Impact of Linear Intrusions on Large Mammal Movement in the Shencottah Gap

Summary

   Maintaining or restoring connectivity between fragmented wildlife populations, has become a global conservation priority. In the Periyar – Agastyamalai landscape, in the southern Western Ghats, tiger (*Panthera tigris*) and elephant (*Elephas maximus*) populations were historically connected are now separated around the Shencottah Gap: an area with multiple land use, human settlements and linear barriers. Restoring landscape - level connectivity for large mammals is a conservation necessity; consequently, there has been increasing interest over the past few years in corridor restoration in this landscape. Restoration will require constructing mitigation structures, however developing these plans has been hampered by the lack of information on animal distribution and visitation rates of areas near linear barriers. The primary goal of this study was to identify potential crossing points and the kind of mitigation structures that need to be deployed to facilitate movement of elephants and large carnivores across the Shencottah Gap. The key findings of this study are the lack of connectivity for elephants across the Shencottah Gap. Currently the elephant populations in the Periyar – Agastyamalai landscape is separated by a negligible distance of ~300 meters around the Shencottah Gap. Results for carnivores indicates periodic dispersal across the gap by leopards, whereas none of the tigers we photographed dispersed across the gap. Tigers where photographed close to the National Highway, within a distance of 100m, however no photographic evidence of dispersal across the gap was obtained. Our results also show that altering the terrain while constructing roads changes the slope and when this exceed twenty degrees, it is less likely that elephants will use such stretches to cross the road. Associated with the linear intrusions are the growth of human settlements and houses, which further hinders elephant dispersal. Using information on intensity of use, we identified two locations within two multi-species corridors where mitigation structures, an underpass and wildlife bridge, can be constructed to facilitate elephant and tiger dispersal. The structural engineering, technical aspects and costing of these structures were also developed. Constructing the suggested mitigation structures will restore the the 300 meter breakage in connectivity across the Shencottah Gap and will helping in creating ~6300 km^2 of connected wildlife habitat in the Southern Western Ghats.

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Introduction

The existence of viable habitat is crucial for the survival of any species. During the last few decades, human population explosion and unplanned growth of infrastructural facilities have led to fragmentation of many wildlife habitats, threatening numerous species of flora and fauna (Struhsaker 1997; Kinnaird et al. 2003; Ripple et al. 2014). Fragmented and isolated wildlife populations are vulnerable to stochastic catastrophic events such as disease outbreak, inbreeding depression, and natural calamities. To safeguard wildlife populations from the negative effects of habitat fragmentation and to enhance population viability, maintaining habitat connectivity is crucial (Clobert et al. 2009; Crooks et al. 2011; Clobert et al. 2012). In landscapes where habitat connectivity has been severed, restoration of connectivity, informed by rigorously designed field surveys is critical to population survival. Unfortunately, maintenance and restoration of connectivity between wildlife habitats are yet to gain precedence in our country. However, during the last few years, considerable progress has been made to create the baseline information needed for establishing a potential connectivity for large mammalian fauna between Periyar and Agastyamalai landscapes in the southern Western Ghats.

Periyar and Agastyamalai landscapes are separated by multiple-use, human dominated areas known as the Ariankavu pass or the Shengottah gap. The connectivity of large mammals between these two landscapes is broken mainly by linear barriers like National Highway (NH-208), Shencottah-Kollam railway line (broad gauge conversion underway), and human settlements along the railway line. Conversion of forest area to plantations of teak and rubber has further fragmented the landscape. Historic movement pathways have been disrupted and consequently the populations of tigers and elephants on either side of Shencottah gap have become isolated (Johnsingh et al. 1991). The negative effects of habitat fragmentation are not the same on all large mammal species (Crooks et al. 2011). Few species can readily adapt to the changes in the landscape over time and alter their movement paths to disperse between fragments. However, other species may not be able to adapt as they might have specialized requirements that limit their dispersal ability (Clobert et al. 2009; Crooks et al. 2011; Clobert et al. 2012; Joshi et al. 2013; Prachi Thatte et al. 2015). To assist the movement

of these species, potential links and mitigation structures between the two landscapes have to be identified .

In this study, we assessed connectivity for tigers, elephants and leopards across the Shencottah Gap. In particular, we assessed and identified potential locations that could facilitate unhindered wildlife movement and suggest appropriate mitigation measures. We chose these three species for assessing habitat connectivity, as they are large vertebrates that range widely within the landscape. They have vast home ranges and consequently, habitat fragmentation would have considerable negative impact on their dispersal ability. Furthermore, tigers and elephants are charismatic species, which are important for gathering the required public and political support for conservation.

Based on the biology of these species (Bailey 1993; Smith 1993; Sunquist et al. 1999; Karanth and Sunquist 2000; Sunquist and Sunquist 2002; Venkataraman et al. 2005; Karanth et al. 2010; Fernando et al. 2012; Karanth 2013a; Stein and Hayssen 2013; Karanth 2013b; Ghosal et al. 2013; Athreya et al. 2014; Odden et al. 2014), our a priori expectations on their movement between Periyar and Agastyamalai landscapes are summarized in Table 1.

