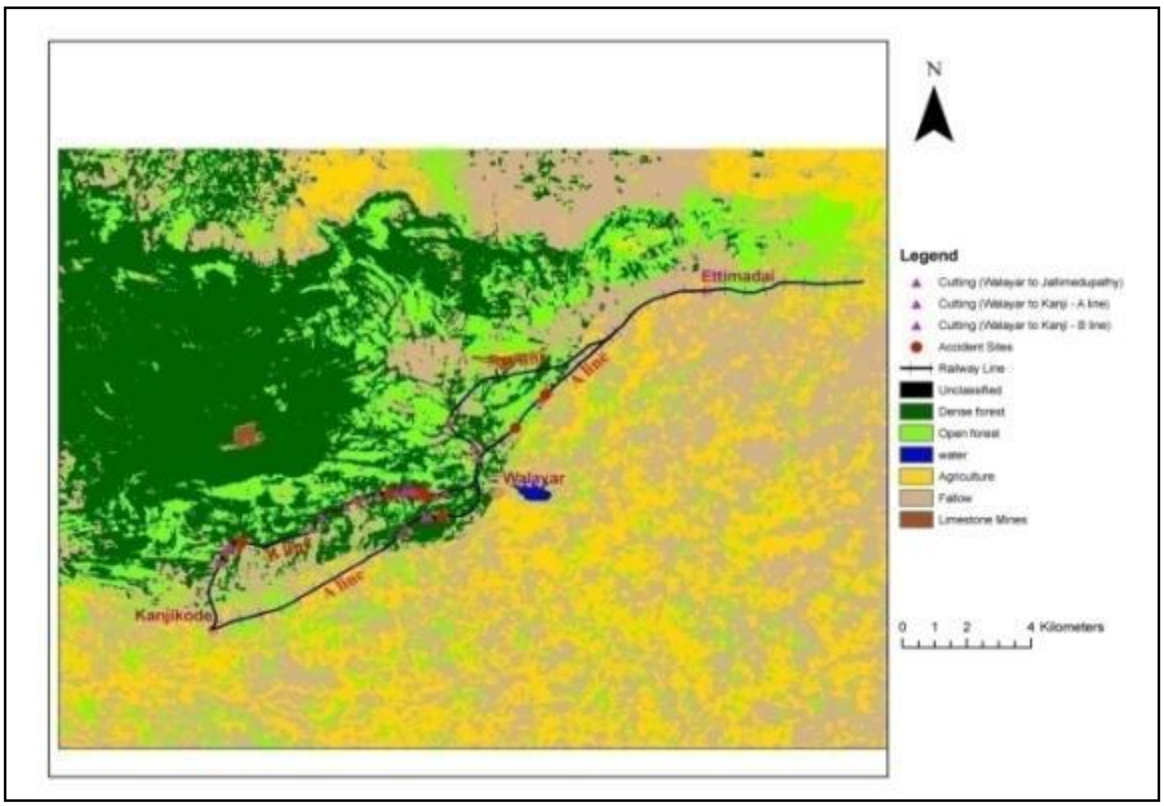
Different kinds of ecological, physical and man-made factors plays contribute to elephant mortality.

Physical factor:

A. **Curve:** Curves are a very important physical feature along the track. Curves increase the probability of accidents due to low visibility. The area between Walayar and Kanjikode especially on the B line has a large number of critical curves. The area with curves and steep cuttings become more prone for accidents. The area between Km 511 and 513 and 516A and 517 has experienced five accidents due to the presence of curves or cuttings. Due to poor maintenance of under growth in curve restrict visibility of loco pilot. The maximum curve degree is 3.94˚ and minimum 0.73˚ and minimum curve length is 1.725m and maximum of 10m.

B. **Cuttings** are highly sensitive sections on the track. Animals get trapped in cuttings at the time of train movement and get killed. The measured minimum width is about 2.5m from middle of the track. Out of nine accidents, six accidents have happened in cutting with steep embankments on the sides of the track. In such a situation the animal does not get space to escape and cannot climb up to the top. The area between Walayar and Kanjikode specially on the B line has a large number of critical cuttings. There are few critical cuttings between Walayar and Ettimadai and Madukarai and Podanur

Fig 3.17: Locations of the cuttings and accidents along the railway track



Technical factors

A. **Speed and frequency of the trains:** After establishment of B line the frequency of trains has increased several folds in this section. Each day more than 50 trains pass through this area. Similarly the speed of trains has also increased gradually. Train speed in some of the section is 80 Km / hour or above. The high frequency and speed of the train has contributed a lot to elephant casualty on this track. Due to increased mortality of elephants, the southern railway has imposed speed restriction of 45 kmph in Ghats section in both Tamil Nadu and Kerala parts.

Ecological factors

A. Land use changes

Unlike other regions this area has also experienced extensive changes in land use pattern in last few decades. In addition to commissioning of B line through forest area in 1974, other development activities and land use changes like, urban developments, industrializations, mining, growth of settlements and change in crop pattern & land tenure together has contributed to the habitat loss especially in the flat areas and foothills. A change detection analysis over period of only nine years between 1990 and 1999 showed decrease in dense forest category. The increase in open forest and decrease in agriculture and fallow land actually could be due to increase in plantation like coconut and banana. In the last one decade several buildings have come up in the foothills especially in Tamil Nadu which was previously open for elephant movement. Industrial developments like MCL & ACC cement factories and their associated infrastructure and activities have contributed to the habitat fragmentation to a certain extent. The limestone mining activities in the prime elephant habitat both in Kerala and Tamil Nadu had created lot of disturbance and blocked the natural movement of elephants. This is also one of the reasons that elephants started using the area close to railway track. Similarly, in past the several years, villages have also expanded. In our questionnaire survey 48% respondents revealed that they shifted to the area in the past 30 years. Cash crop plantation has increased at the cost of fallow land. Change in cropping pattern and land uses in villages situated close to the railway track has created favorable conditions for elephant movement

Table 3.9: Change in village population and land use

S.No	Year of residing in the village	% surveyed population
1	0-20	31
2	21-30	17
3	31-40	14
4	41-Above	38

B. Crop as an attractant

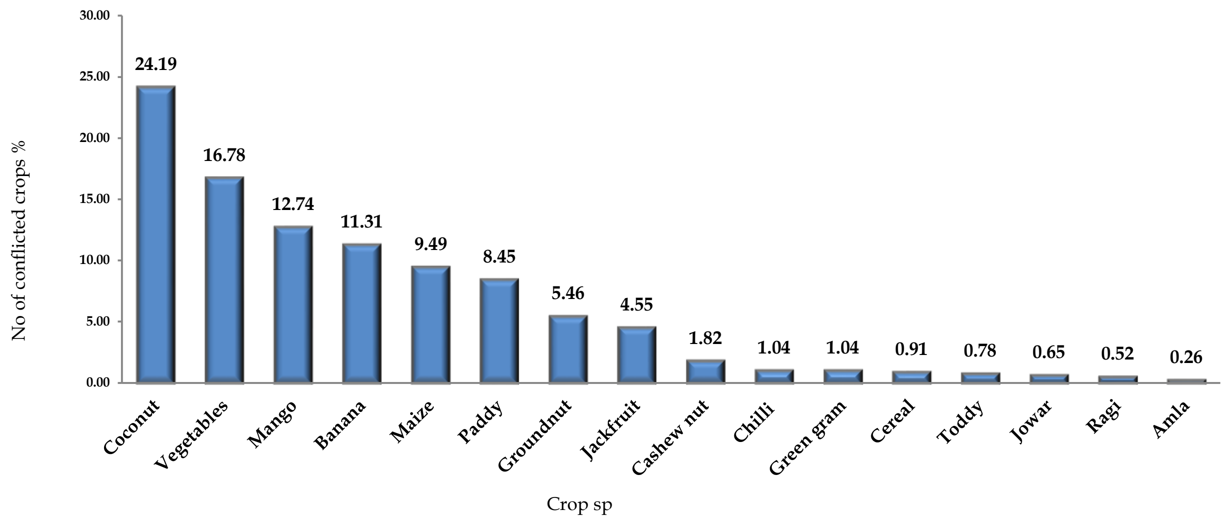
In Tamil Nadu and Kerala part totally 51 revenue villages are located close to the railway track. Throughout the year farmers undertake cultivation, most of these crops attracting wild animals. Paddy is the major crop in Kerala and coconut and banana are major plantation crops. In Tamil Nadu major crops are paddy, gram and groundnut and major plantation is coconut and banana. These crops and plantations are preferred food for elephant. The land holding of more than 50 % People surveyed were two or less than two hectares (Table 3.10). Only 12 % people have land holding of more than five hectares.

Table 3.10: Land holding of villagers

S.No	Area	% of surveyed population
1	0-2 ha	53.6
2	2.1 - 4 ha	22.49
3	4.1 - 6 ha	8.50
4	6.1 -8 ha	3.92
5	Above 8 ha	8.50

In the questionnaire survey 65% of the respondents reported crop depredation by elephants in the last one year to the tune of 58 hectare (Fig 2.18). People also reported an increase in crop depredation cases in the last few years. Elephants use forest patches close to the track as shelter during daytime and raid crop in nearby villages in the evening and night time. Most of the crop raiding takes place between June and December. Period of crop depredation also coincides with the elephant mortality due to train accidents in this area. Crop depredation by herd (52%) and loner (48%) are almost equal.

Fig 3.18: Different types of crops lost to elephant conflict around Podanur to Kottekad during 2011–May 2015 (n = 769)



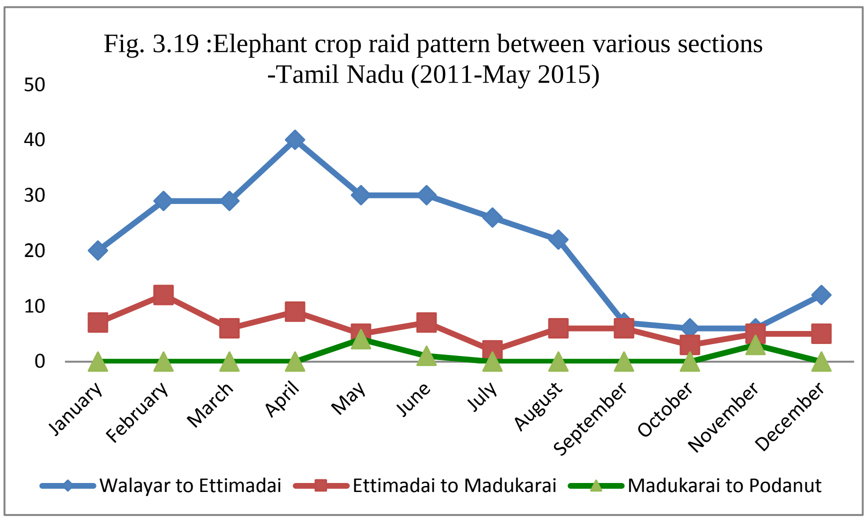


Table 3.11: No of elephant crop raid distance from Railway Track in each section

Distance from track (km)	Kottekad to Kanjikode	Kanjikode to Walayar	Walayar to Ettimadai	Ettimadai to Madukarai	Madukarai to Podanur
0-0.5	47	60	34	16	6
0.5-01	29	76	175	40	7
01-1.5	14	12	6	12	3
1.5-02	33	16	5	12	7
02-2.5	0	9	14	0	2
2.5-03	0	11	78	0	3
03-3.5	3	4	1	0	2
3.5-4	0	0	0	0	2

Ninety three percent of respondent reported that crop depredation management is still undertaken individually. People use combination of method to protect their crops. Out of three mitigation measures adopted widely 93% uses crackers to drive elephants. Power fence is used by only 8% people. More than 92% people who are using power fence placed it in medium (69%) or ineffective (23%) category in conflict management.

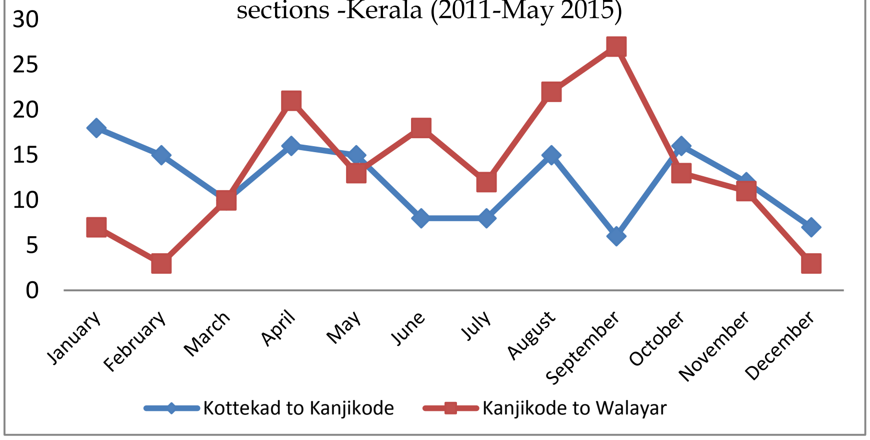


Fig.3.20: Elephant crop raiding pattern between various sections -Kerala (2011-May 2015)

C. Habitat

Line B passes through elephant habitat between Ettimadai-Walayar and Walayar- Kanjikode railway sections. The total habitat available for elephant in the region is less than 200 km^2 (Table 3.12). But most of the area is hilly, of which some are inaccessible for the elephant. The flat lands available are under few small forest patches, agriculture land, plantations, settlements and other development activities. The two comparatively good forest patches in the flat land falls between A and B line (between Km 505A and 508 and Km 511 and 513) and this is exactly where most of the accidents are occurring. Though these are small forest patches, these are the only forests available in the flat land. We did extensive sampling to compare the habitat, utilization status, availability of water, preferred food species, and disturbances. It is evident from the result that habitat quality and utilization pattern is more or less same in the compared areas (Table 3.12 and 3.14). The details of tree species are provided in Annexure 2. Hence habitat does not play a major role. But during the rainy season between the months of June and December the frequency of elephant movement increases due to a combination of reasons like crop raiding, inaccessibility of forest areas that have difficult terrain, disturbances due to blasting and other activities in mining area and blockage in the natural movement area due to several disturbances. Though the habitat present near railway track between Ettimadai - Walayar and Walayar – Kanjikode are small patches but their utilization by the elephant is at par to larger habitat, due to the attractions near it and disturbances in the main habitat.

Table 3.12: Area under different land use classes

S.No	Land use classes	Area in 1990(km2)	Area in 1999(km2)	Change in area(Km2)
1	Dense forest	124.22	122.21	-2.01
2	Open forest	66.69	83.86	17.17
3	Water bodies	2.5	0.5	-2
4	Agriculture & Fallow land	351.82	33.24	-13.58
5	Lime stone mines	1.13	1.24	0.11
6	Total	546.36	546.05	

Table 3.13 Status of habitat utilization, disturbances and water availability

Sl. No.	Area	Percentage of plots with		
		Elephant signs	disturbances	Water bodies
1	Habitat near A and B line between Walayar and Kanjikode, Kerela	36	62	46
2	Habitat in the foothills in Puduchery south between Walayar and Kanjikode,Kerela	60	40	75
3	Habitat in and around Kanjikode and Mallampuzha dam, Kerela	58	100	50
4	Habitat near A and B line between Walayar and Ettimadai, Tamil Nadu	64	72	33
5	Habitat on the north to the ridge around Malabar mine, Kerela	50	16	33
6	Habitat in the hills near Parapatty, Tamil Nadu	71	88	65
7	Habitat near track between Etimadi and Madukari, Tamil Nadu	0	40	0
8	Habitat in foothill near Arivoli Nagar between Etimadi and Madukari, Tamil Nadu	67	100	33

Table 3.14: Status of habitat available around railway track and in the region for elephant in Palkkad and Coimbatore Forest Divisions of Kerala and Tamil Nadu

S.No	Area	No of tree species	Tree density/ha	Status of elephant food species		
				No of trees	Tree density/ha	% of total tree density
1	Habitat between A and B line between Walayar to Kanjikode	41	349	22	241	69
2	Habitat in the foothills in Puduchery south between Walayar and Kanjikode, Kerela	27	490	14	273	57
3	Habitat in and around Kanjikode and Mallampuzha dam, Kerela	28	636	15	465	73
4	Habitat near A and B line between Walayar and Ettimadai, Tamil Nadu	37	338	19	259	76

5	Habitat on the north to the ridge around Malabar mine, Kerela	36	453	21	383	84
6	Habitat in the hills near Parapatty, Tamil Nadu	28	236	14	149	63
7	Habitat near track between Etimadi and Madukari, Tamil Nadu	5	87	1	58	67
8	Habitat in foothill near Arivoli Nagar between Etimadi and Madukari, Tamil Nadu	3	42	2	26	62

Fig.3.21: Forest patch between A&B line Walayar to Kanjikode and Walayar to Ettimadai RLY Stations

D. Impact of disturbance

Cement factories

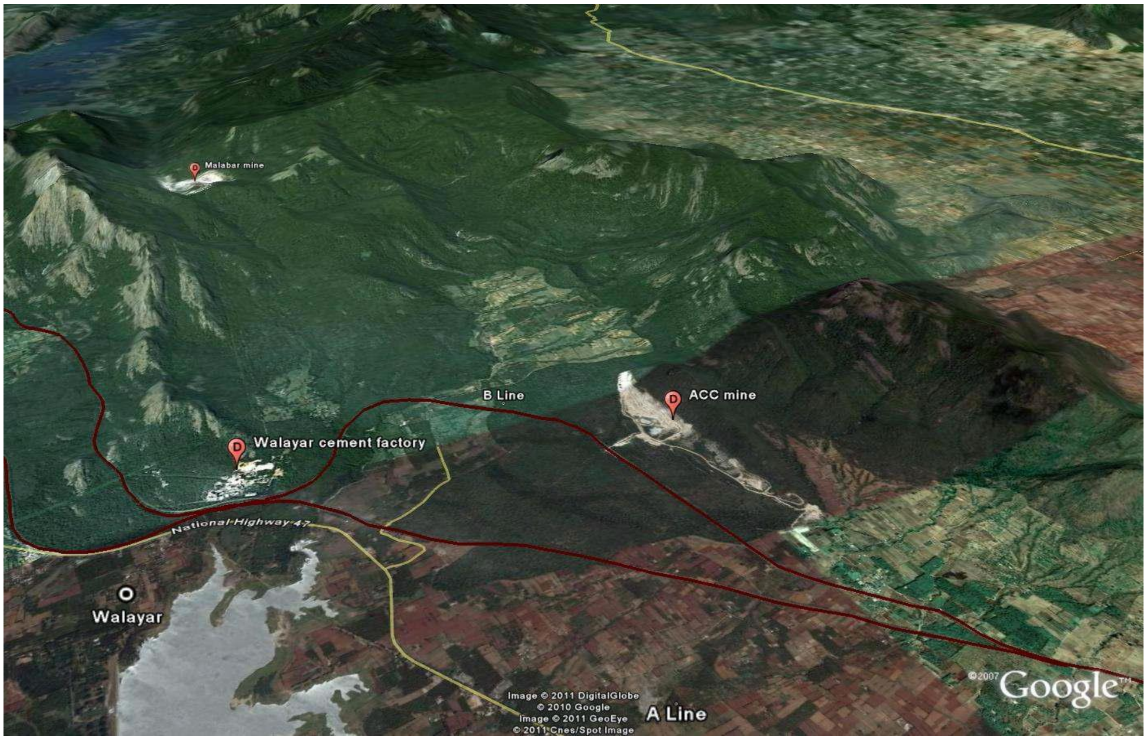
Limestone mining activities in Walayar and Ettimadai landscape is not only an obstruction in the elephant movement but also creates huge disturbances due to operation activities like, blasting, movement of heavy vehicle to carry ore and presence of operation staff. Similarly, indiscriminate building construction, industrial and urban development in the foothill between Ettimadai and Podnaur over the year has also created hurdle in natural movement. These are also the reason now elephants are using forest patches close to the railway track which previously they might not be using so frequently.

There are two mining sights present between Walayar to Ettimadai Railway station- Kerala (Malabar Cement Limited) and another one is in Tamil Nadu (ACC).

1. Malabar Cement Factory (MCL) in Kerala

The MCL factory is run by Kerala Government. The factory started commercial cement production in 1984. Average cement production is 1300 tonnes per day; limestone extraction is about 1000 to 1500 tonnes per day. The mining quarry is located inside the forest that has suitable habitat for wild animals. The limestone is transported through belt bucket elevators and travels 7km inside the forest. The mining have been running throughout the year producing air and sound pollution. **ACC- Cement factory in Tamil Nadu**This factory mining quarry is situated near railway track between Walayar to Ettimadai Railway Stations. This habitat is highly preference by wild animals for foraging but due to heavy noise and blasting, animals are avoiding this habitat and stay close to the railway track

Fig.3.22: Disturbing factors- Malabar Cement Limited (MCL) Mining & Factory, ACC Mines



Under Passage used by elephants

Wildlife crossing structures are gaining national recognition by transportation agencies as effective measures to reduce animal-vehicle collisions and connect wildlife habitats across transportation corridors (Donaldson and Schaus, 2009). Wildlife crossing structures allows wildlife to cross either over or under roadways/railway track without coming into contact with traffic. Building these crossing structures is to reduce the risks associated with wildlife-vehicle/rail interactions, and to provide connectivity between habitat patches.

Seven bridges we seen used by wild animals regularly located inside the forest patch between Walayar to Kanjikode and Walayar to Ettimadai Railway Stations. These forest patches are used by elephants regularly. To avoid mortality of elephants and other animals crossing the railway line passing through the forest, these under passages need to be properly maintained. Walayar to Kanjikode RLY station has five under passage used by wild animals. Some of these under passages are blocked by bushes and trees. Hence, wild animals, especially small ones tends to avoid these under passages.

Fig.3.23: Bridges in forest patch between Kanjikode to Ettimadai Railway Station

Fig.3.24&3.25: Bushes and vegetation under the bridges

Table 3.15.Walayar to Kanjikode-B line

S.No	Bridge No	Km
1	MK 22	510/23
2	MK.37	512/29
3	MK.41	512/35
4	MK.43	513/7-8
5	MK 47	514/43

Table 3.16 Walayar to Ettimadai-B line

S.No	Bridge No	Km
1	MK 18	508//5
2	MK 15	507/7
3	MK 6	505A/3

Cause of elephant mortality in other train hit areas

The study also reviewed the elephant mortality in various states and sites to understand the cause of mortality in these areas. As reflected in table 3.17, the factors responsible for elephant mortality by train hit remain more or less the same. However, it is very important to identify the problem at each site, the critical section and then work on the mitigation plan based on physical features, animal usage, technical and man-made factors to plan site specific mitigation plan.