Table 1: A priori expectations on the ability of the focal species to move between Periyar and Agastyamalai landscapes

Species	Biological traits	Expected dispersal
Leopard	Smaller when compared to tigers. Arboreal and versatile in diet. More tolerant to human disturbance.	Probability of few individuals moving between Periyar and Agastyamalai landscapes is high. Males are dispersing and therefore we expect more males relative to females to cross the barriers.
Tiger	Heavier and shier relative to leopards. Seek dense cover and avoid human disturbed areas. Select large sized prey and therefore more confined to forests	Forest cover is disrupted, however other forms of vegetation might provide the required cover. Nevertheless, the probability of individuals moving between Periyar and Agastyamalai landscapes is low.
Elephant	Largest and gregarious. Precipitous slopes impose physical limitations for movement. Avoid highly disturbed areas	Areas around the National Highway and railway line are inhabited by humans and are highly degraded. The terrain devoid of humans is very rugged. Therefore the probability of individuals moving between Periyar and Agastyamalai landscapes is extremely low.

Methods

Sampling Design

To capture the dispersal events across the Shencottah gap, the sampling design was optimised to record events of animals crossing the linear barriers. For this, we placed about 40 camera traps, ~250m apart, within a radius of 500m around the barriers in each of the potential locations. These cameras were operational throughout the study period. This allowed us to not only record actual crossing, but also attempts made by wildlife to cross the gap. The probability of animals crossing the linear barriers is likely to be influenced by both local and landscape level processes. Moreover, the way in which animals use the area around the potential crossing points could also influence the probability of crossing. Therefore, to capture local level usage we placed cameras ~750m apart within a radius of 5km (henceforth referred to as 1st and 2nd order neighbours) from the potential locations. To capture landscape level usage, we placed cameras ~1.5km apart (henceforth referred to as landscape level sampling points) . The cameras were left operational for a month within the 5km radius and rest of the landscape. After a sampling period of 30-45 days the cameras were shifted to a randomly chosen location, such that the distance between cameras was maintained at 750 m and 1.5 km (Figure 2). Such a nested sampling design and a multi-scale approach will not only help in monitoring animal movement across the gap, it also determines ecological areas which play a key role in animal distribution and usage patterns.

Figure 1: Slopes, vertical embankments, traffic prevent large mammal dispersal across the Shencottah gap
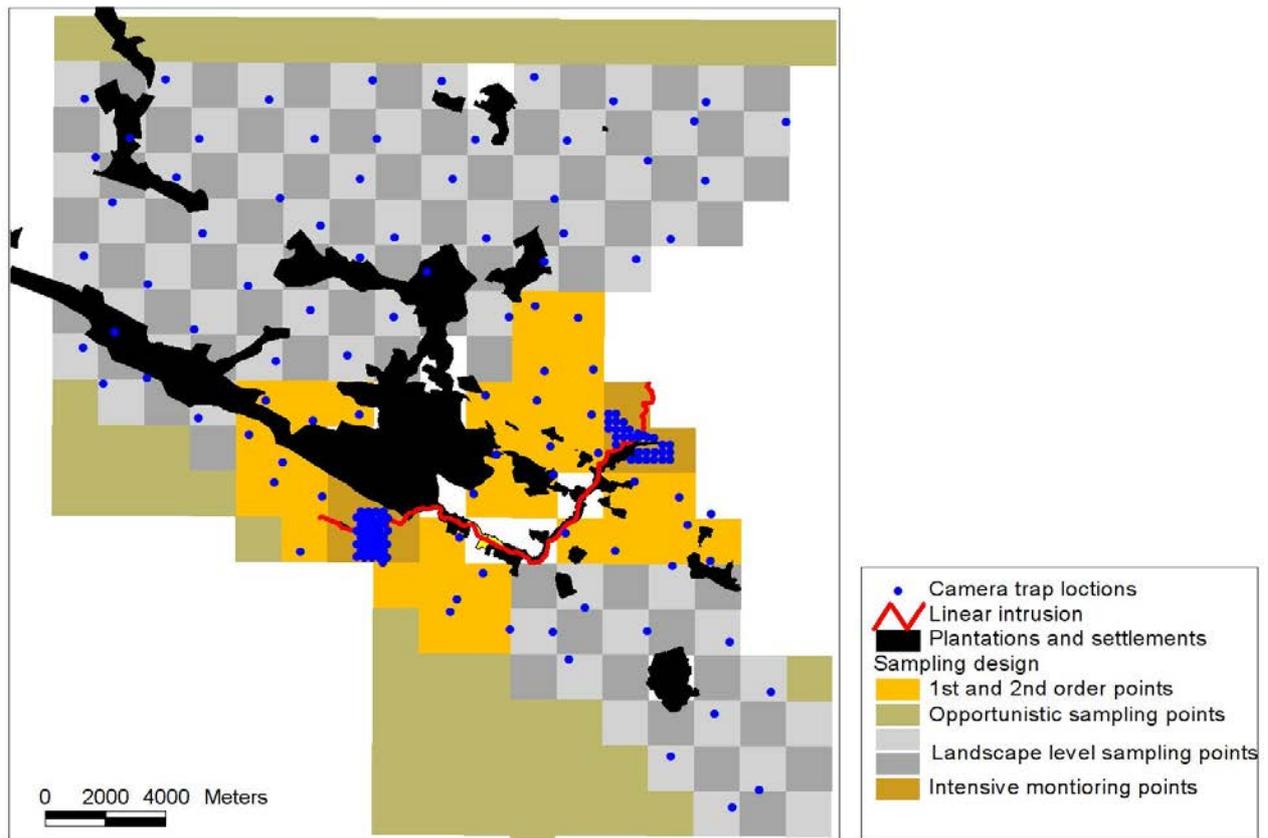
Figure 2: Schematic representation of the sampling design adopted to monitor large mammal distribution and dispersal across linear barriers in the Shencottah Gap.

Road Survey

We surveyed the entire stretch of the National Highway from Thenmala to Puliyarai to identify potential locations in the road that could facilitate wildlife movement. The entire stretch of the road was divided into 100m segments and attributes of the road that could influence wildlife movement were measured in the field. On both sides of the road, attributes such as slope, number of houses, vegetation type, road intersection and stream intersection were measured. A rule-based classification was applied to each side of the segment to classify it into barriers, potential restoration points and potential crossing points. Based on this classification we developed a composite rank at the level of each 100m segment. The ranks ranged from 0 to 5, with 0 being not conducive and 5 being very conducive for wildlife movement (Table 2).

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Table 2: Composite ranks on restoration feasibility (high rank implies high potential for restoration)

Rank	Restoration Feasibility
0	Not possible either due to terrain or houses on both sides of the road
1	Feasibility is less and very expensive. Intervention is required on both sides of the road and one side is a barrier
2	Feasible, but expensive. Intervention is required on both sides of the road
3	Feasible, but expensive. Intervention is required on one side of the road, which is a barrier. The other side provides connectivity
4	Feasible and less expensive. Minimal intervention is required on one side of the road only. The other side provides connectivity
5	Feasible without any intervention.

Additionally we surveyed roads in human dominated landscapes, where known crossing points for elephant exist. Field work was carried out along the select National Highways, State Highways and minor roads to collect data on variables that could influence or affect elephant movement across these roads. Based on our previous studies on elephants, including actual track logs of elephant movement across the roads, points at which elephant are definitely known to cross were selected. In order to also understand their preference to using a few points along the road as against randomly selecting a point we collected data on the variables at randomly chosen points along the surveyed roads.

The factors or variables influencing elephant movement were classified into topographical features (terrain slope, vegetation cover above 5 feet within a buffer of 250 m around the point and presence of water source within a 250 m buffer), anthropogenic activity (vehicular load, number of houses/buildings within a 250 m buffer) and structural feature of the road (width, presence of barriers and structures alongside the roads, curvature, and line of vision). Data on these variables were collected from 64 locations or 128 points (two points at a crossing location, entry and exit).

In order to examine decision-making by individual elephants to cross the road or not to, we constructed recursive partitioning classification trees. This method estimates a regression relationship by binary recursive partitioning in a conditional inference framework in the following manner. The global null hypothesis of independence between any of the input variables (the topography, anthropogenic activity and structure of the road) and the response variable (crossing the road) was first tested and the hypothesis accepted if it could not be rejected. If the null hypothesis could be rejected, the input variable with the strongest association to the response variable was selected and their

association measured by a p-value corresponding to a test for the partial null hypothesis of a single input variable and the response variable. A binary split was then implemented in the selected input variable. The above steps were repeated recursively until a statistically significant binary partitioning of the input variable could not be derived further. The implementation utilized a unified framework for conditional inference or permutation tests, developed by Strasser and Weber (1999). The criterion for the first binary spilt in the input variable was based on multiplicity-adjusted Monte-Carlo-simulated p-values. A split was implemented at the node when the simulated p-value was smaller than 0.05. This statistical approach ensured that the right-sized tree was grown and no form of pruning or cross-validation was required. Further, the resulting classification tree can be used to predict outcomes of a new dataset with associated p-values, an approach that will help in identifying and ranking road segment which will allow dispersal of elephants.

Vehicular Count

During the study we conducted a survey to estimate the vehicular density on the NH-208 in a stretch between Puliyarai and Themala town. A team of 3 people counted and classified vehicles over a 24 hour period. Vehicles were classified into two-wheelers, cars, Light Commercial Vehicles (jeeps, mini trucks), buses and heavy commercial vehicles (trucks). Counts were maintained at 15 minute intervals, and the survey was carried out to get a sample size of 8 for a given day (Eg. 8 Sundays). Other than understanding the temporal trends in vehicular traffic, we were also interested in evaluating the correlation between the number of events (animals photographed) within 500m from the National Highway and average traffic volume. Both data sets were aggregated on an hourly basis and cross correlation plots were used to analyse the animal response to traffic volume.

Results and Discussion

During the sampling period (November 2013 to June 2015) we covered an area of ~360km^2, sampling 388 locations with a total effort of 38916 camera trap days. We also intensively sampled the Kottavasal and MSL corridors, especially in areas around the National Highway, to detect actual events of dispersal by tiger, elephant and leopards during the entire period. In the subsequent sections we present key results from the Shencottah gap for the three species of interest and also discuss the results with respect to connectivity and present restoration plans that needs to be implemented to ensure long term ecological connectivity.

Tigers

Between November 2013 to June 2015, we obtained 53 photo captures of tigers from 39 of the sampled locations. Tiger capture locations are presented in Figure 3. Based on their unique stripe patterns we unambiguously identified 10 individuals within the study area. 7 unique individuals were identified during the pre – monsoon (January - April), 3 each during the monsoon (June – September) and post – monsoon (October - December). The Details of tiger photo captures have been summarized in Tables 3 & 4.