Table: 3.17 Factors responsible for elephant mortality by train hit in select part of India

	Palakkad-Coimabtore	**Odisha**	**Rajaji NP, Uttarakhand**	**North West Bengal**	**Dipor beel Assam**	**Jharkhand**
Landscape attributes						
Sharp curves			Addressed			
Cuttings/embankments			addressed			
Low visibility due to foliage/fog						
Technical factors						
Speed of train						
Frequency of trains						
Elevated tracks						
Tunnel						
Ecological						
Land use change: agriculture, mining, settlement, etc						
Water bodies near track						
Elephant/wildlife corridor						
Disturbances and awareness						
Garbage disposal on track			Addressed			
Awareness: loco pilots	Sensitized		Sensitized			

Mitigation measures undertaken by Railway and Forest Department

The Railways has taken several initiatives to minimize the problem. These include putting up elephant signage along the track (along with WTI) to remind drivers about elephant movement, small awareness signage for the passengers on the railway stations, announcement for the train passengers at Palakkad and Coimbatore and patrolling of the track by their gang man. Other than this, the Railways has also issued a caution to their loco pilots to blow the whistle continuously in elephant movement areas and has reduced the train speed to 45 Km/ hour during night between 6 PM to 6 AM in the accident prone areas.

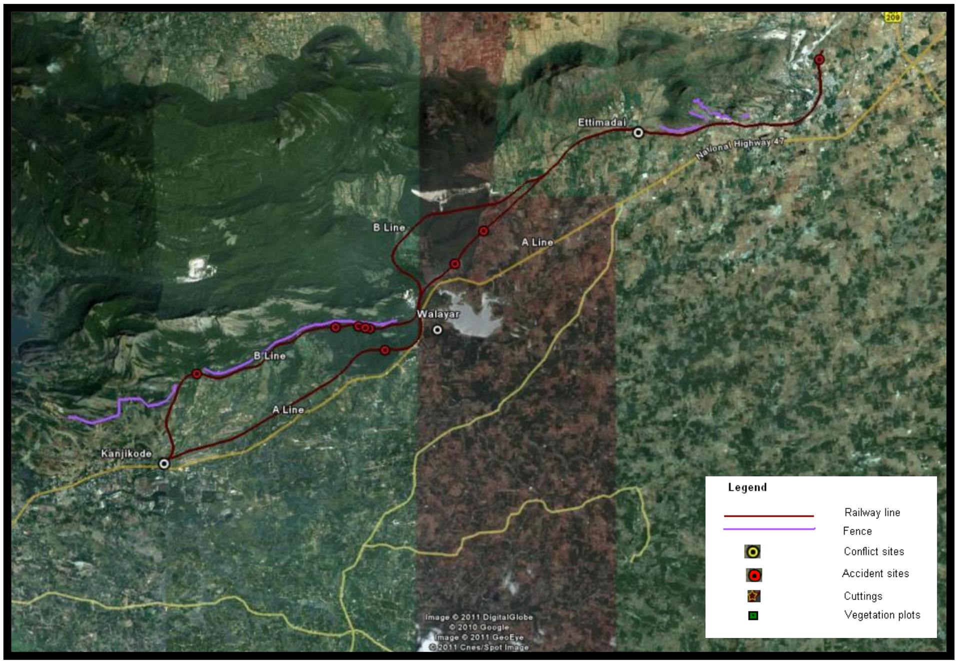
Fig.3.26 : Elephant signage along the railway track

Fig.3.27 : Awareness board for the passengers

a. The Kerala Forest Department has on its part fenced approximately 10 km of railway track between Walayar and Kanjikode in the Walayar range. Maintenance of these fences was found satisfactory except for a few sections. Night patrolling with Railway department also carried out between June to December,
b. The Tamil Nadu Forest Department has also fenced some of the area before Podnaur to restrict the elephant movement on to the road and railway track and very recently they developed EPT in forest patch between Walayar to Ettimadai Railway stations.

These measures fall short of a comprehensive management plan which is required to stop the accidents from happening. The selection of barrier for elephants should be done carefully as per the terrain and its maintenance. Power fences may not be a long term solution due to maintenance problems.

Fig 3.28. Map showing fence and accident sites



Suggested mitigation measures

Site specific mitigation measures needs to be implemented in different sections to mitigate the elephant mortality by train hit. There are few other conservation issues like human-elephant conflict and disturbances in the elephant habitat due to limestone mining and growth of settlements, which is directly and indirectly associated with this problem. Hence, these issues should also be considered holistically while implementing the plan.

Based on the accidents records, elephant movement and other factors responsible for accidents, the following stretches are identified as highly sensitive and prone for accidents on A & B lines:

a. Km 510-513 (Walayar-Kanjikode, Kerala)
b. Km 505-508 (Ettimadai-Walayar, Tamil Nadu and Kerala)
c. Km 515-517 on B line (Walayar-Kanjikode, Kerala)
d. Km 492-493 (Podnaur-Madukkari)

Long term Mitigation Measures:

Following long term mitigation measures needs to be implemented section wise

A. Podanur-Madukkari Section:

Stray movement of elephant occasionally takes place in this section. It is not a high elephant movement area. Both the A and B line run parallel in this section. On 4th February 2008 one accident took place in this section in a cutting (Km 492/1-15) in which four animals died. There are two critical cuttings (Km 492/1-15 & Km 492/17-25) which needs to be widened with gentle slope provided on the sides. The other two cuttings mentioned (49/10-14 & 495/3-9) are low and not critical.

B. Madukari- Ettimadai Section:

Elephant movement along the railway track in this section is also very less and no accident has taken place in this section. Both the A and B line run parallel in this section also. However, the two critical cuttings (Km 500/7-1 & Km 496/45-497/20) need to be widened with gentle slope on the sides.

C. Ettimadai -Walayar Section:

The critical part in this section is mostly confined between Km 505/0-508 on both A and B line. The B line is two km longer than the A line (There are additional kilometers, 505A and 506A on B line). There is regular movement of elephants (loners) in this section across the railway track to use small patch of forest between both the lines and for crop raiding in nearby villages. This forest patch extend on B line from end of the Km 505 to 506A/13 approximately 2.5 km and on A line from 506/14 to 507/14 for approximately one km. In this section the limestone mine of ACC cement factory is situated to the north to the B line at a distance ranging from 100 to 500m.

After Km 507/14, the A line runs completely outside the forest up to the Walayar railway station but B line again goes through forest between Km 507/5 and Walayar railway station (509/15). On B line movement of elephant between Km 507/5 and 509/15 is less.

On A line there is a critical cutting between Km 505/14 and 506/4 in which one accident has taken place on 17th July 2009. Including this, total two accidents have taken place in this section on A line. Though there has not been any accident on B line in the past but, due to frequent elephant movement across the track this section is very crucial.

The B line in this section between Km 505 and 509 should be fenced using old rails from both sides. Fencing should be done in such a way that it ends on bridge to prevent elephant entry inside the fenced area on railway track. The total length of fencing on one side will be around five Kilometer. Fencing on B line can be started from Km 505A/1 from the bridge and can end at suitable place near 506 A/ 15. Again fencing can be started from 507/9 from the bridge on the Walayar River and can end near 509/0. The area where the bridge is not present a girder bridge kind of structure can be constructed to prevent the elephant entry in the fenced area. There are few bridges which elephant can use after little modifications, like replacement of iron structure with concrete on the top and providing slope in the river bed below the bridges (Fig. 2.30). Bridges in this sections are near 505A/11-13, 506/33-35, 506/7-9 (below this is road for ACC mines), 507/5-9 (On Walayar River) and 508/5-7. Vegetation clearance to a width of about 10 meters from track to increase visibility is required.

Fig 3.29: Old rail fencing to prevent elephant movement in Jharkhand

Fig 3.30: Bridge which elephant can negotiate

Similarly the A line should be fenced between 506/14 and 507/14 from one side only for approximately one km. Fencing poles should be placed three meters apart from each other. The minimum length of poles above the ground should be 180 centimeter and below the ground 70 centimeter. There should be two horizontal rails joined to each poles first at the height of 75 centimeter from the ground and another at the top.

The critical cutting between 505/14 and 506/4 can be widened with gentle slopes on the sides. The other option is to fence the cutting from the sides using old rails to prevent the animal movement inside. These options can be selected based on actual estimation of the cost and feasibility. In cuttings minimum three to five meter gap should be provided on the sides depending on the height of the cutting. Providing gentle slopes on the sides is essential.

To prevent crop depredation in nearby village a suitable barrier (power fence/trench) should be made along the entire forest fringe. Other than this there should some strategies to have regulation on mining and growth of settlements.

D. Walayar-Kanjikode Section:

The entire stretch between Km 510 and 518 on B line is critical. The critical sections are Km 510/0-513/15 and Km 515-517. On the A line the problem is between Km 510 and 513. This whole section is situated in Kerala. There is regular movement of family groups and loners as this section also has a small patch of forest between the A and B lines. Elephants use this area both as a habitat and for crop raiding in nearby villages. This is the only area between Walayar and Kanjikode where elephants can manage to cross the hills from the railway track to the northern side of the habitat. This forest patch extends on B line from Km 510 to 513/17 approximately 3.5 km and on A line from 510 to 513 approximately 3 km.

After Km 513, A line runs completely outside the forest up to the Kanjikode railway station but B line goes through forest between Km 513/25 and 518.

On B line there are several critical cuttings which along with blind curves make the area highly prone for accidents. Out of nine accidents, five have taken place on B line in this section. Some of the cuttings are difficult to widen. Even after widening of critical cuttings, the problem in this area will remain the same as there are several blind curves and frequent elephants movement.

The B line in this section should be fenced from both sides using old rails between 510/25 and 518. Fencing can be started from the one end of a bridge at 510/25 near the nallah and end near the edge of the first cutting (510/44). Then it can start from the other edge of the first cutting at 511/9 and can end at 512/11 near the first end of the next critical cutting. Fencing can be started again from 512/19 at the second end of the cutting and can end at 512/29 near the bridge on the nallah. The total fencing till this point will be 1.5 Km in length. Fencing can then be started from 512/31 from the other end of this *nullah* and can end near 518. The B line in this section is two km longer than the A line. Fencing on B line will be approximately 8.5 kilometer on one side. There are several bridges in this sections of which a few of them (between km 510/23-25, 512/29-31, 513/15-17) are crossable for elephants. Some of these bridges are being used by the elephants. Bridges in this area should also be made animal friendly after few modifications like replacement of iron structure by concrete. Fencing of the B line from both sides is important to prevent elephant movement along the track.

Similarly the A line should also be fenced by old rail from one side between 510 and 513 for approximately 3 Kilometers. Therefore, the total old rail fencing required to be done is 8.5 Km on the B line on both sides (total 17 Km) and 3 Km on the A line.

To prevent crop depredation in nearby village a suitable barrier (power fence/trench) should be made along the entire forest fringe as well. This area also needs proper strategies to regulate mining activities.

Temporary watch tower could be constructed at accident sites to monitor elephant movements on track between 6 PM and 6 AM.

Developing appropriate animal detection system to alert train drivers and Station Masters.

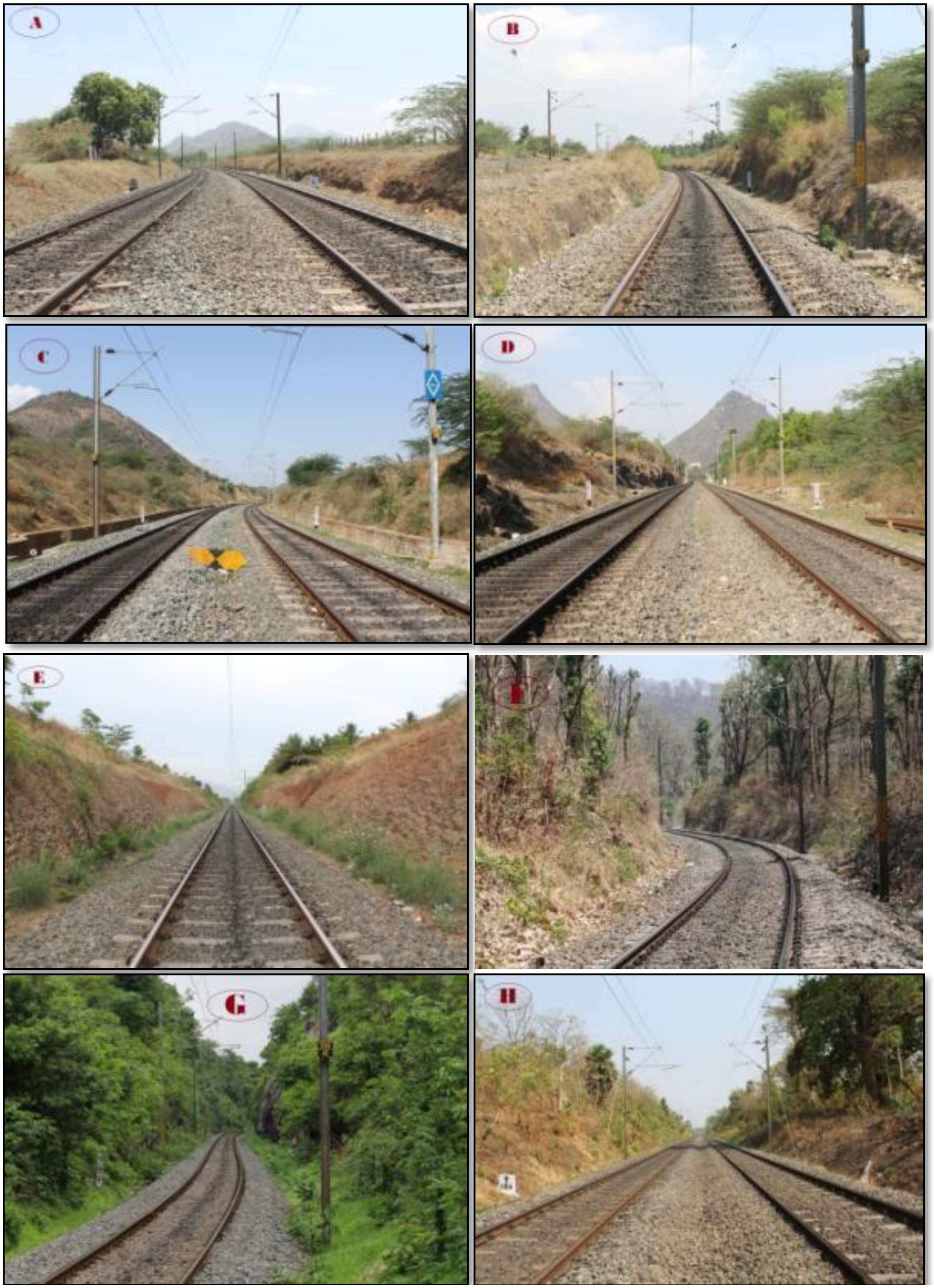
Animal detection system (ADS) should be installed in critical accident prone and accident sites to monitor elephant movement along the track and alert train drivers and Station master. Animal detection system (ADS) has been used by scientists for resolving the problems of animal mortality due to road hits (Huijser *et al.*, 2006). These systems use sensors technology to detect large animals when they approach the road or rail track.

WTI in collaboration with Forest department and railways successfully tested EleTrack (Animal detection system) meant to detect animal presence near/on the track on 22nd April, 2014 (through a different project) at the railway stretch between Walayar to Kanjikode, Kerala on the B Line. The EleTrack should be treated as an "Elephant detection and warning system" and not as a standalone device which will mitigate train hit. It needs to supplemented by other standard operating protocols from both railway and forest officials to act accordingly to the information given.

Photo: elephant mortality on Palakad- Coimbatore railway track

Top left: Elephant calf killed by train hit between Walayar to Kanjikode RLY station during 2010, Top right: 2ndSeptember 2012 elephant carcass between A&B track and decomposed (could not find out reason of death). Middle left: An adult male elephant killed by a passenger train between Walayar and Yettimadai RLY Stations during 2009. Middle right: Three elephants killed in a accident by a passenger train between Madukarai and Podhanoor RLY Stations during 2008. Bottom left & right: **Blind curves on B track between Walayar to Kanjikode RLY stations**

Photo: physical fatures of the railway track



Critical cuttings in the railway track: A&B: Podhanoor to Madukarai, C: Madukarai to Yettimadai, D&E: Yettimadai to Walayar F&G Walayar to Kanjikode, H: Kanjikode to Kottekad.

Photo: elephants on Palakkad- Coimbatore track

Top: An elephant heard cross track B between Walayar to Kanjikode RLY station (Photo: Mr Ashok kumar), top right: Lone bull crossing track B between Walayar to Kanjikode RLY station(Photo: Mr.Hariharan)

Bottom left: Two elephant crossing track between Madukarai to Poadanur RLY Stations; bottom right: Two elephant crossing track ‘B’ between Walayar to EttimadaiRLY Stations

5. Impact of pipelines on forest and wild animals

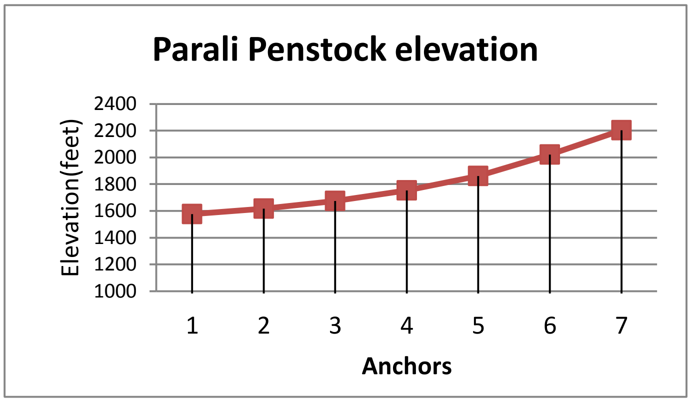
Development of linear infrastructure like irrigation canals and penstock has considerably impacted the natural forest and wild animals. These have the potentially to almost completely fragmenting the forest landscape and isolate wild animals population if not planned properly. Pipelines acts as barrier (Sukumar & Easa, 2006) and filter for wildlife (Jalkotzy *et al*, 1997). Cameron & Whitten (1980) has studied the distribution of caribou population and group composition with respect to the disturbance of pipelines and found that caribou normally avoids the pipeline.

The natural habitat in the Nilgiri Mysore landscape has been fragmented by a number of large hydroelectric power projects and their associated infrastructure like dams, open canals, penstock pipelines and powerhouses (Baskaran 2013).

The project area has seven pipelines collectively passing through a length of around 8.63 km through forests of which two pipelines selected for detailed study.

Parali : The penstock pipe carries water to the Kundah power house III at Parali. The pipeline obstructs the movement of elephants between Geddai and Kallar in the southern slopes of the Nilgiri Mountains. This penstock measures around 1km in length and around 2.5 m in height. The penstock carries water from underground penstock to Parali power house.

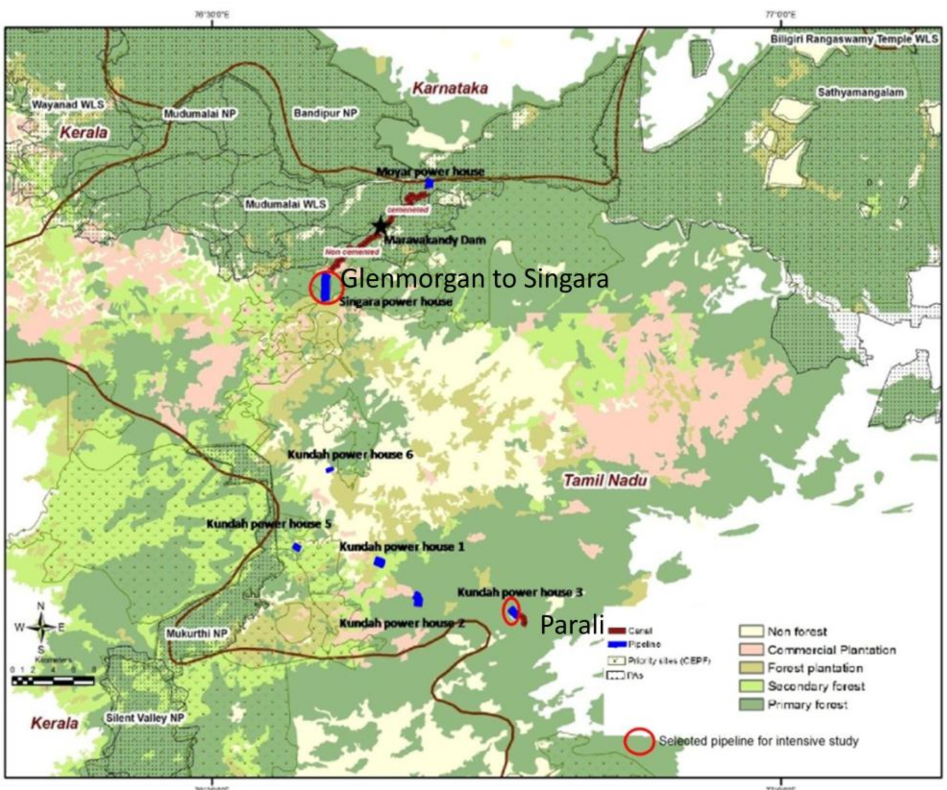
The Kundah power house-3 penstock pipeline with diameter of 2.44m, 2.27m and 2.13m and extended length from head to tail of 1077m is laid on slop of Southern edge of Nilgiri Biosphere Reserve, Coimbatore Forest Division. It has three units which started functioning in different years Unit 1st& 2nd in 1965 and Unit 3rd 1978.



The power house gets water form Pegumbahallah Dam, NiraliPallam and KatteryWeir. A flume channel starts immediately after Penstock pipeline; the canal is only conduit of water from power house and travel through dry deciduous forest for 1000m and merges in to the Bhavani River before Pillu dam.

Glenmorgan to Singara: The pipelines run through the Mudumalai Tiger Reserve for around 2.8km with a diameter of around 2m. The pipeline carries water to Singara power house from Glenmorgan and hinders the movement of elephants and other large mammals (Sukumar & Easa, 2006).