Results show that there are seasonal differences both in the number of tigers photographed and in the number of locations where they have been photographed, with higher proportion during the dry season or pre-monsoon season even after accounting for differences in sampling efforts (Figure 4). Table 4 provides division wise details of number of tigers photographed, indicating presence of tigers throughout the year in Thenmala and Punalur divisions.

Table 3: Number of locations and number of photo captures of tigers during the current study, figures in the parentheses shows number of sampling points

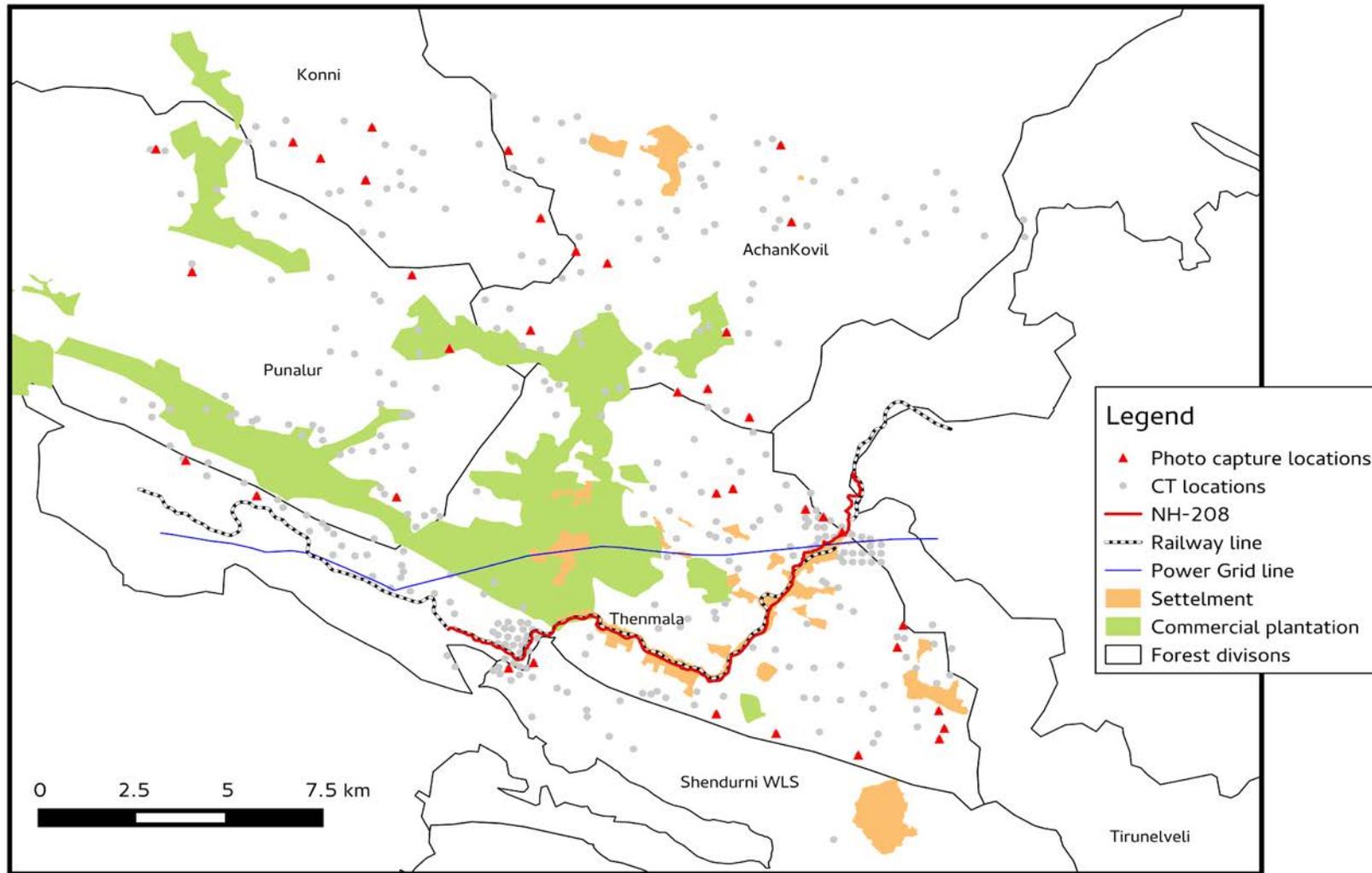| Season	Points	No. of photo captures
Pre-Monsoon	27 (325)	38
Monsoon	6 (196)	8
Post-monsoon	6 (190)	7

Figure 3: Map showing locations of photographic captures of tigers for the period November 2013 – June 2015
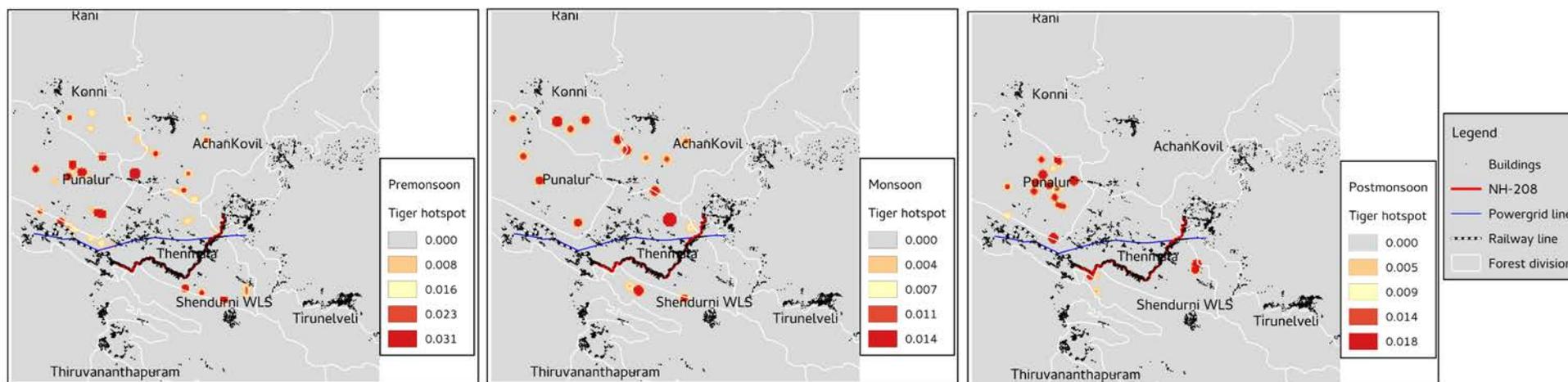
Figure 4: Temporal variation in the encounter rates of tigers indicates seasonal differences in distribution of tigers and also change in intensity along linear intrusions

Figure 5: A resident female in the study area, first photographed in 2009

Figure 6: Same individual photographed in 2014, her estimated home range is 110km^2

Table 4: Seasonal details of tiger photo-captures

Division	Pre-Monsoon	Monsoon	Post-monsoon	Total
AchanKovil	15	00	00	15
Konni	06	04	00	10
Punalur	01	03	01	05
Shendurney Wildlife Sanctuary	00	00	02	02
Thenmala	16	01	04	21

For the first time, we have recorded tigers approaching close to the National Highway, as close as 300m in both the corridors (Figure 3). Details of number of locations and events have been provided in Table 5 and Table 6. Tiger presence was recorded in more camera trap locations in Kottavasal (10% of sampled camera trap locations) in comparison to the MSL corridors (Table 6).

Table 5: Photo capture details of tigers from the two intensively sampled corridors

Corridor	No. of permanent sampling locations	No. of locations with photo captures	Percentage
MSL	38	2	5.26
Kottavasal	31	3	9.67

Table 6: Dates and seasonal patterns in photo captures of tigers from the two intensively sampled corridors

Corridor	Pre-Monsoon	Monsoon	Post-Monsoon
MSL	16/12/2013		
Kottavasal		5/6/2014	16/4/2014 24/3/2015

During this study we recorded a male tiger as close as 100m from the National Highway in the Kottavasal corridor and a tiger (sex could not be determined from the photograph) within 300m in the MSL corridor. While no evidence of tiger dispersal was collected during the sampling period, our long term data (2009 -2015) from this landscape shows both corridors have a high potential to facilitate tiger dispersal.

Synthesis:

Although there is no photographic evidence to show tigers are dispersing, the evidence of them in proximity to the linear barriers further confirms that connectivity at both Kottavasal and MSL needs to be restored to facilitate dispersal. The recent report by National Tiger Conservation Authority (NTCA) on the status of tigers in India suggests

that areas south of Periyar are important only for connectivity between Periyar and Agastyamalai. However, the eleven unique individuals we have identified in the ~360 km^2, fixed home ranges of the two individuals, tends to suggest that this area is not only important for resident populations of tiger (Figure 5 & 6), it is also an important area where connectivity should be restored to link the southern most tiger populations. Restoring connectivity within the MSL and Kottavasal corridor should be a priority in the Tiger Conservation Plans and steps should be immediately initiated.

Leopard

In this study we obtained 530 Leopard photographs from 188 of the sampled locations. Leopard capture locations are also presented in Figure 7. The Details of leopard photo captures have been summarized in Tables 7 and 8. Results show that there are seasonal differences both in the number of leopards photographed and in the number of locations where they have been photographed, with higher proportion of photo captures during the dry season even after accounting for differences in sampling efforts (Figure 8). Table 8 provides division wise details of number of leopards photographed, indicating presence of leopards throughout the year in all divisions.

Table 7: Number of locations and number of photo captures of leopards during the current study, figures in the parentheses shows number of sampling points

Season	Points	No. of photo - captures
Pre-Monsoon	116 (325)	358
Monsoon	38 (196)	87
Post-Monsoon	34 (190)	85