Fig 4.1: location of the two pipelines selected for detailed study



Parali penstock pipeline

Usage of mammals

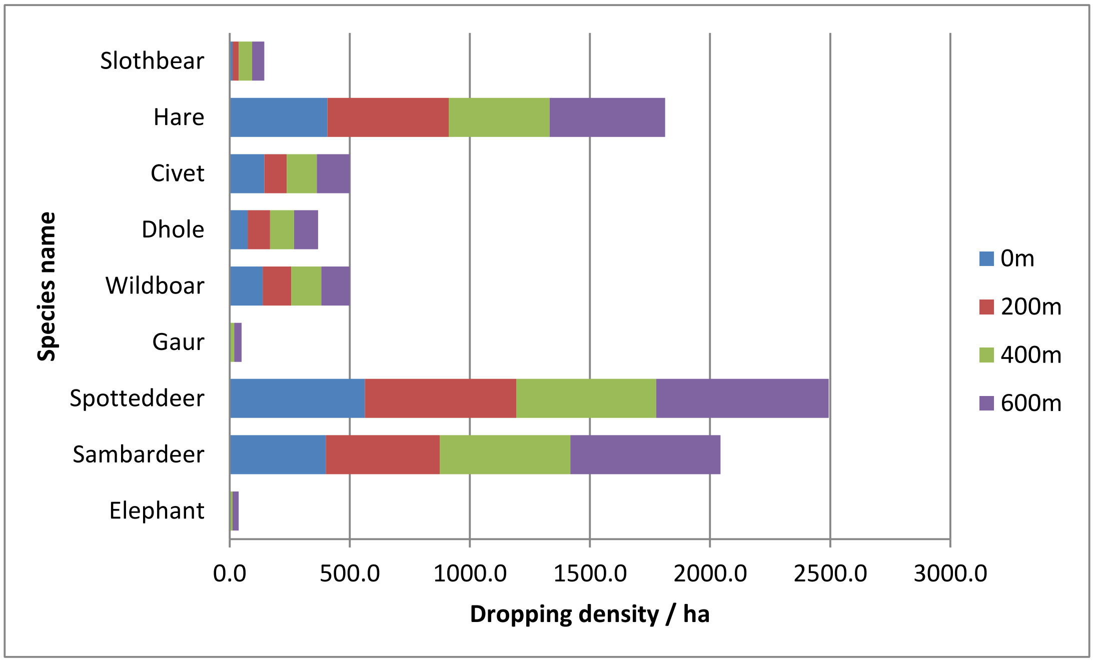
Abundance of mammals with respect to proximity of Pipeline

A total of nine mammal species were recorded from their dung up to 600 meter from the proximity of the pipeline. Dung density of mammals with respect to proximity of pipe line revealed that density was low near the pipe and density increasing according to increase of distance for species like elephant, sambar deer, Indian bison and dhole (Tab.4.1, Fig.4.2). Pearson Correlation results revealed that dropping density of mammals were highly significant with distance from pipeline (r=0.95, p=0.04) indicating that the animals feed in forest close to the pipeline but due to inability to cross (no crossing points), do not come close to the pipeline.

Tab.4.1 Dung density of mammals from proximity of the pipeline

S.no	Species	Dung density / ha			
		0m	200m	400m	600m
1	Elephant	0.0	0.0	12.5	25.0
2	Sambar deer	400.0	475.0	543.8	625.0
3	Spotted deer	562.5	631.3	581.3	718.8
4	Indian bison	0.0	0.0	18.8	31.3
5	Wild boar	137.5	118.8	125.0	118.8
6	Dhole	75.0	93.8	100.0	100.0
7	Civet	143.8	93.8	125.0	137.5
8	Black naped hare	406.3	506.3	418.8	481.3
9	Sloth bear	12.5	25.0	56.3	50.0

Fig.4.2. Pictorial representation of dropping density of mammals from the proximity of the pipeline



Overall relative abundance of droppings of mammals also showed increasing trend with relation to increase of distance from pipeline as 0m (22%), 200m (24%), 400m (25%) and 600m (29%) (Fig.2). Regression analysis revealed that overall dropping density of mammals were highly correlated with the increase of distance from canal (R^2=0.856). Indirect evidences of elephant and gaur were noticed only in 400m and 600m away from the pipeline (Fig.4.3). No evidences could be traced in 0-200m from pipeline which clearly reveals that elephant and gaur are completely avoiding the pipelines. Apart from these species, dropping density of dhole, sambar and sloth bear was less near pipeline and increased as one went away from pipeline. No pattern with respect to distance from pipeline was noticed in species such as black naped hare, civet species and spotted deer.

Fig. 4.3. Relative abundance of mammals from the proximity of the Pipeline

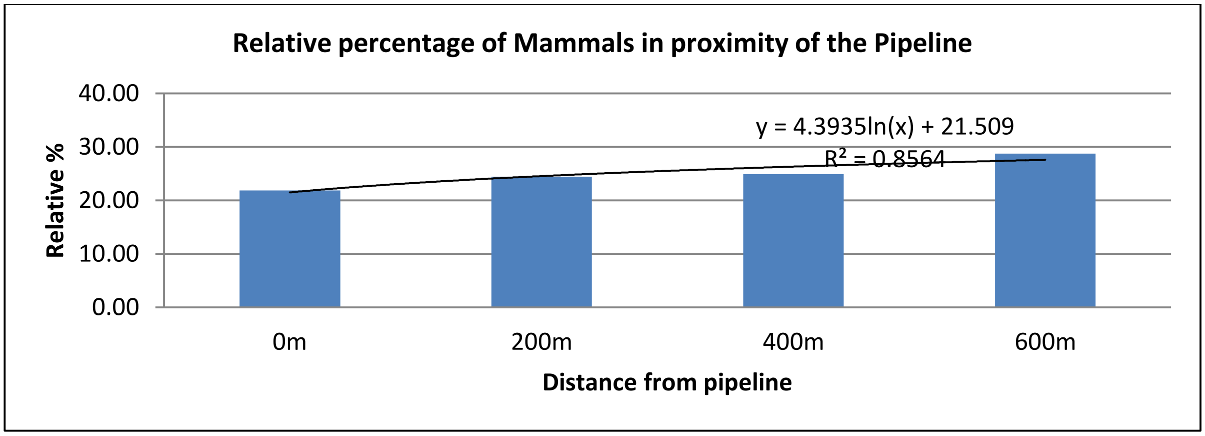
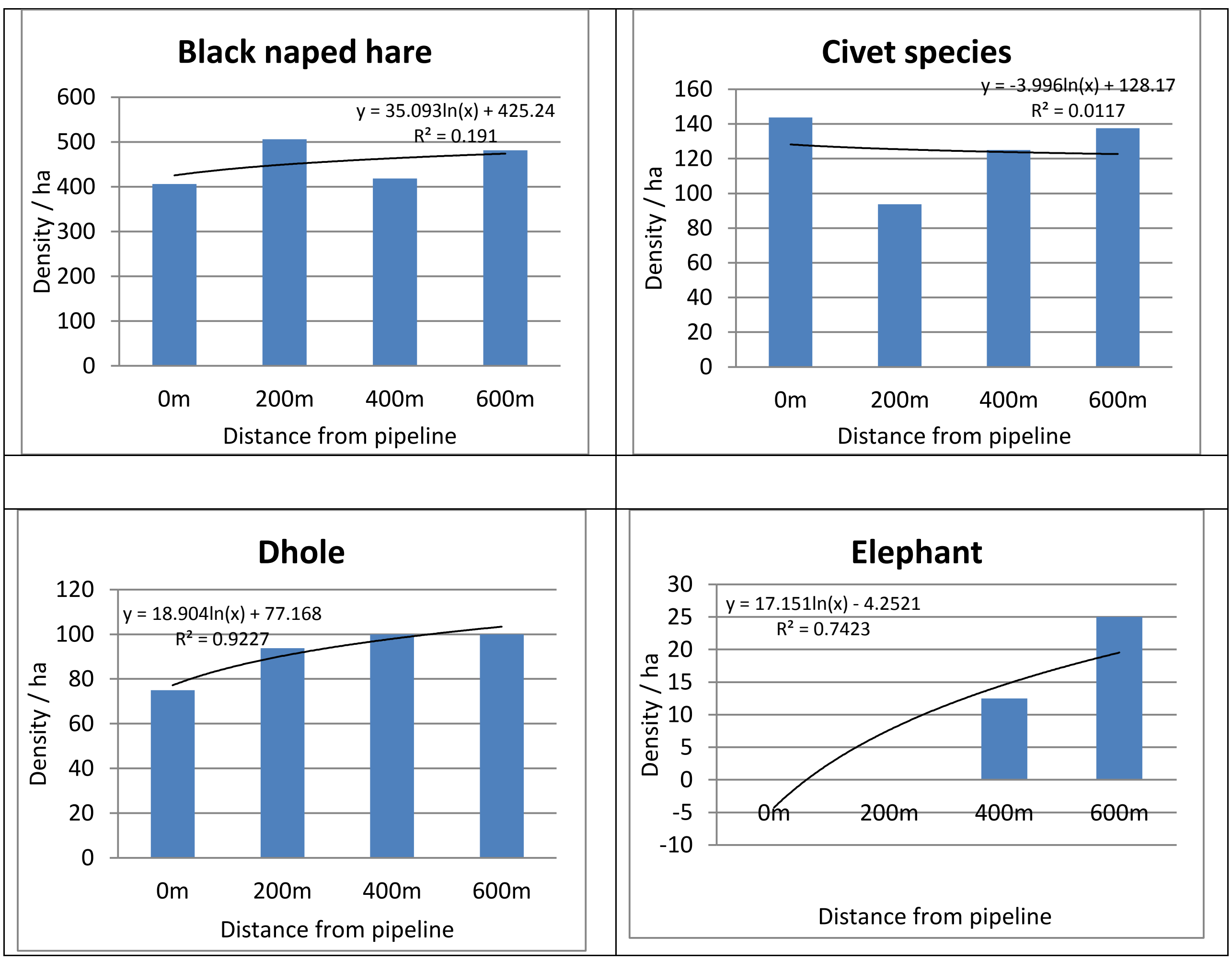
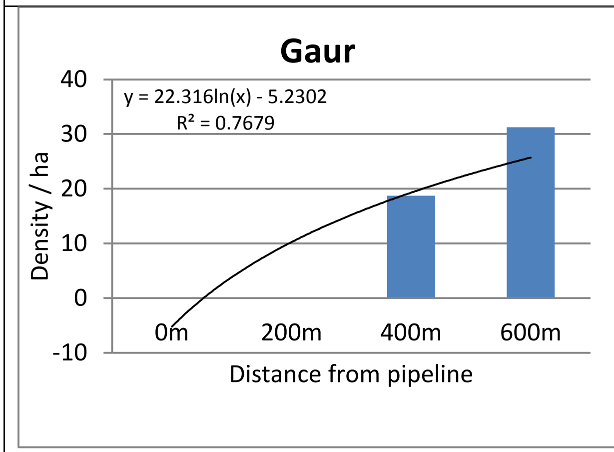
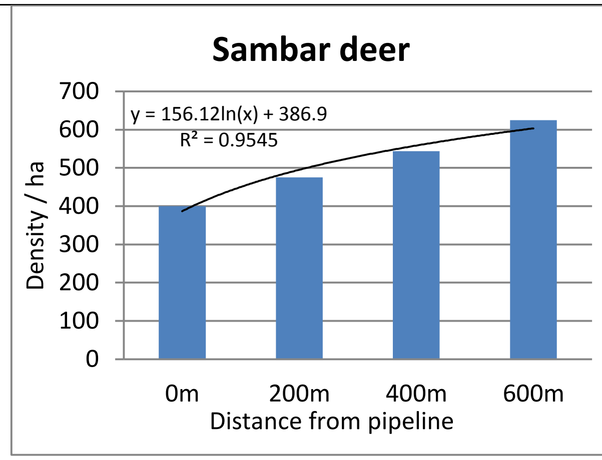
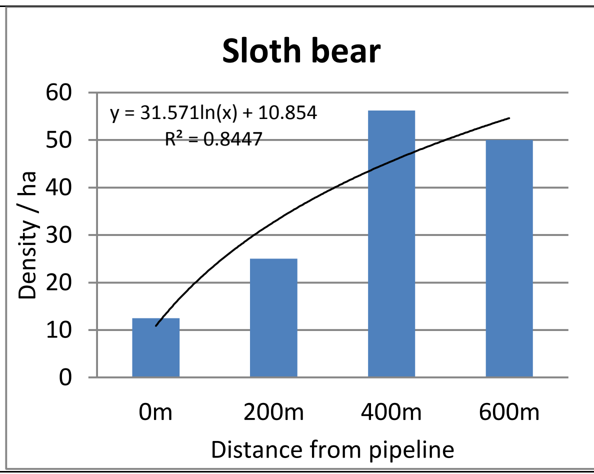


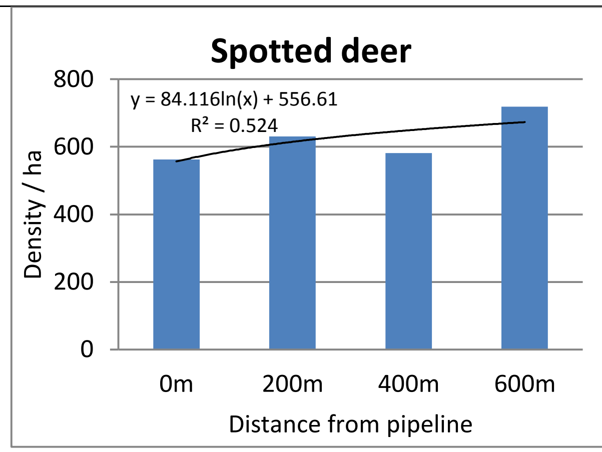
Fig.4.4. Dropping density of individual species from proximity of the pipeline

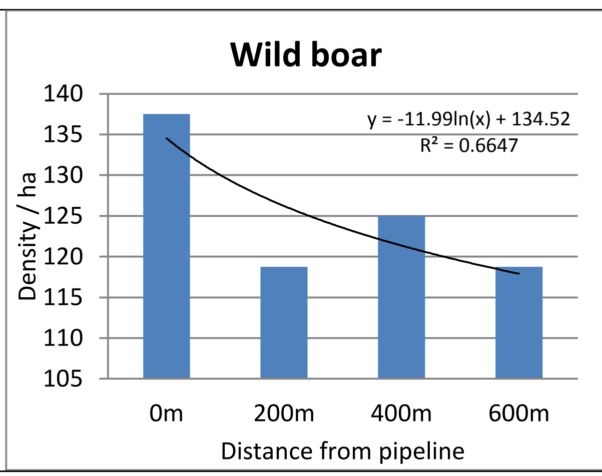



Gaur
y = 22.316ln(x) - 5.2302
R² = 0.7679
Density / ha
40
30
20
10
0
-10
0m
200m
400m
600m
Distance from pipeline


Sambar deer
y = 156.12ln(x) + 386.9
R² = 0.9545
Density / ha
700
600
500
400
300
200
100
0
0m
200m
400m
600m
Distance from pipeline


Sloth bear
y = 31.571ln(x) + 10.854
R² = 0.8447
Density / ha
60
50
40
30
20
10
0
0m
200m
400m
600m
Distance from pipeline


Spotted deer
y = 84.116ln(x) + 556.61
R² = 0.524
Density / ha
800
600
400
200
0
0m
200m
400m
600m
Distance from pipeline


Wild boar
y = -11.99ln(x) + 134.52
R² = 0.6647
Density / ha
140
135
130
125
120
115
110
105
0m
200m
400m
600m
Distance from pipeline

The elephants and gaur due to their large body size cannot cross the 2.44 m wide pipeline and avoids the areas close to the pipeline. The pipeline has considerably affected elephants than any other species since they need large and contiguous habitats to fulfill their daily and seasonal requirements. As the resources may not be available throughout the year in one area or habitat to support large elephant population, hence elephants move long distances to access these resources. Any physical obstruction to the elephant movement in its habitats increases the probability of them raiding crops in fringe villages. Sukumar (1990) suggested that a qualitative change in the home range of the habitat due to various anthropogenic pressures forces the elephants to extend their traditional range and raid crops to meet their daily requirements. Sivaganesan and Ramakrishnan (1997) opined that the major reason for human-elephant conflict could be attributed to invasion of agriculture fields on the forest fringe and various developmental activities in the forest region. An environmental impact assessment on proposed HPCL pipeline project in northern part of Nilgiris suggested that the pipeline project may fragment the elephant habitat and result in loss of habitat and migratory route and could result in severe human elephant conflict in future (Varma, 2000).

The dropping density of sambar deer showed some utilizational proximity with pipeline to some extent and this might be due to water availability from leakage in pipes. Even though these pipelines are not conducive for larger mammals to cross, there are some places between two anchor of pipes providing space for smaller mammals to cross under the penstock pipeline. Dropping density of black naped hare, civet species and wild boar in the proximity of pipeline also corroborates this.

A total of seven anchors were constructed over the penstock pipeline. Of these, the pipeline between anchor No.5-7 situated in the very steep embankment. The gap of pipeline from ground from anchor No.3-7 allows access to smaller mammals to access habitats on both sides of the pipeline. The height of the three pipelines from the ground also varied. There is an over bridge on the pipeline constructed for the movement of humans which is also used extensively by elephants to access habitats in both side of the pipeline. For the free movement of smaller mammals it is suggested to increase the gap between pipeline and ground throughout the pipeline. Also Ramps/overpass could be constructed near 11.24569°N 76.76479°E to facilitate animal movement.

Vegetation abundance

A total of 18 tree species were recorded up to 600 meter from the pipeline. Tree species diversity was similar in all distance categories (Tab.4.2). Overall tree density was high in 600m (187.65/ha) (Fig.4.5). Totally 8 shrub species, 7 weed species, one invasive species and two climbers were recorded (Tab.4.3,4.4,4.5).

Tab.4.2. Density of trees from proximity of pipeline

S.No	Tree species	0m	200m	400m	600m
1	*Albizzia amara*	6.3	12.5	6.25	12.5
2	*Anogeissus latifolia*	13	6.25	12.5	12.5
3	*Atlantia monophylla*	13	12.5	6.25	6.25
4	*Bauhinia racemosa*	13	18.8	12.5	18.8
5	*Capparis sp.,*	6.3	12.5	6.25	6.25
6	*Dalbergia paniculata*	6.3	12.5	6.25	6.25
7	*Dichrostachy scinerea*	13	6.25	6.25	6.25
8	*Ficus microcarpa*	13	6.25	6.25	6.25
9	*Givotia rottleriformis*	6.3	12.5	6.25	6.25
10	*Gyrocarpus jacquini*	6.3	12.5	6.25	18.8
11	*Limoniaalata*	13	6.25	12.5	6.25
12	*Maba buxifolia*	13	6.25	6.25	12.5
13	*Premna sp.*	6.3	12.5	12.5	12.5
14	*Pteralobium hexapetalum*	6.3	6.25	6.25	12.5
15	*Randia malabarica*	13	6.25	12.5	12.5
16	*Sapindus emarginatus*	6.3	12.5	6.25	6.25
17	*Terminalia belliriica*	6.3	6.25	18.8	6.25
18	*Terminalia crenulata*	13	6.25	12.5	18.8

Tab.4.3. Density of shrubs from the proximity of pipeline

	Species	0m	200m	400m	600m
1	*Acacia intsia*	0	68.75	106.25	125
2	*Acacia Pennata*	31.25	25	31.25	43.75
3	*Acacia torta*	43.75	37.5	56.25	81.25
4	*Adadhoda vasika*	62.5	31.25	0	37.5
5	*Carmona retusa*	62.5	18.75	87.5	106.25
6	*Helicteres isora*	87.5	68.75	131.25	112.5

7	*Xanthium indicum*	118.75	87.5	181.25	150
8	*Ziziphus oenoplia*	0	50	43.75	0

Tab.4.4. Density of weeds from the proximity of pipeline

	Species	0m	200m	400m	600m
1	Blepharismaderaspatensis	100	125	81.25	75
2	Euphorbia hitra	56.25	37.5	100	25
3	Mimosa pudica	37.5	0	37.5	0
4	Oxalis corniculata	43.75	50	87.5	106.25
5	Pyllanthusamarus	31.25	18.75	31.25	0
6	Triumfettaannua	25	112.5	68.75	0
7	Ocimumtenuiflorum	12.5	31.25	43.75	31.25

Tab.4.5. Density of invasive species from the proximity of pipeline

	Species	**0m**	**200m**	**400m**	**600m**
1	Lantana camara	68.75	37.5	100	112.5

Overall relative abundance of vegetation showed no pattern with relation to increase of distance from pipeline. Regression analysis on relative percentage of vegetation in proximity of the pipeline revealed that only shrubs have some negative correlation (R^2=0.711) (fig.5). Whereas there was no pattern detected for trees, weeds and invasive species with respect to distance from pipeline.

Fig.4.5 Relative percentage of vegetation from the Pipeline

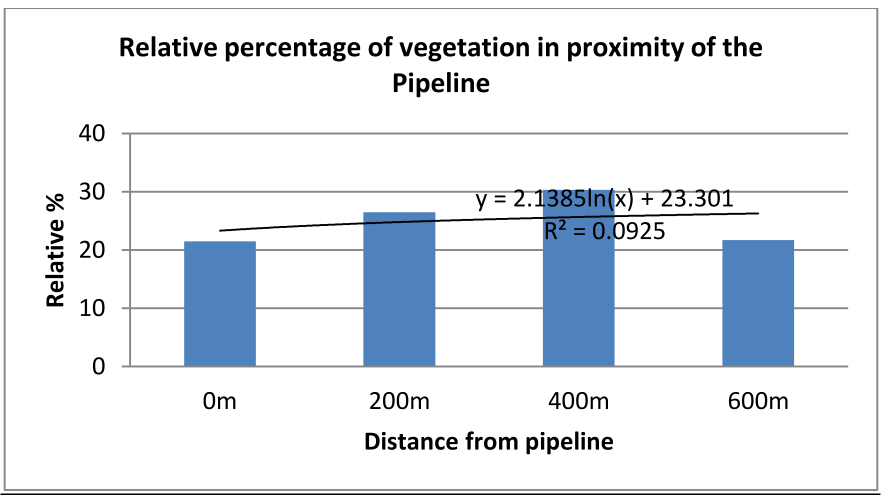
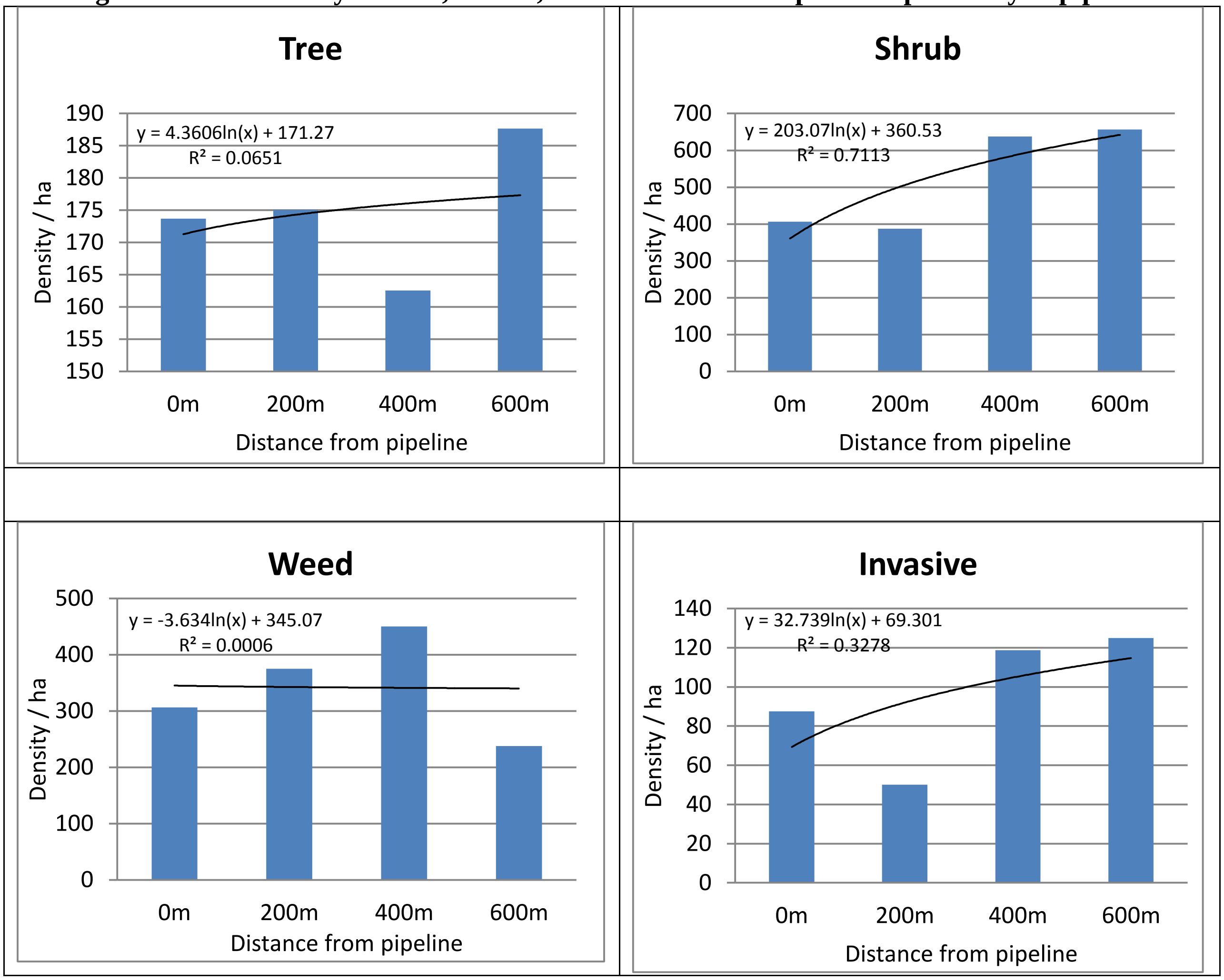


Fig.4.6. Overall density of trees, shrubs, weeds and invasive species in proximity of pipeline



Correlation between Herbivore and Vegetation

Pearson correlation revealed positive correlation between abundance of herbivores and density of vegetation ($r = 0.99$). This meant that abundance of herbivores increased with relation to increase of density of vegetation. This correlation between herbivore and vegetation was also highly significant ($p=0.001$).