Table 8: Seasonal details of leopard photo-captures

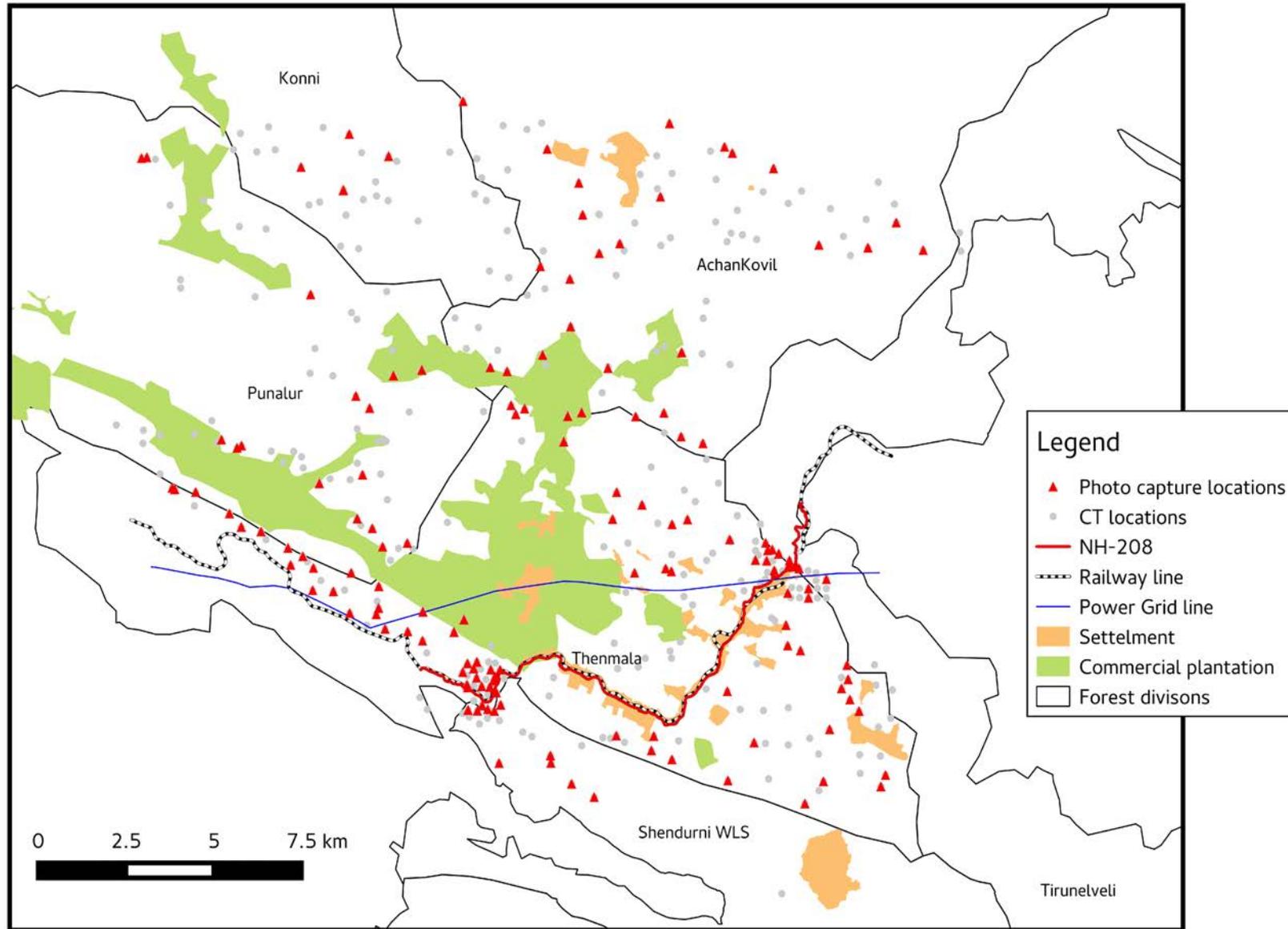| Division	Pre-Monsoon	Monsoon	Post-monsoon	Total
AchanKovil	02	13	38	53
Konni	03	03	07	30
Punalur	01	08	33	42
Shendurney Wildlife Sanctuary	05	06	17	28
Thenmala	74	57	263	394

Figure 7: Map showing locations of photographic captures of leopards for the period November 2013 – June 2015
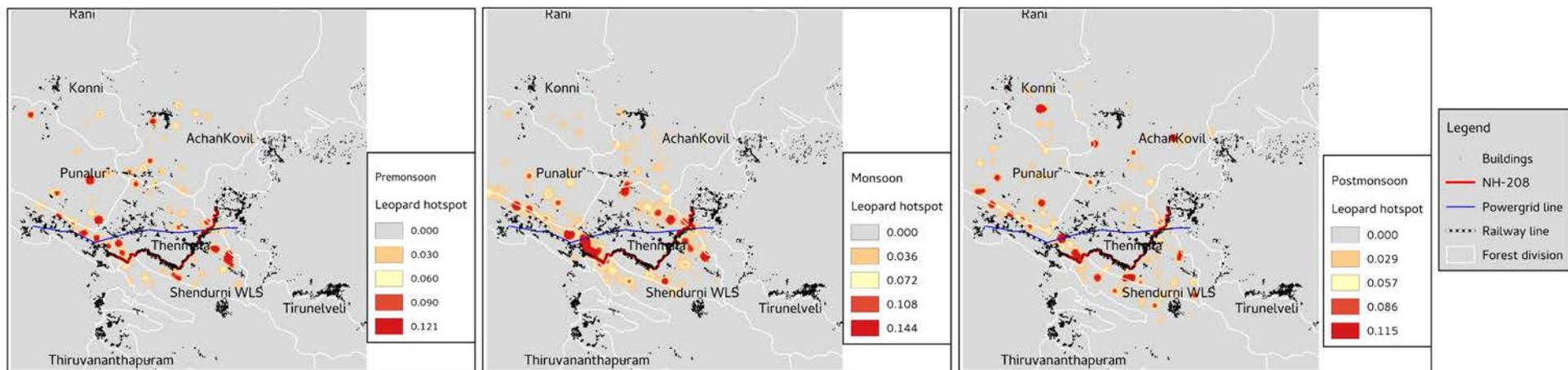
Figure 8: Temporal variation in the encounter rates of leopards indicate seasonal differences in distribution of leopards and also change in intensity along linear intrusions