GLENMORGAN- SINGARA PIPELINE

Abundance of mammals with respect to proximity of pipeline

Evidence of 11 mammal species were recorded up to 600 meter from pipeline (Tab.4.6, Fig.6). Overall, relative abundance of droppings of mammals showed that 0m attributed high (30%) followed by 600m (29%), 400m (21%) and 200m (20%) (Fig.7). There was however no correlation in the overall dropping density of mammals with different distance classes from pipelines. Dung density of elephant showed positive correlation with the increasing distance from the pipeline ($R^2 = 0.673$) whereas dropping density of gaur was negatively correlated with the increasing distance from the pipeline ($R^2 = 0.776$) (Fig.4.9).

Table.4. 6. Mammal dropping density from proximity of the pipeline

Mammal dropping density/ha				
Distance from pipeline				
Species	0m	200m	400m	600m
Black naped hare	271.88	162.50	93.75	178.13
Elephant	56.25	43.75	50.00	34.38
Gaur	6.25	18.75	31.25	28.13
Common langur	9.38	6.25	12.50	12.50
Leopard	0.00	0.00	3.13	0.00
Sambar	212.50	203.13	200.00	334.38
Sloth bear	12.50	6.25	3.13	6.25
Small carnivore	3.13	6.25	3.13	6.25
Spotted deer	115.63	0.00	93.75	65.63
Tiger	0.00	6.25	0.00	6.25
Wild boar	6.25	9.38	3.13	12.50

Fig.4.7. Pictorial representation of mammal dropping density from proximity of the pipeline

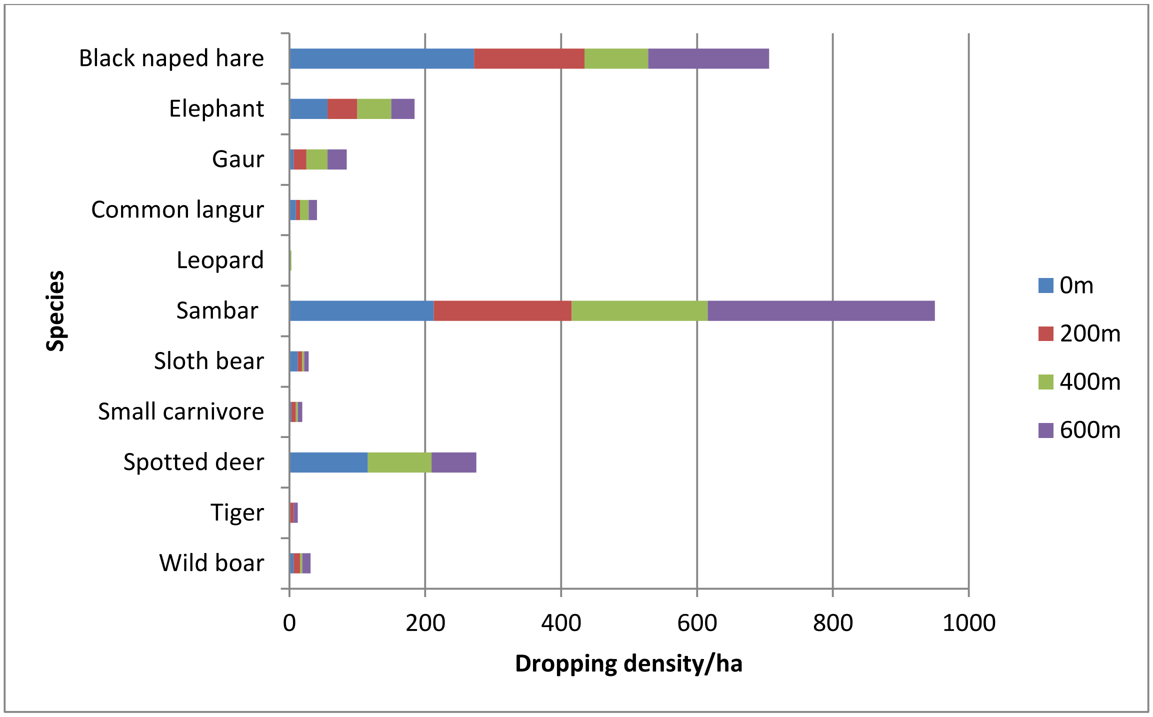


Fig.4.8 Relative abundance of mammal droppings from proximity of the pipeline

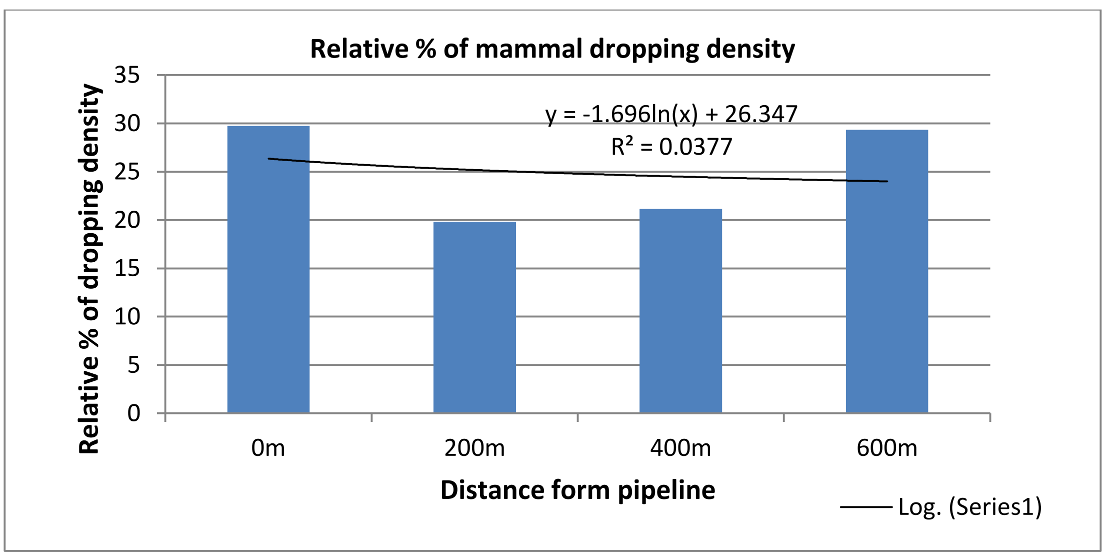
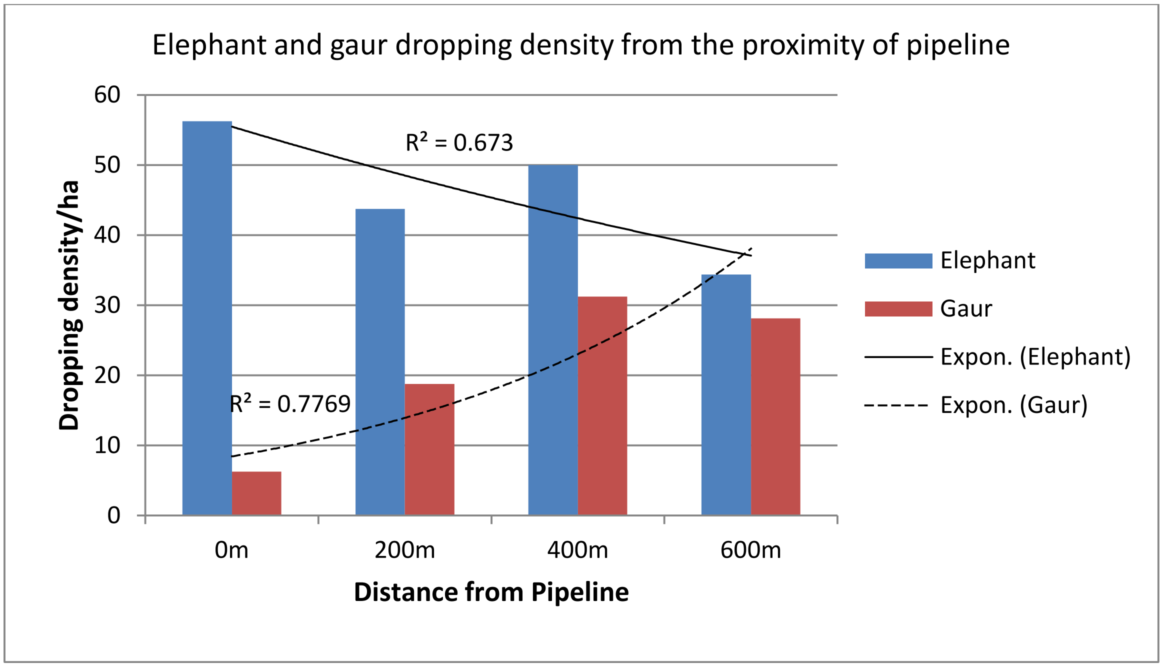


Fig.4.9. Dropping density of elephant and gaur from the proximity of pipeline



A total of 15 mammalian species were recorded during the dung encounter survey along the pipeline. Of these, the encounter rate of droppings of Sambar deer was high followed by elephant and gaur (Fig.4.10). It is interesting to note that although elephants are not able to cross the pipe line except two places, it has the second highest encounter rate along the pipeline.

Fig. 4.10. Encounter rate of mammals along the pipeline

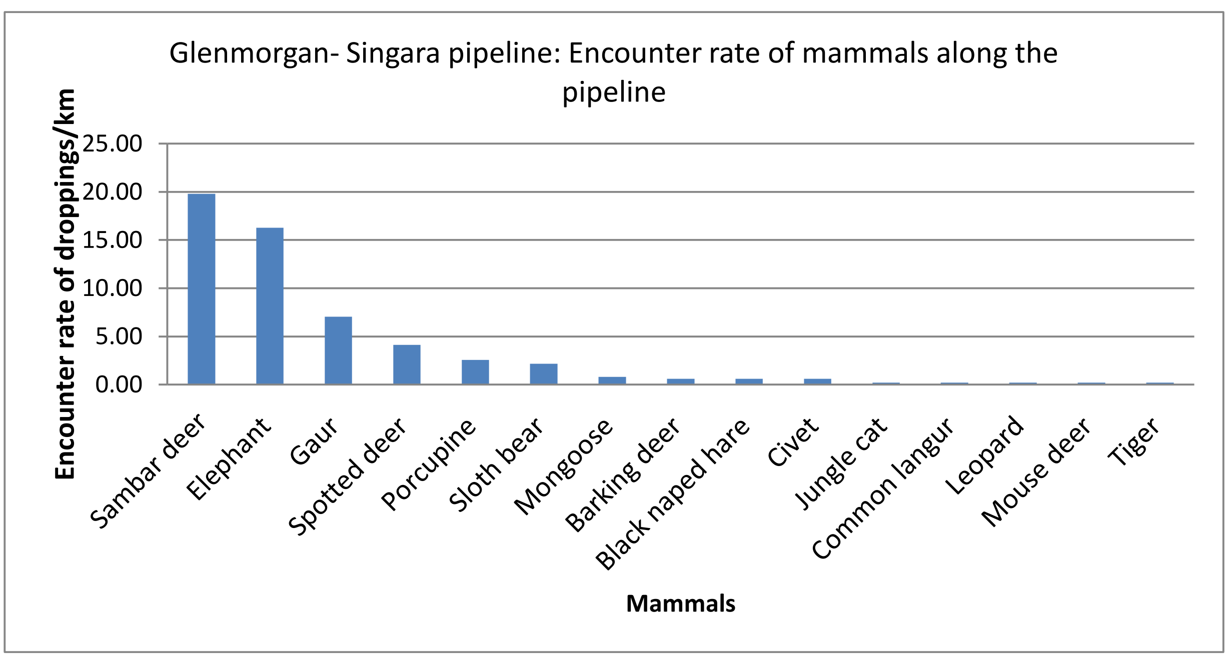
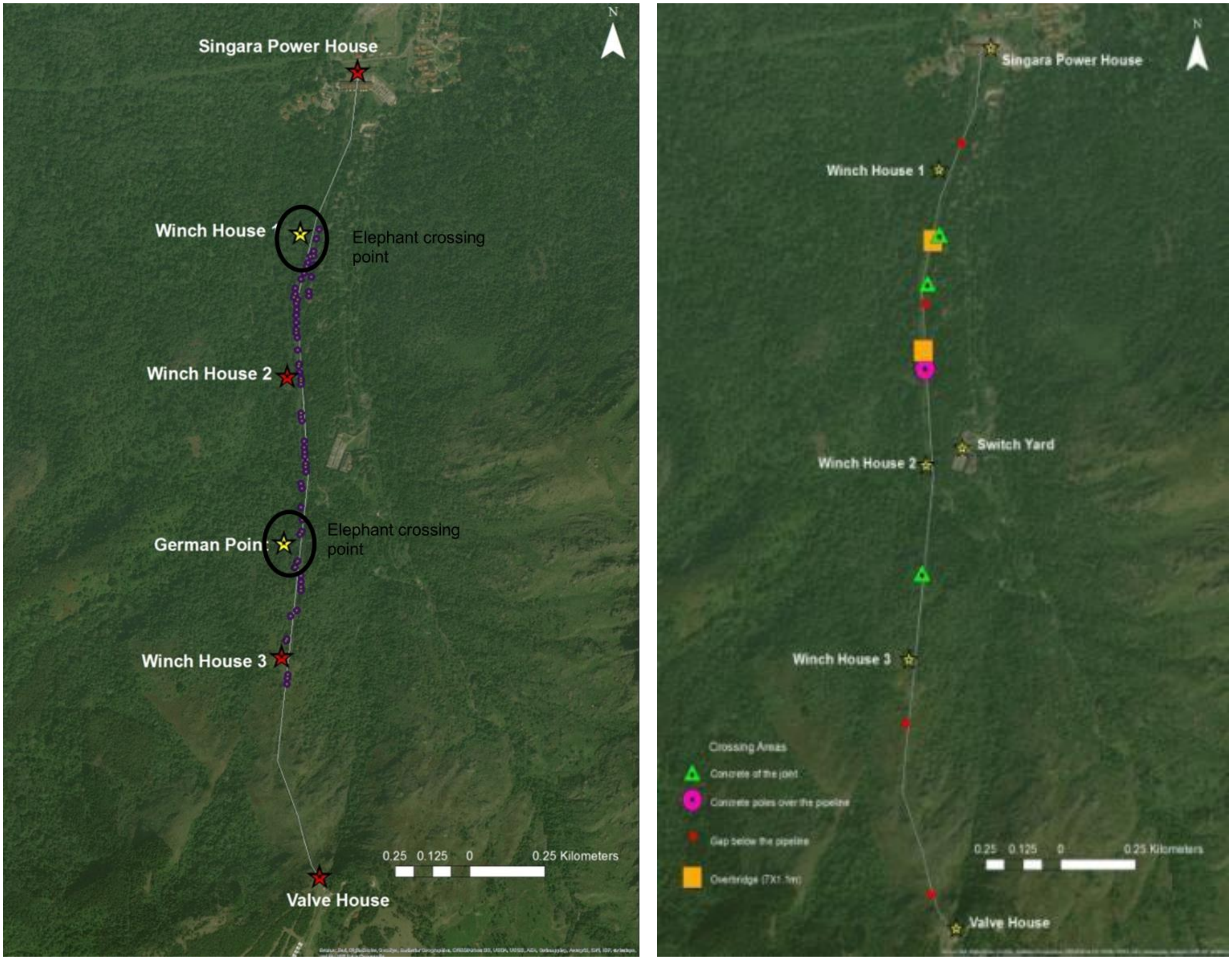


Fig 4.11 Elephant crossing point on pipeline (left) and crossing point for other smaller animals (right)



Abundance of vegetation

A total of 19 tree species were recorded up to 600 meter from the proximity of the pipeline. Tree species diversity was almost similar in all distance categories (Table 4.7). Overall tree density from proximity of pipeline showed no correlation with relation to distance (R^2=0.247) (Fig.4.18).

Tab.4.7 Tree density from proximity of the pipeline

species	0m	200m	400m	600m
Acacia nilotica	6.25	6.25	6.25	6.25
Anogeissus latifolia	18.75	15.625	37.5	12.5
Bambusa arundinalis	0	71.875	131.25	71.875
Butea monosperma	0	0	0	6.25
Cassia fistula	12.5	0	0	0
Celtis tetrandra	25	15.625	15.625	0
Chloroxylon swietenia	6.25	0	0	0
Dalbergia latifolia	0	3.125	0	0
Givitia tilifolia	3.125	6.25	0	3.125
Grewia tilifolia	18.75	9.375	28.125	15.625
Lagerstroemia lanceolata	37.5	21.875	18.75	21.875
Limonia acidissima	0	12.5	0	0
Mangifera indica	3.125	0	0	0
Phyllanthus emblica	12.5	12.5	6.25	6.25
Premna tomentosa	0	0	6.25	0
Syzygium cumini	6.25	3.125	3.125	9.375
Tamarindus indica	9.375	3.125	3.125	3.125
Tectona grandis	15.625	3.125	0	6.25
Terminalia tomentosa	6.25	0	0	0
Unidentified	18.75	50	71.88	62.50

Total of three invasive species were recorded in the sampled plots of which, percentage of mean cover was high for *Lantana camara* followed by *Chromolaena odorata* and *Parthenium hysterophorus*. No correlation for any invasive species with relation to distance from pipeline was seen.

Fig. 4.11. Overall tree density from the pipeline

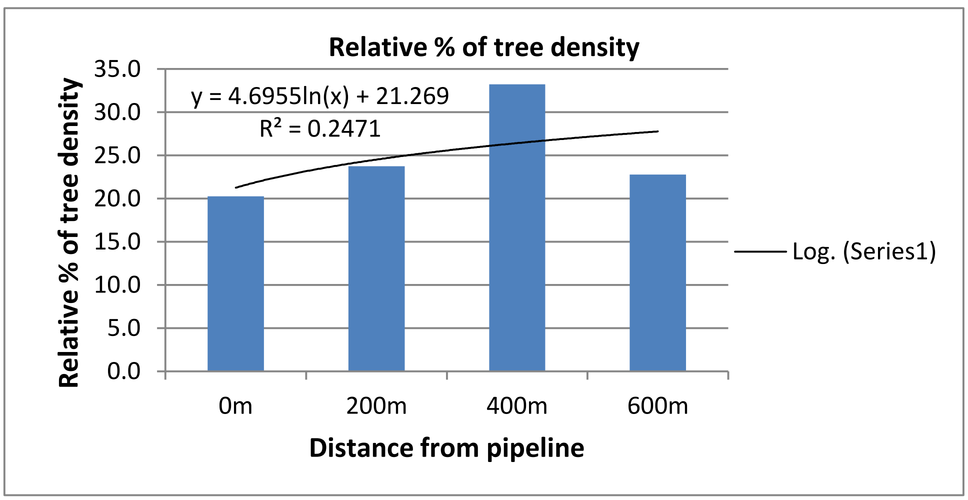
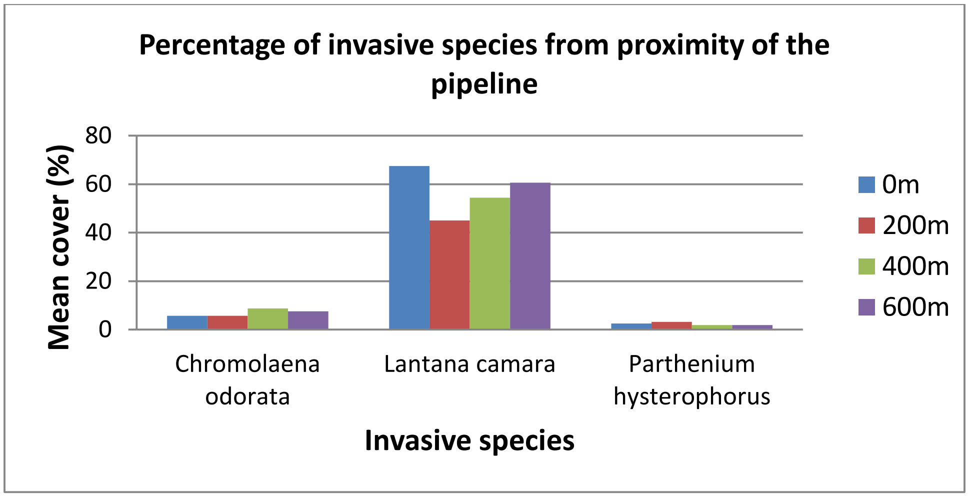


Fig.4.12. Percentage of invasive species from proximity of the pipeline



Recommendations

Parali pipeline

1. Built an over passage on penstock near anchor no 5 (GPS location N 11.24569 and E 76.76479). At this place the penstock is between two embankments and the study found large evidence of animal usage on both ends.
2. Increase the gap between pipeline and ground at most places along the pipeline

Glenmorgan- Singara pipeline

1. Construct new crossing structure between winch house 1 and 2 to facilitate crossing of large mammals especially elephants and gaur.
2. Increase the number of crossing structures by shaping the concrete joints of the pipeline
3. Maintenance and restructuring of existing crossing structures like gap below the pipeline, over bridges and concrete poles over the pipeline for facilitating movement of animals.

Photo: Parali pipeline

Top left: A view of Parali penstock pipeline, Top right: Water leakage in the pipeline joint, Middle left: Shows suitable place making ramp/overpass to facilitate animal movement, Middle right & Bottom left: WTI team measuring gap between pipe and ground, Bottom right: Close up view of alignment of parali pipeline.

Photo: Glenmorgan-Singara pipeline

Top left: A view of Glenmorgan- Singara penstock pipeline, Top right: Picture shows gap between pipeline and ground, Middle left: The elephant crossing point at 'German point' over the pipeline, Middle right: Concrete joint over the pipeline, Bottom left: Spotted deers crossing the pipeline area, Bottom right: Elephant dung piles on the Winch track.

5. Impact of Canals/flume channels on forest and wild animals

India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario. Out of the total power generation installed capacity in India, hydro power contributes about 22%. However, the development of canals, flume channels and pipelines to transport water to the power houses may have adverse impact on environment and ecology if not planned properly viz. deforestation, fragmentation, loss of bio-diversity including disappearance of rare species of animals and plants, soil erosion, faster rate of reservoir sedimentation, socio-economic implications, relocation and rehabilitation of people, increased seismic risk, change in aquatic system, climatic change, change in flow regimes downstream of the dam, etc . For example the canals and flume channels in Coimbatore Forest Division (Parali), Mudumalai Tiger Reserve (Maravakandy- Moyar), Anamalai Tiger reserve (Contour canal), Jharkhand and South Bengal (Subernarekha canal), North Odisha (Reengali canal), etc have severely fragmented the wildlife habitat and increased conflict with human and wildlife. Human-elephant conflict has increased over the years and now mitigation measures are being planned to minimize conflict.

The Nilgiri- Mysore landscape has only two canals/ flume channels, namely

Parali canal: This canal of length around one km carries water from Parali power house to Bhavani River in Coimbatore forest division. The width of the channel is around nine meter and the depth is around seven meter. The channel does not allow movement of any wildlife throughout its length except at a bridge on a road crossing the channel

Maravakandy to Moyar flume channel: This canal carries water from Singara Power house to Moyar Power house in Mudumalai Tiger Reserve. The flume channel runs as a non- cemented structure from Singara to Maravakandy for a length of 8.63 km and through a largely cemented structure for 6.81 km from Maravakandy to Moyar power house. The stretch between Maravakandy to Moyar flume channel was taken up for detailed study. The width of the channel varies from 11- 13m and passes through the Moyar- Avarahalla elephant corridor (Varma *et al.*, 2005). Elephants cannot cross this channel except few selected places. Tyagi (1995) and Daniels *et al* (2008) have recommended to install bridges across this canal to mitigate the impact on the movement of wildlife especially elephants.

Objective: to understand the edge/ barrier effect of canals/ flume channel on wildlife and plan mitigation measure

Methodology

To assess the effect of canals/ flume channels on movement of wild animals and abundance of vegetation, 20 x 20 m plots were laid at an interval of 200m along the one km line transect from the road. Transects were laid radially at both side of road in all major vegetation types. In each plot variables such as name of the animal, number of animal droppings, name of the tree and number of trees were recorded. Two 5m x 5m sub plots were laid in the corner of 20x20 m plot to record shrubs and herbs. Also two 1x1 m sub plots were laid in the alternative corner of plots for weeds and invasive species.

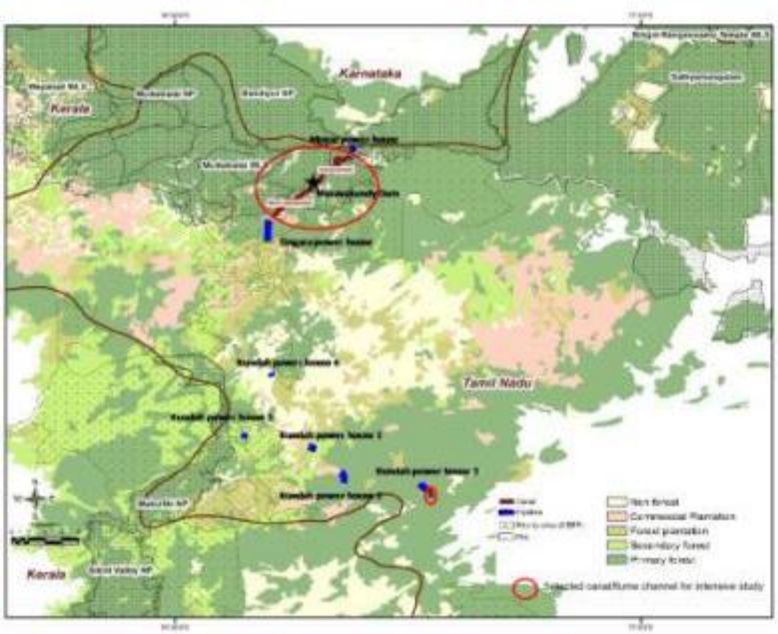


Fig 5.1 Map showing location of Parali canal and Maravakandy to Moyar flume channel

Parali canal (open tunnel)

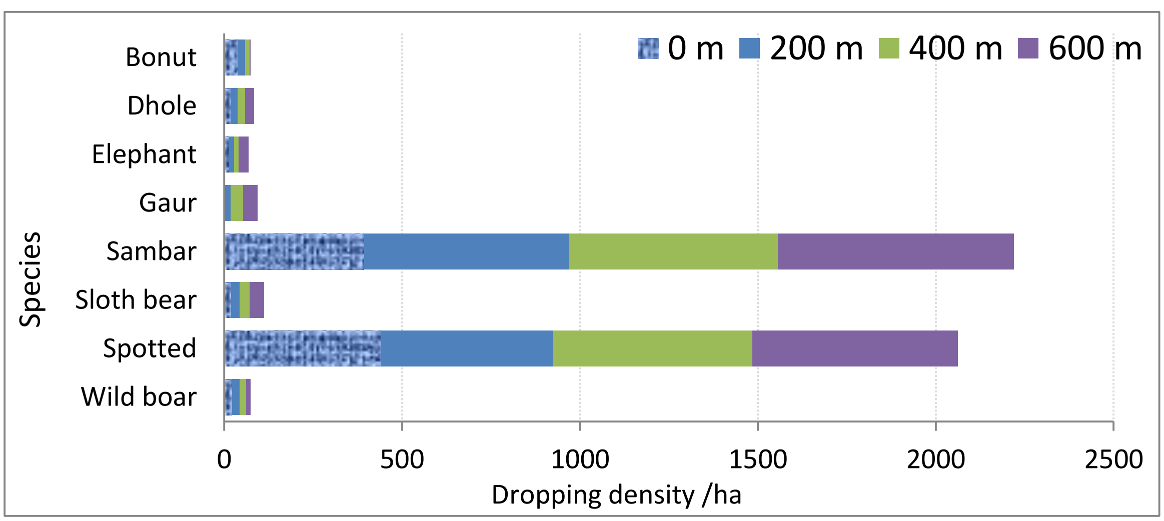
Abundance of mammals with respect to proximity of canal

Evidences of eight mammal species were recorded up to 600 meter from the canal. Dung density of mammals with respect to proximity of canal revealed that animal abundance was low near the canal and increases with distance from the canal for species such as gaur, sambar deer, sloth bear spotted deer and dholes (Tab.5.1, Fig.5.2). On the contrary, dung density was high near the canal for the species such as bonnet macaque and wild boar and density decreased according to increase of distance. No pattern was noticed in dung density of elephant.

Tab.5.1. Dropping density of mammals from proximity of the canal

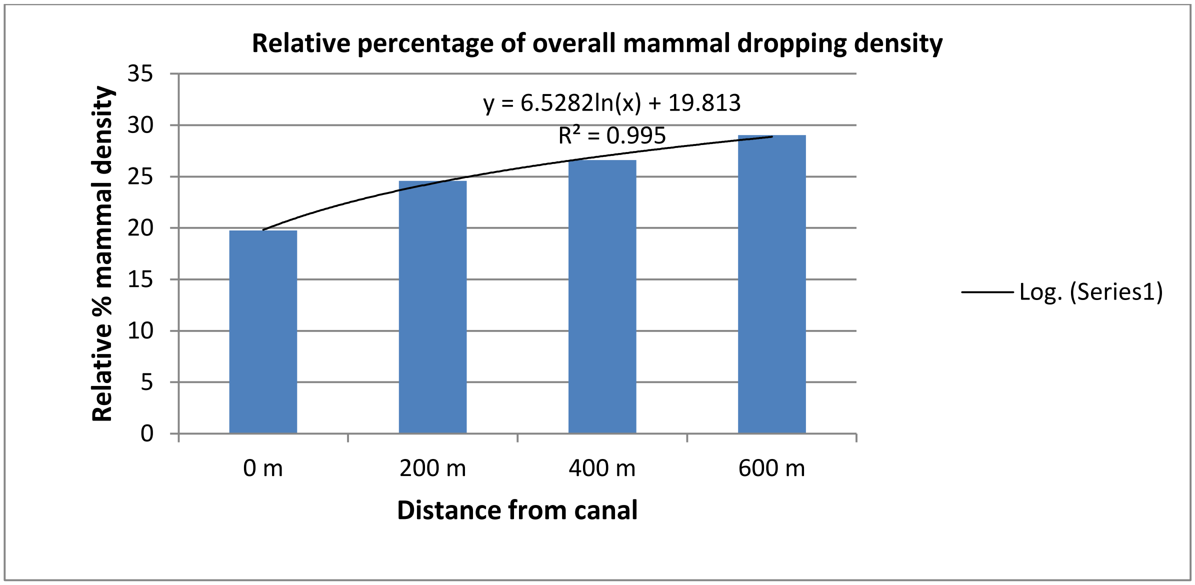
S.no	Species	Mammal dropping density / ha			
		Distance from Canal(m)			
		0	200	400	600
1	Bonnet macaque	37.5	21.88	12.5	3.13
2	Dhole	18.75	18.75	21.88	25
3	Elephant	12.5	15.63	12.5	28.1
4	Gaur	3.125	15.63	34.38	40.6
5	Sambar	393.8	575	587.5	663
6	Sloth bear	18.75	25	28.13	40.6
7	Spotted deer	440.6	484.4	559.4	578
8	Wild boar	21.88	21.88	18.75	12.5

Fig.5.2. Pictorial representation of mammal dropping density from proximity of canal



Overall relative abundance of mammal dung also showed an increasing trend in relation to increased distance from canal at 0m (19.7%), 200m (24.6%), 400m (26.6%) and 600m (29%) (Fig.5.3). Regression analysis revealed that overall dropping density of mammals was correlated with increase in distance from canal (r=0.995).

Fig.5.3. Relative percentage of overall mammal dropping density

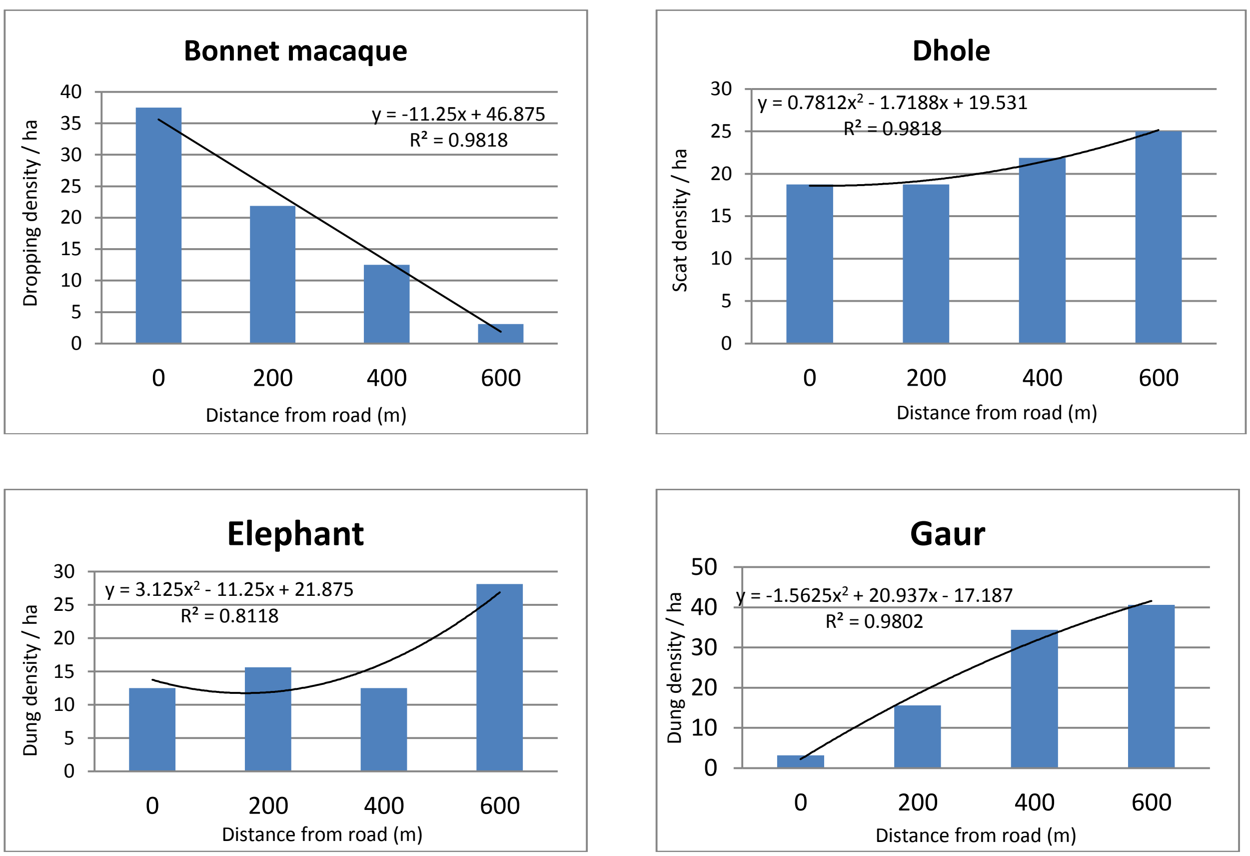


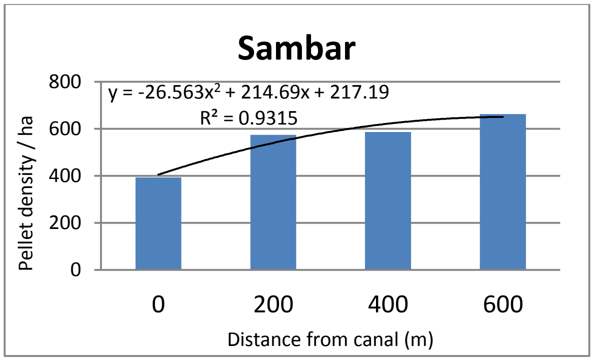
Dung density of bonnet macaque and wild boar were high near canal and decreases with increase distance from canal. Regression analysis also showed strong positive correlation with increase of distance from canal for bonnet macaque (R^2=0.981) and some correlation for wild boar (R^2=0.664) (Fig.5.4). On the contrary, dung density was less near the canal and increased according to increase of distance from canal for the species such as dhole, gaur, sloth bear, spotted deer, sambar and elephant. Regression analysis also showed high negative correlation with increase of distance from canal for these species.

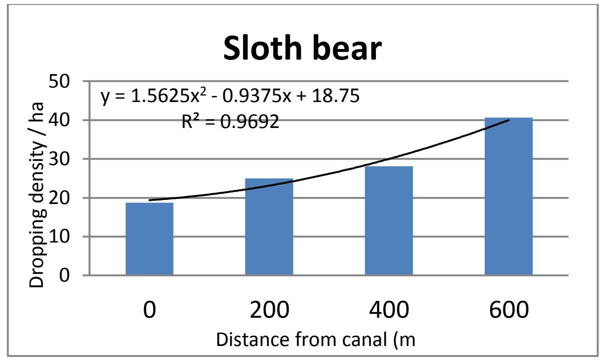
Except primates, none of the animals can cross the canal nor have access to water for a distance about 800 m from the end of Parali canal due to steep cutting edges in both side of the canal. Although some species are still using the proximity of canal area and this could be due to availability of grass and herbs on both side of the canal. There is only one bridge over the pipeline near the Executive Engineer Office, Parali Power house III and another bridge over canal that provides accessibility to villages (namely Neeralipallam, Paralikkadu, Nellimarathur, Pillur etc. settlement). Wild animals also use these bridges mostly at night. Apart from these two bridges, movement of larger mammals is completely blocked for the distance about 1 km by 8 foot high pipeline followed by steep canal for the distance about 800 m. Hence it is suggested to construct green bridge over the canal for the free movement of all mammalian species. The suitable location of the bridges can be between GPS location N11.23922^{o}/ E76.77408^{o} and N11.24033o/E76.77391^{o}.

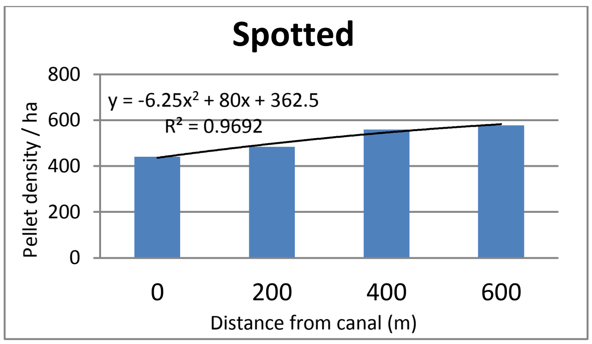
Rodney van der Ree *et al* (2015) suggested that the crossing structure should allow the wild animals cross canal without risk and this should be at least 30-50m wide and length depends on the width of the canal. The bridge could be camouflaged with vegetation to give a natural look to animals.

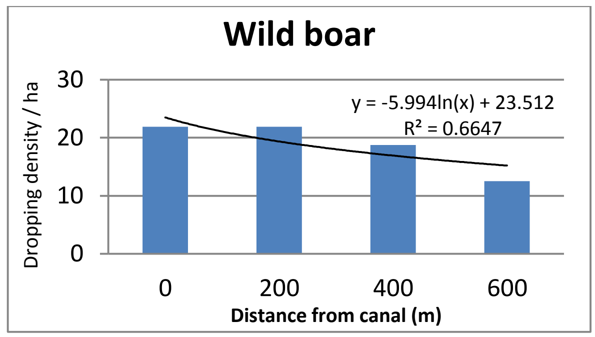
Fig.5.4. Dropping density of mammals from the proximity of the canal





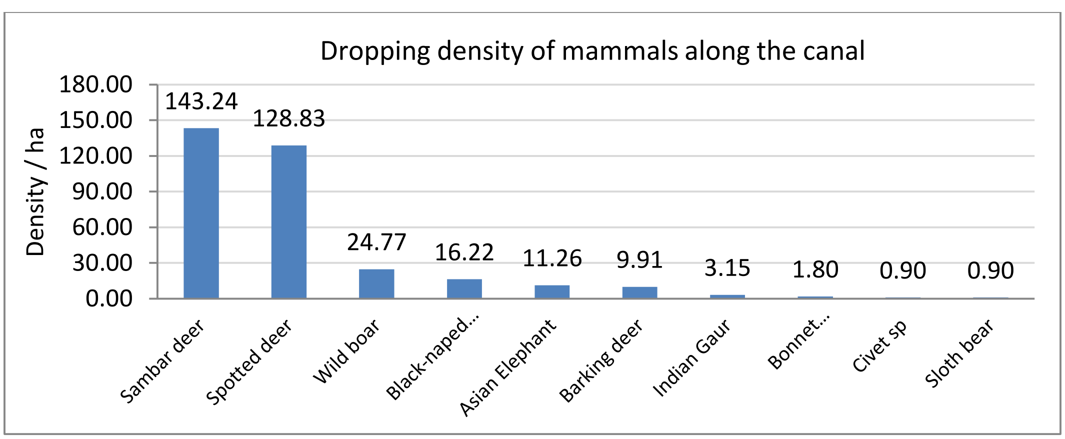






Dung density of mammals along the canal bank (fig 5.5) revealed that the spotted deer (143.24/ha) and sambar deer (128.83/ha) abundance was very high compared to other species such as wild boar (24.77/ha), Black naped hare (16.22/ha) and elephant (11.96/ha). Larger availability of Spotted deer and Sambar deer could be attributed to better grass cover near canal as well as staying in open along the canal at night to avoid carnivore predation.

Fig 5.5 Dung density of mammals along the canal



Vegetation abundance

A total of 24 tree species were recorded up to 600 meter from the proximity of the canal. Tree species diversity was almost similar in all distance categories such as 0m (n=24), 200m (n=22), 400m (n=22) and 600m (n=21) (Tab. 5.2). In all 13 shrub species, seven herb species and an invasive species (*Lantana camara*) were recorded in the study area (Tab.5.3- 5.5). Overall, tree density and herb density was high at 0m and was 153.56/ha and 284.4/ha respectively. Regression analysis did not reveal any correlation for trees and herbs with the distance categories from canal (Fig.5.4). Also no pattern was noticed for shrubs and invasive species with relation to distance categories from canal through the regression analysis. Regression analysis results on overall vegetation also showed that there is no correlation with distance categories from canal (Fig.5.6).