Figure 9: A male leopard who frequently disperse across the linear intrusions photographed in the Kottavasal corridor

Figure 10: More than eleven instance of this male crossing the NH has been recorded since July 2012

Our results based on individual identification of leopards indicate that leopards cross the NH and railway line and these events were recorded in the Kottavasal and MSL corridors. Leopard presence was recorded in more camera trap locations in MSL (53% of sampled camera trap locations) in comparison to the Kottavasal corridors (Table 9). Details of number of locations and events have been provided in Table 9 and 10. In the Kottavasal corridor 90 occasions of leopards within 500m from the NH were recorded and thirteen successful crossing by leopards were recorded. These events occurred on 09/12/2013, 02/01/2014, 14/01/2014, 02/02/2014, 02/03/2014, 10/03/2014, 02/04/2014, 29th – 31st May 2014, 25th – 30st June 2014, 20/07/2014, 7th – 12th August 2014, 27/09/2014, 29/12/2014.

In the MSL corridor 123 occasions of leopards within 500m from the NH and railway line were recorded. Successful dispersal events were recorded on 5/12/2013, 04/01/2014, 24/01/2014, 10/02/2014, 12/03/2014, 16/04/2014, 04/06/2014, 13/02/2015.

Table 9: Photo capture details of leopards from the two intensively sampled corridors

Corridor	No. of permanent sampling locations	No. of locations with photo captures	Percentage
MSL	38	20	52.63
Kottavasal	31	17	54.83

Table 10: Dates and seasonal patterns in photo captures of leopards from the two intensively sampled corridors

Corridor	Pre-Monsoon	Monsoon	Post-Monsoon
MSL	01/01/2014-30/01/2014 01/02/2014-26/02/2014 02/03/2014-29/03/2014 02/04/2014-30/04/2014 16/05/2014-25/05/2014 12/02/2015-24/02/2014 18/03/2015-22/03/2015 10/04/2015-13/04/2015 01/05/2015-23/05/2015	02/06/2014-22/06/2014 04/07/2014-29/07/2014 15/08/2014-31/08/2014 16/09/2014-26/09/2014	05/12/2013-28/12/2013 03/10/2014-25/10/2014 07/11/2014-30/11/2014 05/12/2014-09/12/2014
Kottavasal	02/01/2014-29/01/2014 06/02/2014-16/02/2014 02/03/2014-10/03/2014 02/04/2014-21/04/2014 01/05/2014-29/05/2014 03/01/2015-21/01/2015 18/04/2015-29/04/2015	06/06/2014-30/06/2014 17/07/2014-30/07/2014 07/08/2014-28/08/2014 26/09/2014-27/09/2014	27/01/2013 09/12/2013-19/12/2013 14/10/2014-29/10/2014 06/11/2014 18/12/2014-30/12/014

Synthesis:

The number of events where leopards have come within 500m of the linear intrusions is much higher in the MSL corridor when compared to the Kottavasal corridor, even after accounting for differences in sampling efforts. In both corridors the number of such events differed seasonally, it was much higher during pre-monsoon in the Kottavasal corridor whereas the post - monsoon period had higher number of events in the MSL corridor. While there are seasonal differences, this did not proportionally affect the number of successful dispersal events we detected during the study period. However, the Kottavasal corridor continues to play an important role for leopard dispersal. This suggests that the connectivity between these two landscapes exists, however it is very fragile and if immediate steps are not taken there is a potential that this connected leopard population might become isolated in the future.

Results from this study and earlier datasets (2010 - 2013) also indicate that the same male (Figures 9 & 10) has been regularly dispersing through the Kottavasal corridor. This not only establishes that the Kottavasal corridor continues to provide functional connectivity for leopards, it also highlights that the individual continues to use this corridor as a part of his home range. Thus restoring and enhancing connectivity will not only maintain long distance dispersal, but also provide safe passage for daily/seasonal movement.