Table 5.2. Density of trees from proximity of Canal

		Tree density/ha			
		Distance from canal			
S.No	**Scientific name**	**0**	**200**	**400**	**600**
1	*Albizzia amara*	9.40	6.25	6.30	12.50
2	*Anogeissus latifolia*	6.49	3.12	6.20	9.38
3	*Atlantia monophylla*	9.40	6.25	6.30	15.65
4	*Bauhinia racemosa*	6.25	9.40	6.30	9.40
5	*Capparis sp.,*	12.50	6.25	13.00	3.13
6	*Cordia sp.,*	3.13	3.13	3.10	3.13
7	*Dalbergia paniculata*	3.13	0.00	3.10	0.00
8	*Dichrostachys cinerea*	6.25	0.00	0.00	3.13
9	*Elaedendrone glacum*	9.40	3.13	6.30	9.40
10	*Ficus microcarpa*	3.13	6.25	3.10	3.13
11	*Givotia rottleriformis*	3.13	0.00	3.10	3.13
12	*Gyrocarpus jacquini*	9.40	6.25	6.30	9.40
13	*Hardwickia binata*	3.13	3.13	0.00	3.13
14	*Limonia alata*	6.25	9.40	6.30	9.40
15	*Maba buxifolia*	3.13	3.13	3.10	0.00
16	*Pongamia glabara*	6.25	3.13	6.30	0.00
17	*Premna sp.*	9.40	6.25	19.00	15.65
18	*Prosophis juliflora*	3.13	0.00	3.10	0.00
19	*Pteralobium hexapetalum*	12.50	12.50	6.30	12.50
20	*Randia malabarica*	6.25	9.40	6.30	6.25
21	*Sapindus emarginatus*	9.40	9.40	3.10	6.25
22	*Tamarindus indica*	3.13	3.13	3.10	3.13
23	*Terminalia belliriica*	3.13	3.13	0.00	3.13
24	*Terminalia crenulata*	6.25	3.13	6.30	9.38

Tab.5.3. Density of shrubs from proximity of Canal

S.No	Scientific name	0	200	400	600
1	Acacia torta	15.63	21.88	18.75	12.50
2	Cassia didymobotrya	28.13	12.50	6.25	6.25
3	Grewia flavescens	0.00	0.00	12.50	71.88
4	Grewia hirsute	31.25	40.63	18.75	31.25
5	Helicteres isora	18.75	34.38	21.88	6.25
6	Maytenus emarginata	9.38	21.88	12.50	9.38
7	Ventilago maderaspatana	34.38	28.13	28.13	0.00
8	Ziziphus oenoplia	28.13	40.63	25.00	31.25
9	Euphorbia hitra	27.78	41.67	30.56	33.33
10	Leucas aspera	27.78	16.67	33.33	33.33
11	Mimosa pudica	30.56	44.44	44.44	61.11
12	Desmodium triquetrum	2.78	0.00	8.33	16.67
13	Tephrosia purpurea	30.56	27.78	19.44	13.89

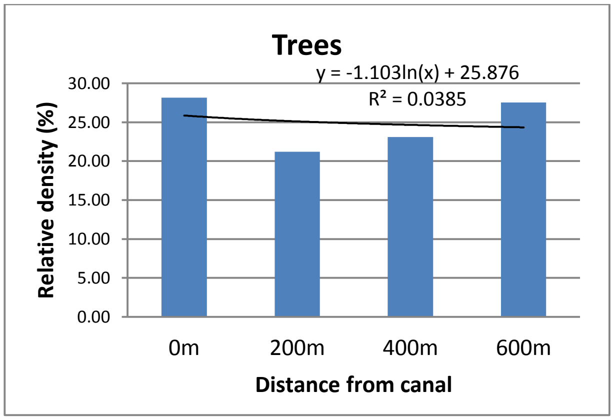
Tab.5.4. Density of herbs from proximity of Canal

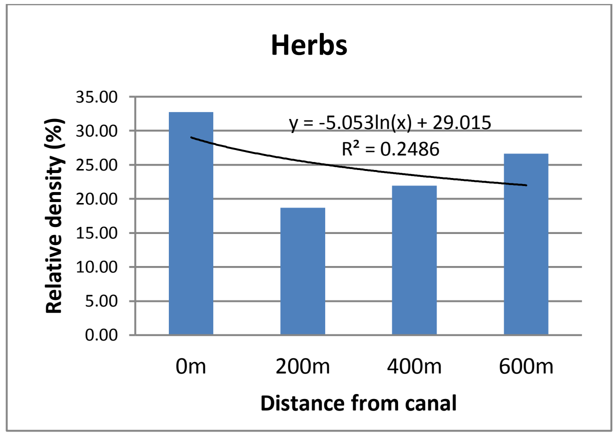
S.no	Species name	0m	200m	400m	600m
1	*Achyranthes aspera*	28.13	9.38	37.50	28.13
2	*Blepharis maderaspatensis*	59.38	50.00	12.50	50.00
3	*Jasminum trichotomum*	50.00	40.63	40.63	50.00
4	*Ocimum tenuiflorum*	59.38	12.50	34.38	28.13
5	*Oxalis corniculata*	46.88	15.63	21.88	31.25
6	*Hibiscus micranthus*	6.25	6.25	15.63	25.00
7	*Zizyphus xylopyrus*	34.38	28.13	28.13	18.75

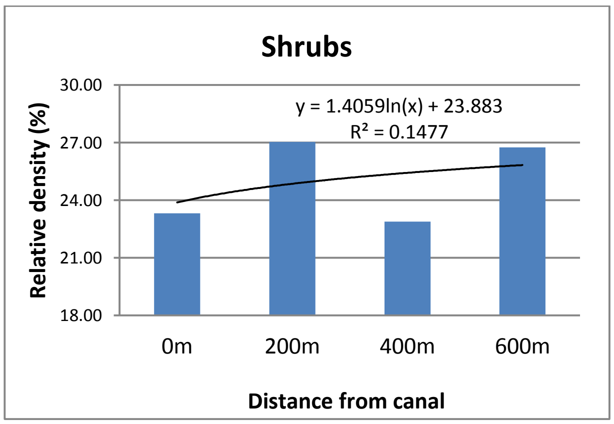
Tab.5.5. Density of invasive species from proximity of Canal

		0m	200m	400m	600m
1	*Lantana camara*	68.75	84.38	28.13	50.00

Fig.5.6. Overall abundance of trees, herbs, shrubs and invasive species in proximity of canal







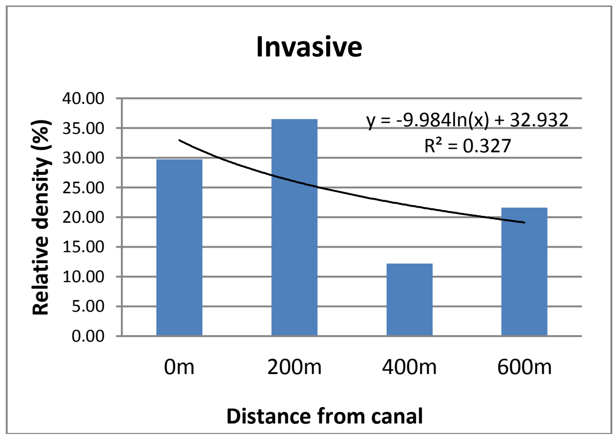
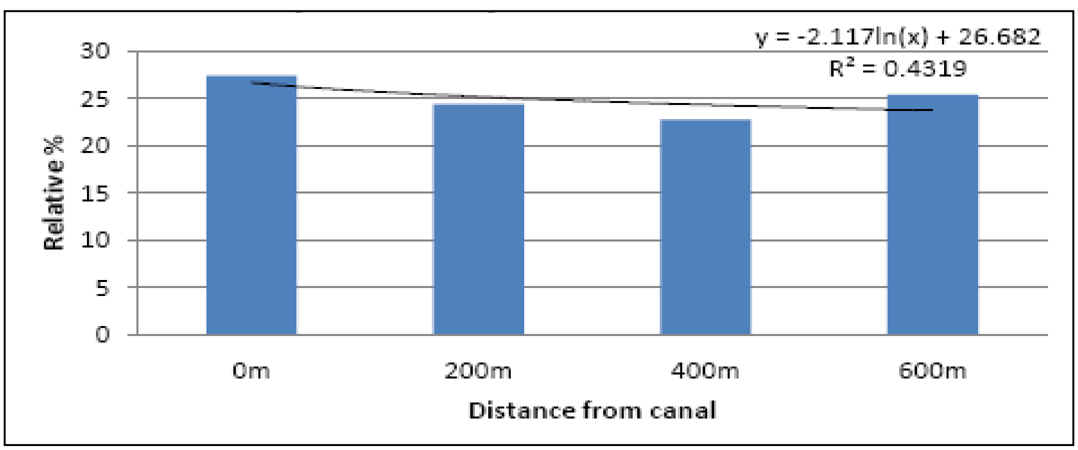


Fig.5.7 Relative percentage of overall vegetation in proximity of the canal



Correlation between herbivores and vegetation

Pearson correlation was performed to assess the relationship between abundance of herbivores and abundance of vegetation and this indicated a negative correlation between them (r = -0.855). Actually abundance of herbivores was less near the canal and increasing with increase the distance from canal. This negative correlation could be due to herbivores avoiding proximity of canal due to hindrance in crossing the canal and this could be the major reason of avoiding the canals rather than vegetation in the proximity of the canal.

MARAVAKANDY- MOYAR FLUME CHANNEL

Abundance of mammals with respect to proximity of canal: Eleven mammal species were recorded up to 600 meter from the canal. Dung density of mammals with respect to proximity to canal revealed that animal abundance was high near the canal and decreased with increase of distance for species such as elephants, gaur, porcupine, sloth bear and tiger (Tab.5.8, Fig.5.9). Regression analysis revealed that the correlation was weak with proximity to canal for sloth bear (R^2=0.429) and tiger (R^2=0.429) (Fig.5.10). On the contrary, abundance was low near the canal for the small carnivores and increased according to increase of distance from canal. Since small carnivores cannot cross the canal, they might not prefer the habitats close to canal. On the other hand, larger mammals such as elephants and gaur indicated them utilizing the proximity of canal due to large requirement of water at least twice in a day and ability to cross the canal at certain points across the canal. Ramkumar & Arumugam (2004) have identified about 39 elephant crossing points along the Flume channel between Maravakandy dam and Moyar reservoir. The canal however acts as a barrier for smaller carnivores even though there are two wide bridges, two under passes, three narrow bridges and 13 narrow bridges with cross bars (to prevent entry of cattle in forests). It was found during the study that all the narrow bridges are mostly covered with cactus and other thick vegetation restricting animal movement. Also the cross bars over the 13 narrow bridges prevent most of the animals from crossing the canal. Since water level and velocity will be high most of the time in a day in the canal, most of the animals except elephant and gaur mostly depend on narrow bridges to cross the canal. The cross bars hardly serves the purpose of restricting cattle movement since cattle mostly enter from near the Maravakandy dam and near Moyar village. Hence, it is recommended to remove the cross bars from these 13 narrow bridges and maintain them periodically free of cactus to facilitate movement of animals.

Table 5.8. Dropping density of mammals from proximity of the canal

Species	0m	200m	400m	600m
Black-naped hare	312.50	512.50	496.88	456.25
Elephant	84.38	84.38	71.88	59.38
Gaur	40.63	28.13	31.25	15.63
Leopard	0.00	0.00	3.13	0.00
Porcupine	21.88	18.75	15.63	6.25
Sambar	112.50	321.88	290.63	203.13
Sloth bear	21.88	12.50	15.63	15.63
Spotted deer	562.50	1118.75	768.75	721.88
Small carnivore	3.13	3.13	6.25	6.25
Tiger	9.38	0.00	3.13	3.13
Wild boar	9.38	59.38	15.63	12.50

Fig.5.9. Pictorial representation of mammal dropping density from proximity of canal

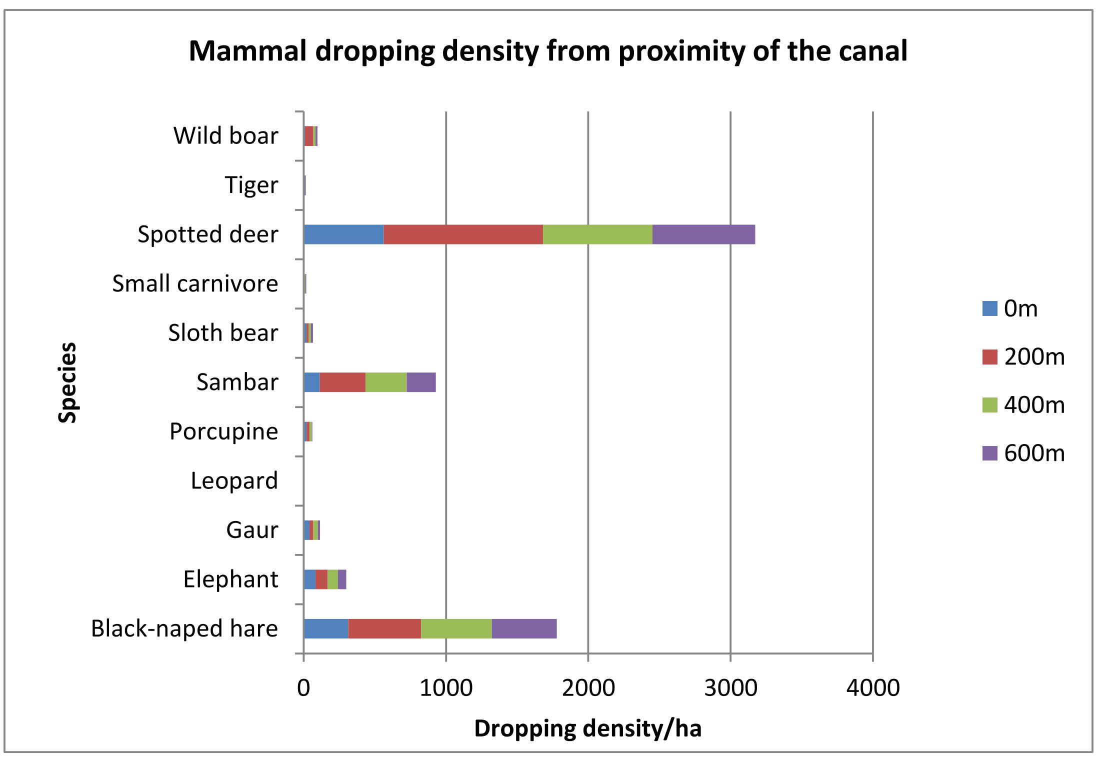
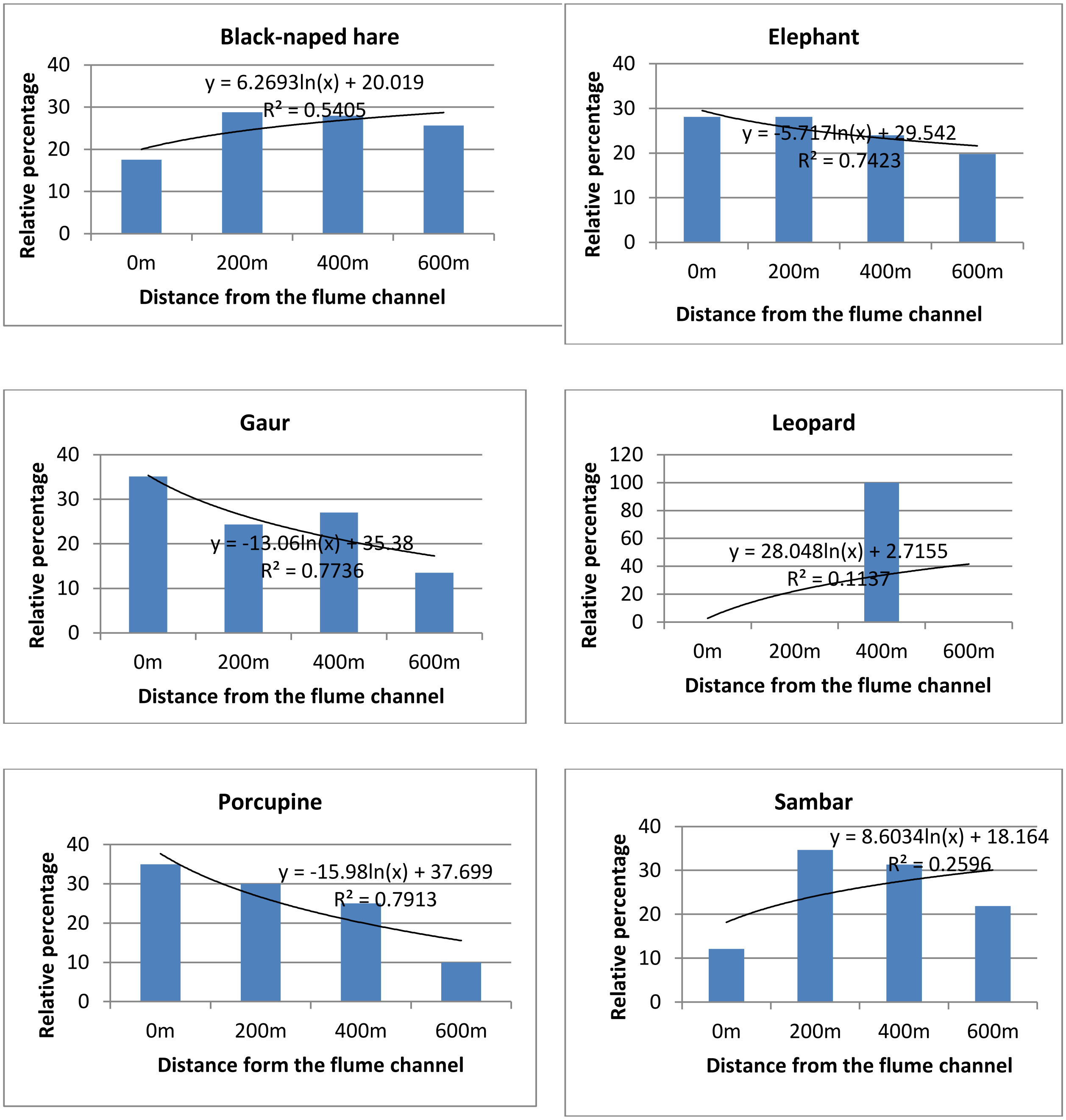
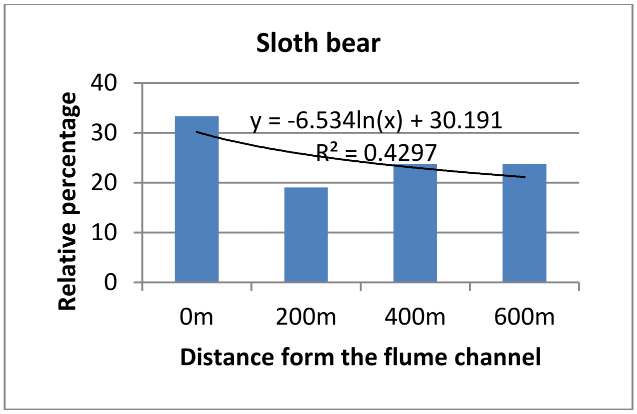
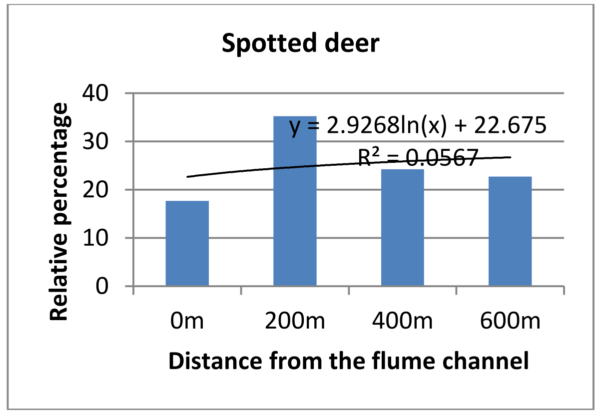
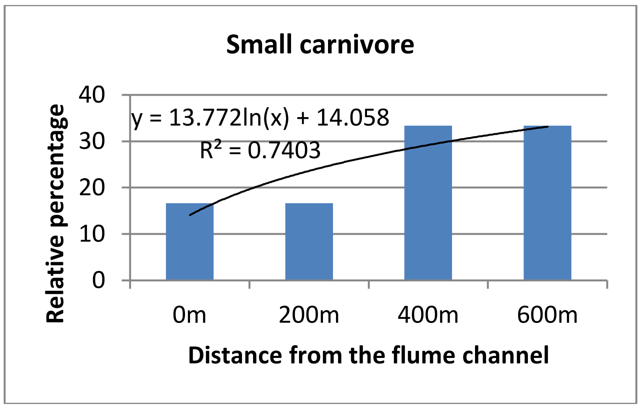


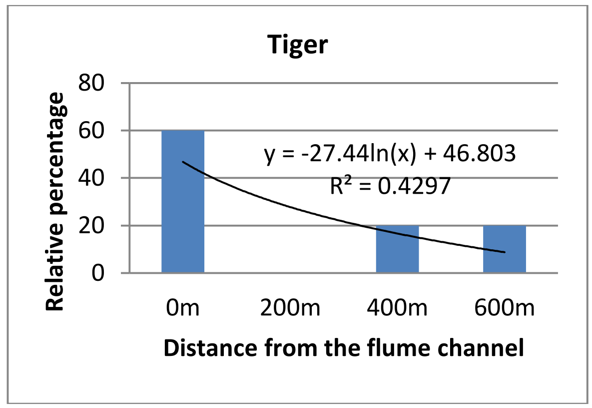
Fig.5.10. Dropping density of mammals from the proximity of the canal




Sloth bear
y = -6.534ln(x) + 30.191
R² = 0.4297
Relative percentage
40
30
20
10
0
0m
200m
400m
600m
Distance form the flume channel


Spotted deer
y = 2.9268ln(x) + 22.675
R² = 0.0567
Relative percentage
40
30
20
10
0
0m
200m
400m
600m
Distance from the flume channel


Small carnivore
y = 13.772ln(x) + 14.058
R² = 0.7403
Relative percentage
40
30
20
10
0
0m
200m
400m
600m
Distance from the flume channel


Tiger
y = -27.44ln(x) + 46.803
R² = 0.4297
Relative percentage
80
60
40
20
0
0m
200m
400m
600m
Distance from the flume channel

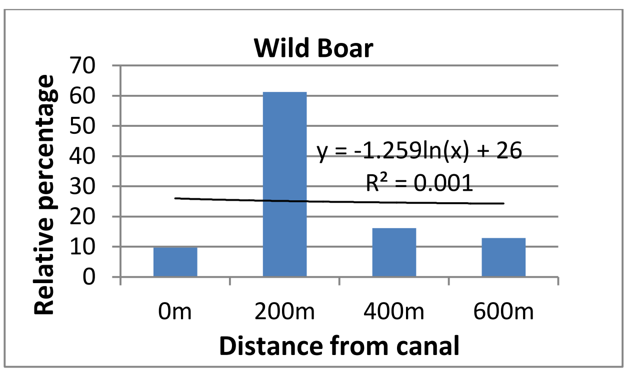

Wild Boar
y = -1.259ln(x) + 26
R² = 0.001
Relative percentage
70
60
50
40
30
20
10
0
0m
200m
400m
600m
Distance from canal

Table 5.8 Locations of elephant crossing points along the Flume channel between Maravakandy` dam and Moyar reservoir

Sl. No	Latitude	Longitude
1	11.57774	76.65624
2	11.57845	76.65664
3	11.5787	76.65679
4	11.57952	76.65734
5	11.58056	76.65752
6	11.58186	76.65761
7	11.58222	76.65767
8	11.58312	76.65864
9	11.5836	76.65959
10	11.58431	76.65995
11	11.58507	76.66119
12	11.58488	76.6619
13	11.58477	76.66229
14	11.58471	76.66303
15	11.58477	76.66355
16	11.58488	76.66419
17	11.58488	76.66468
18	11.58486	76.6662
19	11.58455	76.66714
20	11.58442	76.66744
21	11.58436	76.668
22	11.58457	76.66906
23	11.58505	76.67001
24	11.58546	76.67035
25	11.58649	76.67053
26	11.58943	76.66932
27	11.59014	76.67133
28	11.59052	76.67415
29	11.59135	76.67452
30	11.59344	76.67443
31	11.59431	76.6742
32	11.59538	76.67372
33	11.59702	76.67306
34	11.59832	76.67347
35	11.59832	76.67347
36	11.6002	76.67545
37	11.59955	76.67652
38	11.59815	76.6785
39	11.59829	76.68043

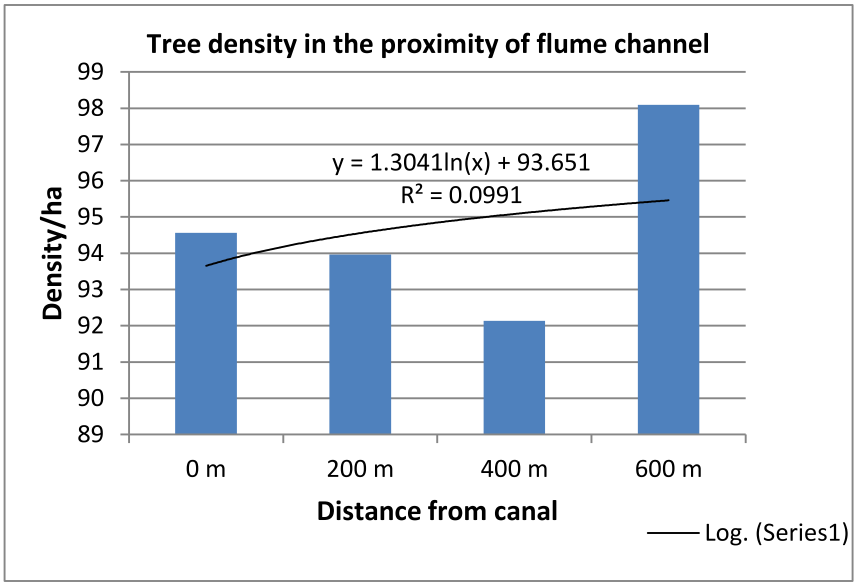
Vegetation abundance

A total of 20 tree species were recorded up to 600 meter from the canal. Tree species diversity was almost similar in all distance classes such as 0m (n=15), 200m (n=16), 400m (n=13) and 600m (n=14) (Tab.5.8). Overall tree density was not correlated to distance classes (Fig.5.10).

Table.5.9. Tree density from proximity of the flume channel

	Density/ha			
	Distance from flume channel			
Species	**0m**	**200m**	**400m**	**600m**
Acacia leucophloea	4.92	1.30	3.92	5.80
Alenthus excelasa	0.00	0.00	1.96	0.00
Anogeissus latifolia	11.48	11.69	7.84	4.35
Bambusa arundinalis	0.00	1.30	5.88	1.45
Bauhinia recemosa	9.84	0.00	0.00	0.00
Butea monosperma	9.84	0.00	3.92	2.90
Cassia fistula	3.28	2.60	3.92	2.90
Cassine glauca	9.84	2.60	5.88	2.90
Celtu tetrandra	0.00	1.30	0.00	0.00
Chloroxylon swietenia	1.64	7.79	11.76	15.94
Cordia gharaf	1.64	1.30	0.00	1.45
Diospyros Montana	3.28	0.00	0.00	7.25
Erythoxylem monogynum	0.00	20.78	0.00	0.00
Ficus bengalensis	0.00	1.30	0.00	0.00
Givotia rottleriformis	1.64	1.30	5.88	4.35
Limonia acidissima	1.64	2.60	1.96	4.35
Premna tomentosa	8.20	3.90	0.00	4.35
Randia dumentorum	8.20	24.68	19.61	23.19
Tectona grandis	1.64	0.00	1.96	0.00
Ziziphus ziziphus	14.75	6.49	13.73	15.94
Unidentified	2.73	3.03	3.92	0.97

Fig.5. 10. Overall tree density in the proximity of flume channel



Recommendations

Parali canal

1. Construct two green bridges over the canal for free movement of animals (GPS location 11.23922 N/ 76.77408E and 11.24033N/76.77391E).

Maravakandy- Moyar flume channel

1. Remove the cross bars on the narrow bridges to facilitate the movement of animals across the flume channel

2. Periodic maintenance of the bridges and underpass and remove the cactus and other vegetation in the bridges to facilitate the movement of animals through them.

Photo: Parali canal

Top left: A view of Parali canal, Top right: Water flow of canal, Middle left: A view of over bridge on canal,. Middle right: Elephant dung piles on bridge over canal, Bottom left: WTI team investigating indirect evidences of elephant movement in end of the canal, Bottom right: Elephant crossing point near end of the canal

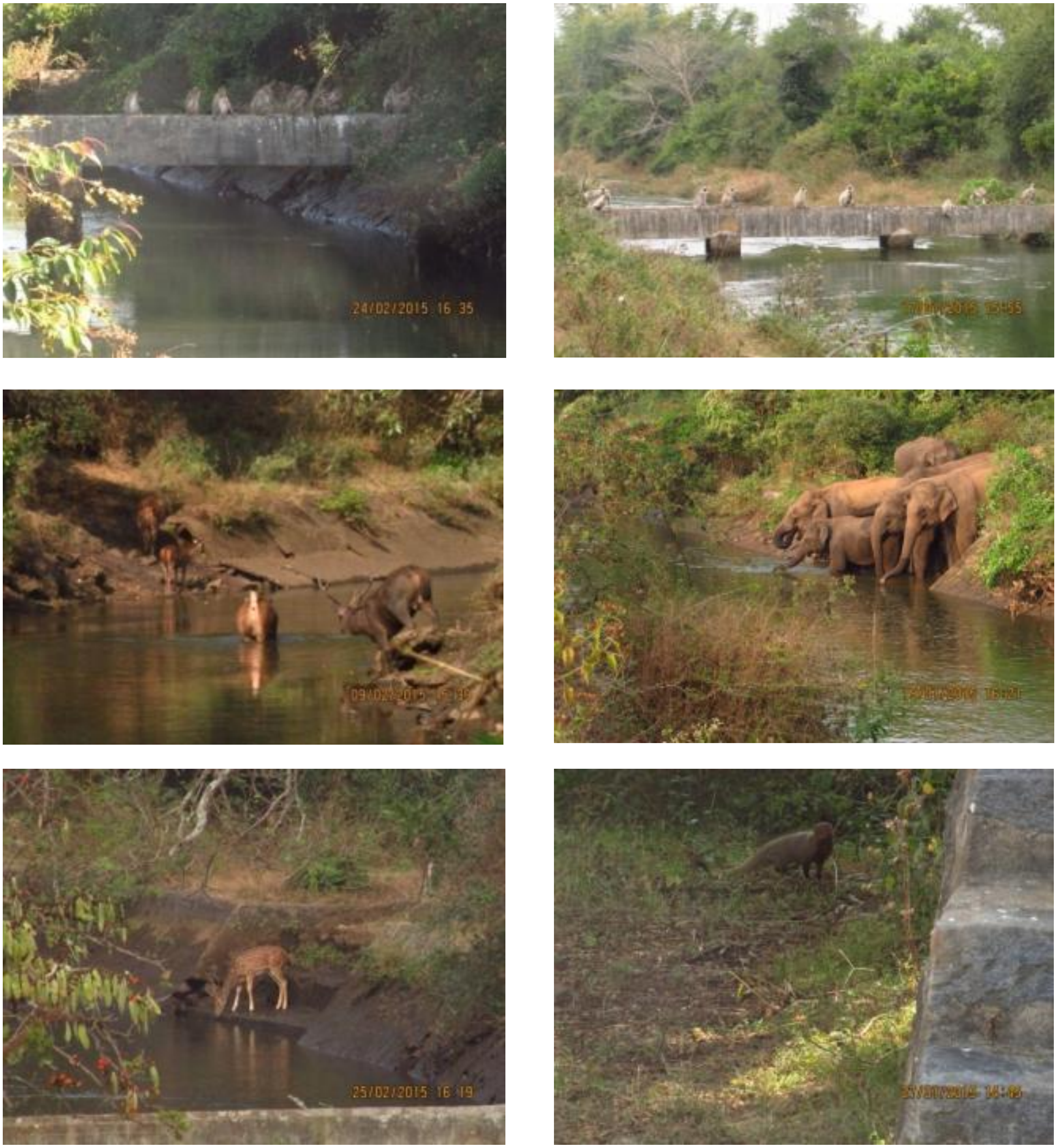
Photo: Moyar flume chanel

Top: Over view of flume channel, Bottom: Flume channel with Cemented side walls

Photo: Maravakandy- Moyar flume channel: crossing points

Top left: Narrow bridge over flume channel, Top right: Narrow Bridge with over flume channel, Middle left: WTI team investigating animal crossing on bridge over flume channel, Middle right: Broad bridge over flume channel, Bottom left: Animal crossing point, Bottom right: Steps made for accessing water for wild animals

Photo: Maravakandy- Moyar flume channel



Top left: A troop of bonnet macaque sitting on narrow bridge on flume channel, Top right: A troop of common langur crossing the flume channel through narrow bridge, Middle left: A herd of sambar deer crossing the flume channel when the water level is low, Middle right: A herd of elephant drinking water in the flume channel, Bottom left: A spotted deer drinking water in the flume channel, Bottom right: Common mongoose on wide over bridge

6. Impact of power lines on forest and wild animals

The impacts of power lines on wildlife are not much studied in India. The impacts of power lines can be due to electrocution and ground vegetation clearing (Raman, 2011). Power lines (mostly distribution), through electrocution cause mortality of birds (Barrett & Weseloh, 2008, Bevanger & Broseth, 2004, Tere and Parasharya, 2011) and elephants (Gubbi, 2012, Varma, 2000). Power lines also impact forests and wildlife through the ground vegetation clearing beneath it (Laurance *et al*, 2009) proliferating weed and invasive in the clearance and nearby forests.

Power transmission infrastructure, especially overhead transmission lines that are part of the national grid, are also a significant concern from an ecological perspective as they are often proposed to be developed or pass through ecologically sensitive landscapes. Power lines, mostly high and extra high voltage lines, are often established along long linear clearings that cut through natural areas like forests, grasslands, wetlands, and as a result, bring up a series of ecological concerns that are still not widely recognized in the power sector (Raman and Madhusudan, 2015).

Power lines passing though forests involve felling of trees and clearing vegetation along the alignment and for widths between 10 m to 50 m or more and this translates to a minimum loss of 1 to 5 hectares of forest cover for every kilometer of power line. Powerline passing through dense forest, fragments the area due to vegetation clearance and such internal habitat fragmentation can negatively affect the survival of many plant and animal species, as well as lead to various forms of degradation (Goosem 1997, Laurance *et al*. 2009, Anon 2011, Raman and Madhusudan 2015). The vegetation clearance also leads to greater diurnal fluctuations in light, temperature and humidity, loss of vegetation and also seen to facilitate growth of invasive and weeds. The fragmentation of forest and loss of canopy also creates a barrier effect to movements of arboreal mammals, especially primates.

Wildlife mortality due to electrocution is another major concern. Large animals such as elephants have suffered electrocution deaths due to sagging of powerlines and due to drawing directly from the mains to electrify fences around farms. Mortality of about 76 flamingos due to collision with high tension electric wires and distribution wires were reported in Gujarat between 2002-2005

(Tere and Parasharya, 2011). On an average, about 40 elephant die due to electrocution (unscientific electric fence/ overhead) in India every year. The Elephant Task Force (Rangarajan *et al*. 2010) has proposed recommendations to mitigate the problems due to powerline. Where canopy is broken due to powelines and roads, arboreal mammals such as primates are seen to use the powerlines to cross from one side to another and at times this has lead to animal mortality. Powerlines are also implicated in collisions and deaths of large birds such as bustards, flamingos, and cranes (Parasharya *et al* 2000, Bevanger and Broseth 2004, Sundar and Choudhury 2005, Tere and Parasharya 2011, Patil *et al*. 2011).

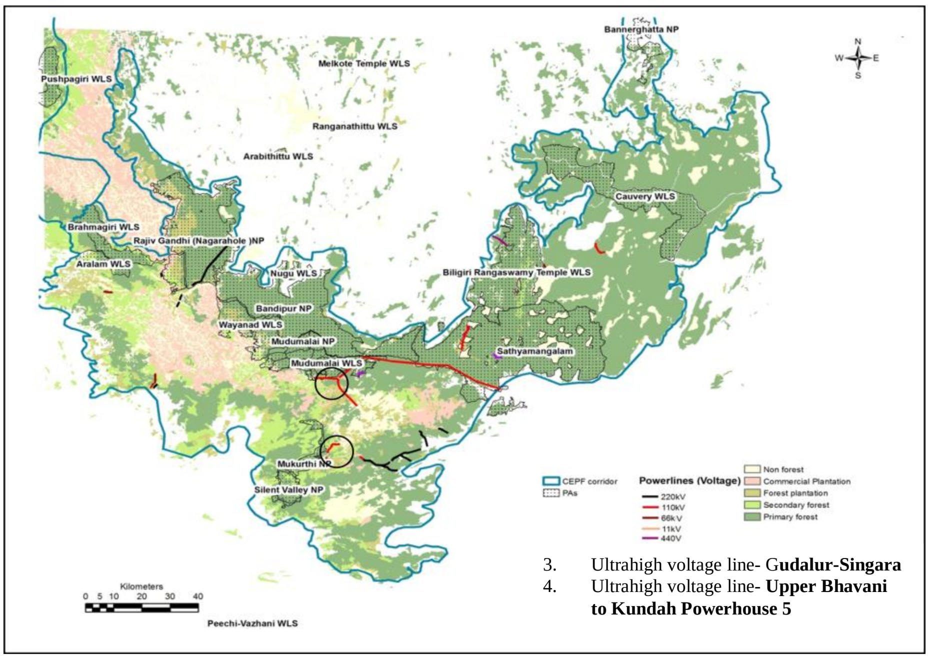
Raman (2011) summarized the main ecological problems associated with power lines transmission as follows: · Canopy-breakage when passing through closed canopy forest areas, · Higher light penetration and desiccation, · Higher daytime temperatures, greater diurnal fluctuation in temperatures, · Spread of invasive alien species, · Higher wind speeds and resultant windthrow, · Cutting of all trees and vegetation on either side resulting in second growth and weeds, · Construction- and maintenance-related disturbance and movement of people, Risk of electrocution.

The Nilgiris is the only district that has highest number hydro electric projects in Tamil nadu. A total of 12 hydro electric power houses such as Pykara PH, Pykara Micro PH, Moyar PH, Kundah PH 1, Kundah PH II, Kundah PH III, Kundah PH IV, Kundah PH V, Kundah Ph VI, Mukurthi mini PH, Maravakandy PH and PUSHEP PH are located in Nilgiris district of Tamil Nadu. Numerous power lines were created in Nilgiris to distribute electricity to various states such as Kerala, Karnataka and various districts of Tamil nadu through Nilgiri forests. The Nilgiris district is also known for rich biological diversity. However the impacts of power lines on wildlife are very little studied in Nilgiris. Thus the present study has been taken up in order to understand the impact of power lines on wild animals and ground vegetation in two power lines namely Gudalur-Singara UHVL and Upper Bhavani-Kundah Powerhouse 5 UHVL in the Nilgiris district of Tamil Nadu.

Gudalur-Singara UHVL: The 110kV power line passes through deciduous forests in Mudumalai Tiger Reserve for the length of 13 km. Vegetation clearance below and on either side of the powerlines along their length is one major reasons of habitat loss, degradation and fragmentation of natural habitat. The electricity board of Tamil Nadu clears the vegetation under the power line periodically and this creates a long vegetation cleared stretch of width around 13m throughout the power line.

Upper Bhavani to Kundah Powerhouse 5 UHVL: The 110kV power line passes through evergreen and shola forests of Nilgiri South forest division for a length of around 12 km with a ground vegetation clearance of 11m.

Fig.6.1 Map showing power lines selected for study



Methodology

To assess the impact of power lines on wild animals and vegetation, 10 x 10 meter plots were randomly laid under the power line and adjoining forest on both sides at a distance of 20 meter from the power line edge. In each 10 x 10 meter plot, indirect evidences of mammals were recorded. Also two 5 x 5 meter sub plots were laid in the corner of each 10 x 10 meter plots. Data on variables such as proportion of shrubs, herbs, grass, invasive species and barren land were collected.

Results and discussion

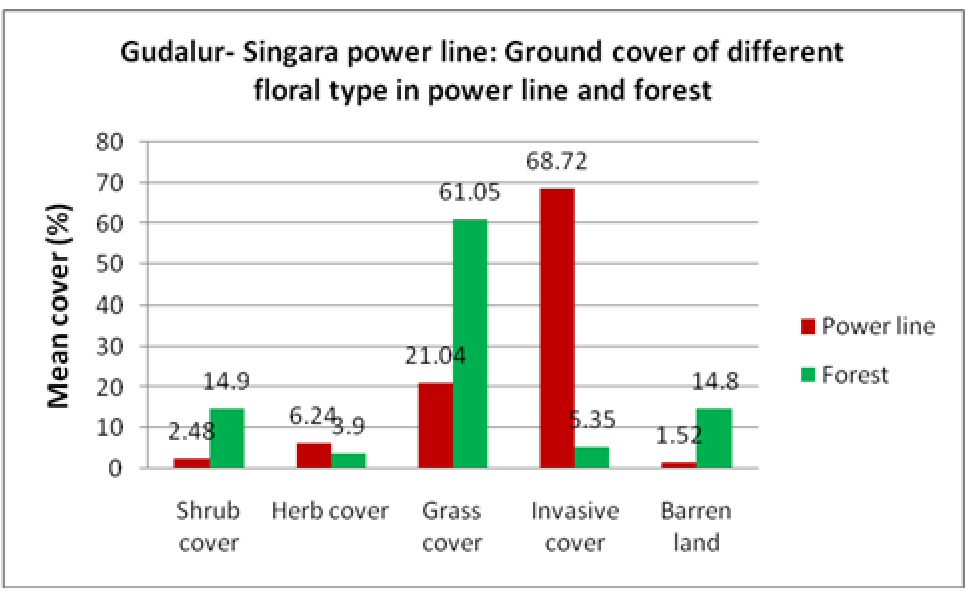
Gudalur- Singara UHVL

Impact on ground vegetation:

The ground vegetative cover comprising of shrubs, herbs, grass and invasive species were recorded during the study. Among the four ground vegetation categories, mean cover of invasive species (68.72%) was higher under the power line than forest (5.35%) (Fig.6.1). Whereas grass, shrub and barren land was high in forest at 61.05%, 14.9% and 14.8% rather than in power line at 21.04%. 2.48% and 1.52% respectively.

A total of 10 invasive species were recorded in the area cleared for the power line and forest.. Cumulative ground cover of invasive species was more than 80% under power line whereas it was only about 10% in forest. The major invasive species recorded in power line and forest were *Lantana camara Chromolaena odorata and Mimosa pudica.* Mean invasive cover in both areas revealed that *Lantana camara, Chromolaena odorata and Mimosa pudica* were much high in power line *(*44.73%, 10.93% and 9.80% respectively) rather than forest (2.59%, 1.07% and 0.78% respectively) (Tab. 6.1).

Fig. 6.1 Mean cover of ground vegetation in power line and adjacent forest

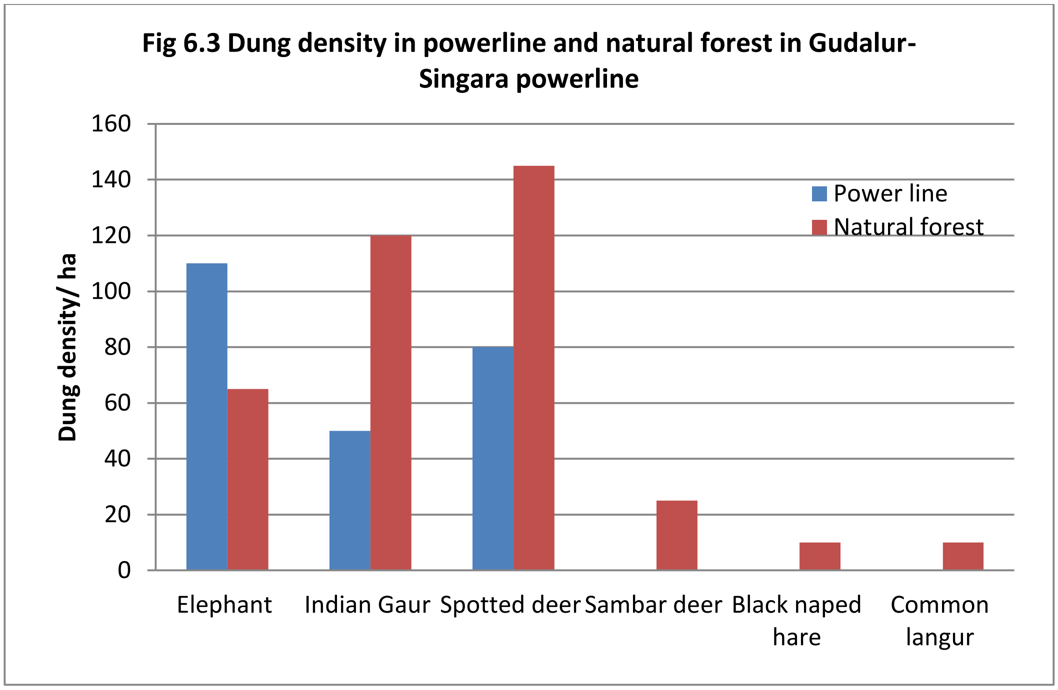


Tab.6.1. Invasive plant species and their mean cover in Gudalur- Singara power line and natural forest

Sl No	Species	Mean invasive cover (%)	
		Power line	Adjoining Forest
1	*Lantana camara*	44.73	2.59
2	*Chromolaena odorata*	10.93	1.07
3	*Mimosa pudica*	9.80	0.78
4	*Ageratum conizoides*	1.28	0.14
5	*Synedrella nodiflora*	1.42	0.04
6	*Senna tora*	0.57	0.00
7	*Ageratum adenophora*	0.36	0.07
8	*Pteridium acquilinum*	0.00	0.07
9	*Senna hirsuta*	0.07	0.04
10	*Senna spectabilis*	0.00	0.04

Animal use in power line and adjacent forest

The study also looked at the indirect evidences of mammals in the vista cleared area of power line and adjacent forest. Evidences of dung of six species viz., elephant, gaur, spotted deer, sambar deer, black naped hare and common langur was recorded in the forest (Fig.6.3). Whereas only three species namely sambar deer, black naped hare and common langur were recorded in the power line. Dung density of elephant was high under the power line than forest. It could be attributed due to preference of elephants in open areas for the movement.



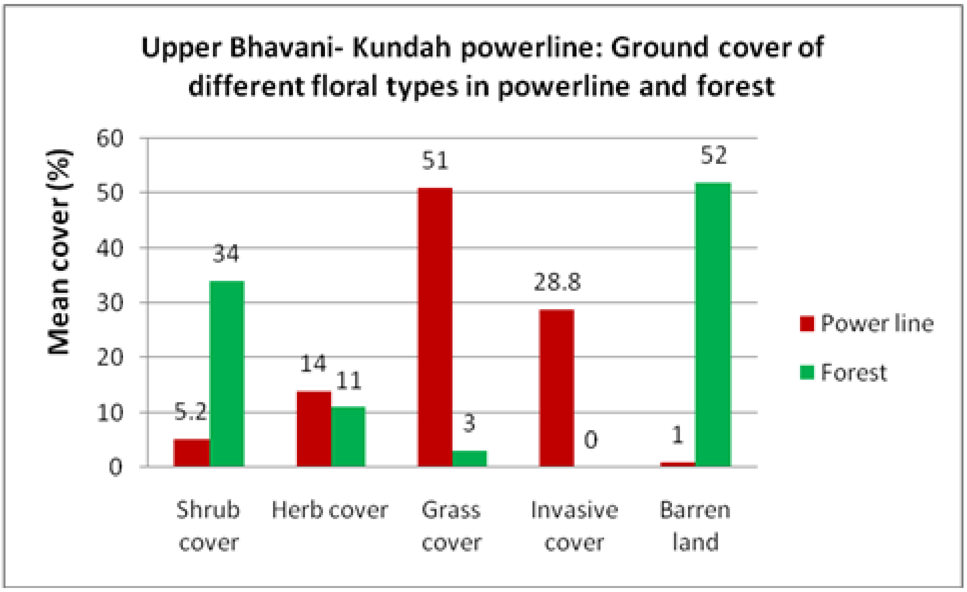
Upper Bhavani- Kundah power line

The power line from Kundah to Upper Bhavani of voltage 110 kV runs through shola grassland forests in Nilgiri South Forest Division. It mostly runs through grass lands and plantations of exotic species like wattle, pine etc. Small stretches of the line pass through shola forests. We conducted a survey in these stretches through shola to study the impact of ground vegetation clearance on forest and wildlife.

Impact on ground vegetation:

The ground vegetative cover of shrubs, herbs, grass, invasive species and barren land were recorded during the study. Among the four ground vegetation categories, grass, invasive species and herbs were more in power line as 51%, 28.8% and 14% rather than forest as 3%, 0% and 11% respectively (fig. 6.4). It is interesting to note that invasive species were not reported in adjacent forest.

Fig.6.4. Mean cover of different types of vegetation across power line clearance and adjacent shola forest



A total of six invasive species were recorded in power line. Among the invasives, the density of *Pteridium acquilinum* found to be very high at 32640/ha followed by *Ulex europaeus (*1760/ha), *Acacia* sp (1680/ha), Wattle (1120/ha), *Cytisus scoparius (560/ha) and Ageratum adenophora (160/ha).* The vegetation clearance and resultant canopy opening could be attributed in the invasion of these species in power line. The complete absence of invasive in shola plots can be attributed to the closed canopy of the shola patches.

Table.6.2. Mean cover of invasive species in Upper Bhavani- Kundah power line and natural forest

		Ageratum adenophora	*Pteridium acquilinum*	*Acacia* sp	Wattle	*Cytisus scoparius*	*Ulex europaeus*
Power line	Density/ha	160	32640	1680	1120	560	1760
	Relative %	0.4	86.1	4.4	3.0	1.5	4.6
Adjacent Forest	Density/ha	0	0	0	0	0	0
	Relative %	0	0	0	0	0	0

Recommendations

1. Many tree branches were seen close to the power line and could results in electrocution. Thus ensure that the canopy is away from the power line to avoid any possible electrocution in Glenmorgan- Singara power line.

2. Clearing of vegetation should be undertaken in such a way that only invasive and weeds should be removed and not native species as this will facilitate growth of invasive and weeds as indicated from the observation above and other studies. Minimize width of vegetation clearance, especially when passing over valley. Consider reducing the seasonal removal of ground vegetation along the power line in both Glenmorgan- Singara as well as Upper Bhavani- Kundah power line.

3. Strict monitoring of power lines to prevent sagging and electrocution of animals.

4. In forest area, if possible replace the existing power lines with insulated ones

Photo:

Top left: Over view of Gudalur- Singara power line, Top right: Over view of Upper Bhavani- Kundah power line, Middle left: The growth of exotic invasive plant species under the vista cleared area of Upper Bhavani- Kundah power line, Middle right: Tree canopy touching the Gudalur- Singara power line, Bottom left: The exotic invasive plant species, *Ageratum adenophora* located under the Upper Bhavani- Kundah power line; bottom right: bamboo bushes touching the Gudalur- Singara power line

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ANNEXURES

Annexure-1 : Tree density per hectares at different distance from road on NH 209

S.no	Species name	0m	200m	400m	600m	800m	1000m
1	*Aadirachtaindica*	3.95	10.53	9.21	9.87	5.26	5.26
2	*Acacia chundra*	3.29	1.32	2.63	0.66	1.97	1.97
3	*Acacia ferruginea*	2.63	1.97	5.26	2.63	2.63	3.95
4	*Acacia latronum*	5.26	9.21	14.47	3.95	7.24	3.29
5	*Acacia leucophloea*	7.24	9.21	4.61	7.24	4.61	1.97
6	*Acacia suma*	5.26	4.61	3.95	3.95	3.29	2.63
7	*Ailanthus excels*	3.29	4.61	3.29	1.97	3.95	0.00
8	*Acacia planiferons*	2.63	4.61	1.97	2.63	2.63	1.97
9	*Albiziaamara*	3.95	3.95	4.61	1.32	1.32	0.66
10	*Albizialebbeck*	1.32	3.95	3.29	1.97	2.63	0.66
11	*Anogeissuslatifolia*	24.34	28.95	20.39	18.42	15.13	8.55
12	*Bauhinia racemosa*	0.66	3.95	3.29	1.97	3.95	1.97
13	*Bombaxceiba*	0.66	2.63	0.66	3.29	0.66	2.63
14	*Boswellia serrate*	0.00	2.63	3.95	1.97	3.95	1.32
15	*Buteamonosperma*	0.00	2.63	4.61	0.66	1.97	2.63
16	*Canthiumdicoccum*	0.00	5.92	1.32	2.63	3.29	0.66
17	*Chloroxylonswietenia*	0.00	12.50	18.42	7.24	7.89	1.32
18	*Commiphora caudate*	0.00	3.29	7.24	1.32	6.58	1.32
19	*Dalbergialatifolia*	0.00	0.00	3.95	1.32	3.95	0.00
20	*Eriolaenaquinquelocularis*	3.29	1.32	4.61	3.95	4.61	0.00
21	*Eucalyptus spp*	19.74	19.74	18.42	16.45	11.84	1.97
22	*Givotiarottleriformis*	0.00	2.63	5.26	3.29	3.29	1.32
23	*Gmelinaarborea*	1.32	5.92	6.58	2.63	2.63	0.00
24	*Grewiatiliaefolia*	1.32	5.92	5.26	1.97	2.63	0.66
25	*Kydiacalycina*	0.00	0.66	3.95	1.32	2.63	1.32
26	*Lagerstroemia lanceolata*	0.00	1.97	5.26	0.66	5.92	0.00
27	*Mangiferaindica*	0.00	1.32	3.29	3.29	1.97	0.00
28	*Phyllanthusemblica*	0.66	0.66	4.61	0.66	3.29	0.00
29	*Pongamiapinnata*	0.00	4.61	2.63	3.95	4.61	1.97
30	*Prosopisjuliflora*	21.71	24.34	23.03	24.34	21.71	19.74
31	*Randiadumetorum*	1.97	5.92	5.26	7.89	7.24	0.00
32	*Stereospermumpersonatum*	0.00	5.26	7.24	7.89	3.95	3.29
33	*Strychnospotatorum*	0.00	4.61	4.61	4.61	5.92	3.29
34	*Tamarindusindica*	0.00	10.53	3.95	8.55	4.61	3.29
35	*Ziziphusmauritiana*	0.00	7.24	7.24	5.26	3.95	1.97
36	*Feroniaelephantum*	0.00	1.97	3.95	2.63	3.29	0.00

Shrub density per hectares at different distance from road on NH 209

		0m	200m	400m	600m	800m	1000m
1	*Acacia intsia*	147.37	168.42	147.37	178.95	84.21	63.16
2	*Acacia Pennata*	0.00	63.16	31.58	52.63	84.21	94.74
3	*Acacia torta*	52.63	231.58	242.11	52.63	94.74	21.05
4	*Adadhodavasika*	0.00	52.63	52.63	0.00	31.58	0.00
5	*Caesalpiniabonduc*	31.58	105.26	326.32	136.84	115.79	52.63
6	*Carissa carandas*	52.63	73.68	52.63	31.58	63.16	42.11
7	*Carissa carandaslinn*	21.05	21.05	0.00	0.00	21.05	0.00
8	*Carissa spinarum*	136.84	147.37	84.21	94.74	189.47	126.32
9	*Carmona retusa*	115.79	52.63	136.84	63.16	136.84	105.26
10	*Cassia auriculata*	136.84	136.84	136.84	21.05	42.11	73.68
11	*Chromolaenaodorata*	52.63	31.58	63.16	94.74	63.16	115.79
12	*Grewiaflavescens*	63.16	84.21	136.84	42.11	84.21	63.16
13	*Grewiahirsuta*	200.00	231.58	115.79	252.63	73.68	147.37
14	*Grewiarhamnifolia*	42.11	0.00	42.11	52.63	189.47	0.00
15	*Helicteresisora*	284.21	221.05	357.89	252.63	200.00	147.37
16	*kydiacalycina*	0.00	0.00	0.00	0.00	0.00	21.05
17	*Lagasceamollis*	115.79	168.42	115.79	21.05	157.89	42.11
18	*Maytenusemarginata*	10.53	21.05	115.79	21.05	42.11	21.05
19	*Opuntiastricta*	115.79	336.84	221.05	126.32	189.47	126.32
20	*Plumbagozeylanica*	63.16	42.11	94.74	210.53	63.16	31.58
21	*Solanumsp*	0.00	0.00	0.00	42.11	31.58	0.00
22	*Solanumsurattense*	115.79	42.11	136.84	0.00	105.26	21.05
23	*Toddaliaasiatica*	73.68	189.47	52.63	52.63	136.84	94.74
24	*Ventilagomaderaspatana*	105.26	84.21	168.42	52.63	73.68	0.00
25	*Xanthiumindicum*	242.11	221.05	126.32	221.05	157.89	136.84
26	*Ziziphusoenoplia*	231.58	157.89	200.00	210.53	126.32	147.37

Herb density per hectares at different distance from road on NH 209

		0m	200m	400m	600m	800m	1000m
1	*Achyranthesaspera*	389.47	410.53	263.16	242.11	263.16	157.89
2	*Aervalanata*	568.42	210.53	210.53	63.16	136.84	178.95
3	*Hibiscus micranthus*	73.68	42.11	0.00	31.58	73.68	10.53
4	*Ocimumtenuiflorum*	252.63	157.89	189.47	105.26	200.00	136.84
5	*Stachytarphetajamaicensis*	115.79	73.68	115.79	189.47	84.21	84.21

Annexure -2

Table 3.18: Density of tree species near A and B line between Walayar to Kanjikode Kerala,		
S.No	Tree species	Density/ha
1	Allophylus cobbe	0.55
2	Aporusa lorideliyana	0.55
3	Cassia tora	0.55
4	Emblica officinalis	0.55
5	Eucalyptus hybrid	0.55
6	Ficus racemosa	0.55
7	Prosopis juliflora	0.55
8	Randia brandisii	0.55
9	Terminalia tomentosa	0.55
10	Vitex altissima	0.55
11	Bridelia crenulata	1.10
12	Bridelia retusa	1.10
13	Lannea coromandelica	1.10
14	Pterocarpus marsupium	1.10
15	Zizyphus microphylla	1.10
16	Zysigium cummini	1.10
17	Beutia monosperma	2.20
18	Citrus medica	2.20
19	Grewia tiliiaefolia	2.20
20	Pavata indica	2.20
21	Prosopus spicigera	2.20
22	Acacia ferruginea	2.75
23	Bauhinia purpurea	2.75
24	Holoptelia integrifolia	2.75
25	Azadarachta indaca	3.30
26	Ficus hispida	3.30
27	Tamarindus indicus	3.85
28	Dalbergia latifolia	4.40
29	Taberuaementana heyneana	4.95
30	Helectres isora	5.49
31	Lagerstroemia lanceaata	7.69

Table3.19:Density of tree species in the foothills in Puduchery south between Walayar and Kanjikode, Kerala		
S.No	Tree species	Density/ ha
1	Acacia mylotica	1.59
2	Bridelia crenulata	1.59
3	Bridelia retusa	1.59
4	Dalbergia latifolia	1.59
5	Ficus hispida	1.59
6	Holarhena antidysentrica	1.59
7	Albizia odoratisima	3.17
8	Chloroxylon monogynum	3.17
9	Erythryna varigata	3.17
10	Milia dubia	4.76
11	Pavata indica	4.76
12	Dalbrgia sisso	7.94
13	Grewia tiliiaefolia	7.94
14	Hopea parviflora	7.94
15	Lagerstroemia lanceaata	7.94
16	Taberuaementana heyneana	9.52
17	Ficus racemosa	11.11
18	Tectona grandis	11.11
19	Lannea coromandelica	12.70
20	Terminalia tomentosa	12.70
21	Mallotus philippensis	33.33
22	Tetramelos nudiflora	39.68
23	Terminalia paniculata	44.44
24	Scliechera ollesa	46.03
25	Anogeissus latifolia	63.49
26	Pterocarpus marsupium	65.08
27	Xylia xylocarpa	80.95
	Total	490.48

32	Marinda tinctoria	7.69
33	Scliechera ollesa	9.89
34	Mallotus philippensis	12.64
35	Alangium salvifolium	14.29
36	Bombax ceiba	16.48
37	Holarhena antidysentrica	18.13
38	Terminalia paniculata	20.33
39	Anogeissis latifolia	20.88
40	Xylia xylocarpa	52.75
41	Tectona grandis	112.09
	Total	349.45

Table 3.20: Density of tree species in and around Kanjikode and Mallampuzha Dam, Kerala

S.No	Tree species	Density/ha
1	Bridelia retusa	2.63
2	Cassia tora	2.63
3	Dalbergia latifolia	2.63
4	Ficus racemosa	2.63
5	Grewia tilliaefolia	2.63
6	Madhuca neriifolia	2.63
7	Milia dubia	2.63
8	Morinda tinctoria	2.63
9	Terminalia bellerica	2.63
10	Terminalia tomentosa	2.63
11	Albizia oborattissima	5.26
12	Pterocarpus marsupium	5.26
13	Emblica officinalis	7.89
14	Holarhena antidysentrica	7.89
15	Taberuaementana heyneana	7.89
16	Chloroxylon monogynum	13.16
17	Anogeissus latifolia	15.79
18	Lannea coromandelica	18.42
19	Accasia sp	21.05
20	Alangium salvifolium	21.05

Table 3.21: Density of tree species near A and B line between Walayar to Ettimadai,Tamil Nadu

Sl. No.	Tree Species	Density/ha
1	Acacia catechu	0.81
2	Beutia monosperma	0.81
3	Bridelia crenulata	0.81
4	Citrus medica	0.81
5	Dalbergia paniculata	0.81
6	Ficus benghalensis	0.81
7	Grewia tilliaefolia	0.81
8	Macaranga peltata	0.81
9	Prosopus spicigera	0.81
10	Pterocarpus marsupium	0.81
11	Bambusa bamboo	1.63
12	Chloroxylon monogynum	1.63
13	Gmelina arborea	1.63
14	Milia dubia	1.63
15	Prosopis juliflora	1.63
16	Holoptelia integrifolia	2.44
17	Dalbergia latifolia	3.25
18	Ficus racemosa	3.25
19	Lagerstroemia lanceaata	3.25
20	Xylia xylocarpa	3.25

21	Bombax ceiba	23.68
22	Ficus hispida	26.32
23	Tectona grandis	26.32
24	Scliechera ollesa	31.58
25	unknown	31.58
26	Marinda tinctoria	55.26
27	Terminalia paniculata	63.16
28	Xylia xylocarpa	228.95
	Total	636.84

21	Anogeissus latifolia	4.07
22	Lannea coromandelica	4.07
23	Albizia oborattissima	4.88
24	Ficus hispida	4.88
25	Taberuaementana heyneana	4.88
26	Terminalia paniculata	4.88
27	Holarhena antidysentrica	5.69
28	Azadarachta indaca	6.50
29	Pavata indica	8.94
30	Scliechera ollesa	10.57
31	Acacia ferruginea	15.45
32	Alangium salvifolium	17.07
33	Marinda tinctoria	18.70
34	Acacia mylotica	20.33
35	Tamarindus indicus	52.85
36	Tectona grandis	60.98
37	Bombax ceiba	61.79
	Total	338.21

Table 3.22: Density of tree species north to the ridge around Malabar mining, Kerela

S. No.	Tree species	Density/ha
1	Albizia lebbeck	1.33
2	Anogeissis latifolia	1.33
3	Bridelia retusa	1.33
4	Ficus racemosa	1.33
5	Gmelina arborea	1.33
6	Helicteres isora	1.33
7	Hopea parviflora	1.33
8	Kingiodendron pinnatum	1.33
9	Mallotus philippensis	1.33
10	Morinda tinctoria	1.33
11	Prosopis juliflora	1.33
12	Pterocarpus marsupium	1.33

Table 3.23: Density of tree species in the hills near Parapatty, Tamil Nadu

Sl. No.	Tree species	Density/ha
1	Scliechera ollesa	1.89
2	Albizia oborattissima	3.77
3	Beutia monosperma	3.77
4	Bombax ceiba	3.77
5	Ficus benghalensis	3.77
6	Lannea coromandelica	3.77
7	Mangifera indica	3.77
8	Pavata indica	3.77
9	Peltaphorum pterocarpum	3.77
10	Xylia xylocarpa	3.77
11	Anogeissus latifolia	5.66
12	Pterocarpus marsupium	5.66

13	Terminalia bellerica	1.33
14	Tetramelos nudiflora	1.33
15	Wrightia tinctoria	1.33
16	Bauhinia purpurea	2.67
17	Aporusa lindeliyana	4.00
18	Dalbergia lanceolaria	4.00
19	Delonix regia	4.00
20	Lagerstroemia lanceaata	4.00
21	Beutia monosperma	5.33
22	Holarhena antidysentrica	5.33
23	Pithecelobium dulce	5.33
24	Bombax ceiba	8.00
25	Alangium salvifolium	9.33
26	Albizia oborattissima	9.33
27	Cassia fistula	10.67
28	Dalbergia latifolia	12.00
29	Emblica officinalis	12.00
30	Bambusa bamboo	14.67
31	Macaranga peltata	17.33
32	Terminalia paniculata	25.33
33	Schlechira oliosa	38.67
34	Grewia tiliiaefolia	45.33
35	Xylia xylocarpa	73.33
36	Tectona grandis	122.67
	Total	453.33

13	Tetramelos nudiflora	5.66
14	Dalbergia latifolia	7.55
15	Dalbergia paniculata	9.43
16	Lagerstroemia lanceaata	9.43
17	Terminalia bellerica	9.43
18	Terminalia paniculata	9.43
19	Taberuaementana heyneana	11.32
20	Acacia ferruginea	15.09
21	Grewia tiliiaefolia	15.09
22	Holarhena antidysentrica	15.09
23	Unknown	15.09
24	Bambusa bamboo	18.87
25	Prosopis juliflora	22.64
26	Tectona grandis	24.53
	Total	235.85

Annexure-3

Lists villages surveyed in Tamil Nadu and Kerala

Railway Sections	Name of the Villages	Distance from A&B track	Distance from B track	Distance from A track	Distance from forest
Podhanoor to Madukkarai	SugunaPuram	1500m	--	--	150m
	Mayilkal	1500m	--	--	100m
	Arivozhli Nagar	2km	--	--	50m
	Malaiswamykovil	100m	--	--	100m
	Andikonarthottam	50m	--	--	50m
	Madukkarai	500m	--	--	500m
Madukarai to Ettimadai	Ettimadai	500m			500m
	Madukarai	500m			500m
Ettimadai to Walayar	Ettimadai.	200m	--	--	250m
	Muruganpathy	50m	--	--	700m
	Ayyanpathy	500m	--	--	100m
	Playamanthai	--	1000m	--	100m
	Modamathithottam	--	1500m	--	50m
	Pudupathy	--	50m	--	500m
	Chinnampathy	--	3000m	--	100m
	Jallimedupathy	--	50m	50m	50m
	Nadupathy	--	500m	--	100m
	Chavadi Para	--	1000m	1000m	50m
Walayar to Kanjikode	Vattapara	100m	1000m	--	200m
	Athupathy	700m	700m	--	100m
	Kottamutti	700m	200m	--	200m
	Vathiyarchalla	500m	500m	--	50m
	Velachery	2100m	50m	--	50m
	Pytokkad	1300m	500m	--	300m
	Velledi	1300m	200m	--	100m
Kanjikode to Kottekad	Aarangottukulambu	500m	--	--	500m
	Arugudi	2000m	--	--	50m
	Kaarakkad	500m	--	--	500m
	Kanjikkodu	100m	--	--	50m
	Kongattupadam	1000m	--	--	50m
	Kunuppuli	500m	--	--	50m
	Mukroni	20m	--	--	500m
	Paaralodu	50m	--	--	50m
	Padalikkad	1000m	--	--	1000m
	Pannimada	500m	--	--	500m
	Parayampallam	200m	--	--	100m
	Puduchery west	1000m	--	--	1000m
	Pulpulli	100m	--	--	100m
	Thudiyadi	100m	--	--	100m
	Thuthupallam	500m	--	--	1500m
	Tudiyadipara	100m	--	--	100m
	Vellaroaduchalla	1500m	--	--	100m
	Venoli	1500m	--	--	1000m