Elephants

For the period November 2013 to June 2015 we obtained 745 photographs of elephants from 140 sampled locations. Elephant presence across the study area is presented in Figure 11. Results show that there are seasonal differences both in the number of elephants photographed and in the number of locations where they have been photographed, with higher proportion of photo captures during the dry season even after accounting for differences in sampling efforts (Table 11 & Figure 12). Table 12 provides division wise details of number of elephants photographed, indicating a large number of elephants in the Thenmala division, throughout the year.
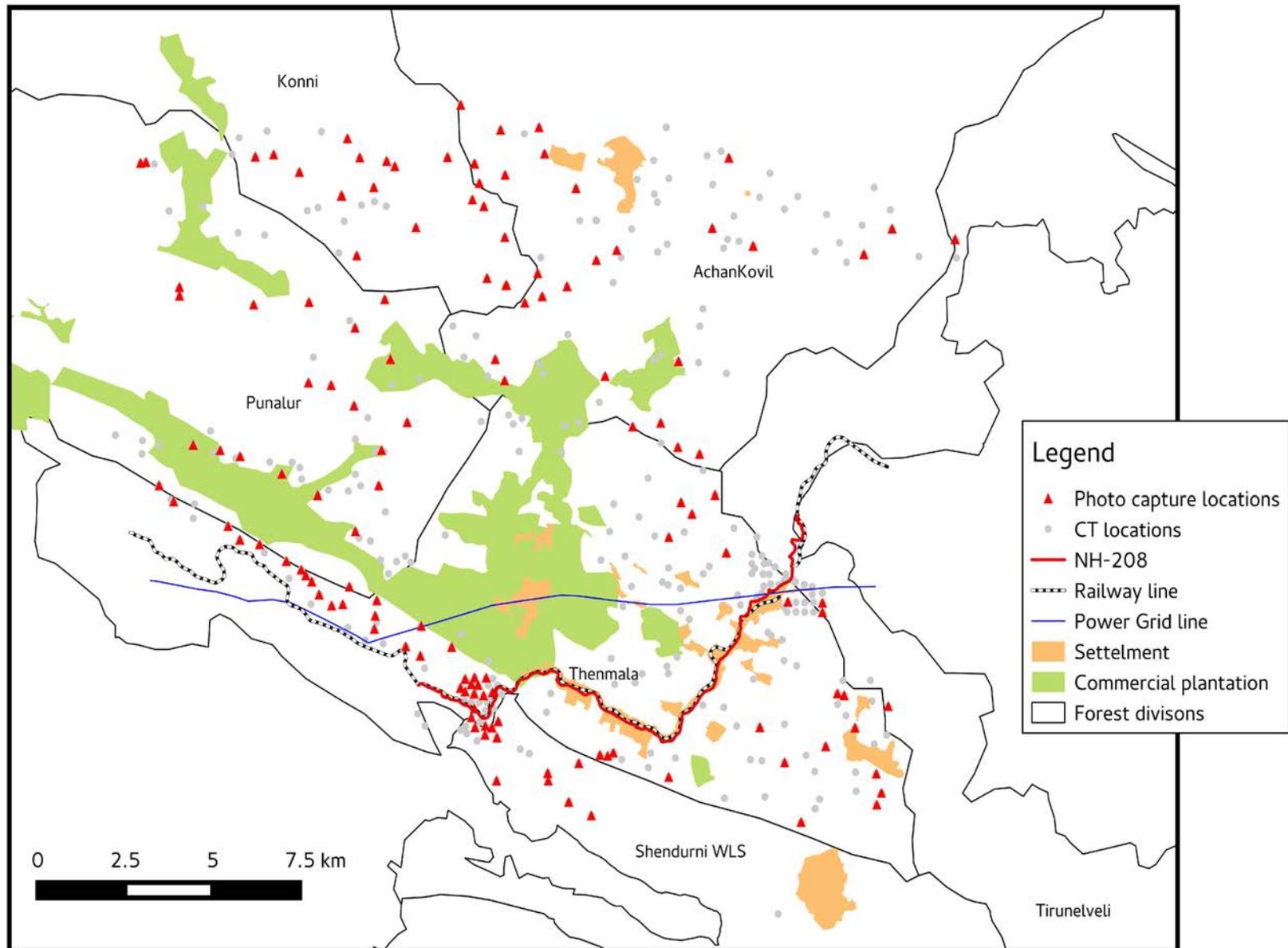
Figure 11: Figure 4: Map showing locations of photographic captures of elephants for the period November 2013 – June 2015
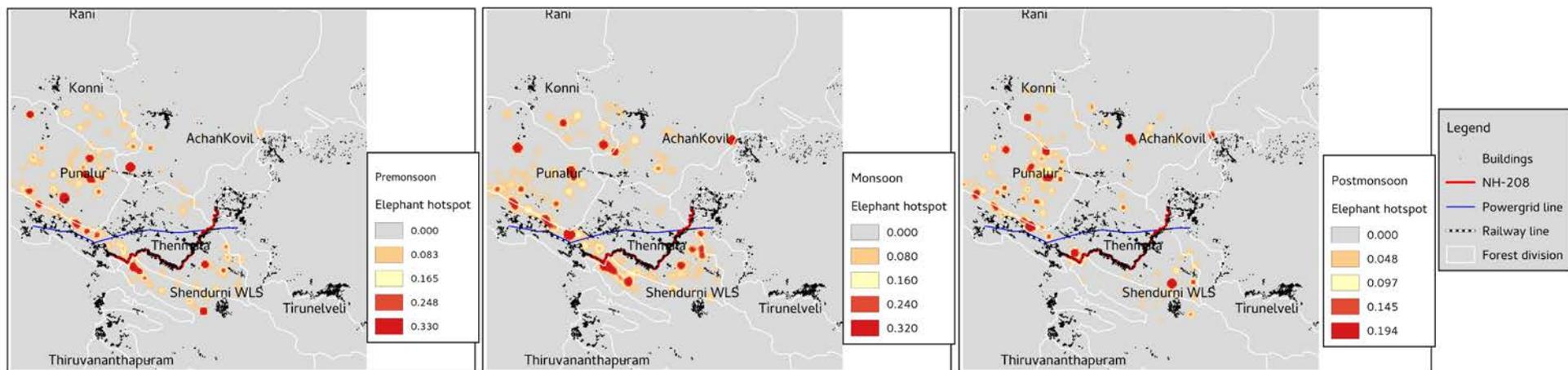
Figure 12: Temporal variation in the encounter rates of elephants indicate seasonal differences in distribution of elephants and also change in intensity along linear intrusions

Figure 13: Female elephant with calves photographed close to the NH in the MSL corridor

Figure 14: Adult bull photographed close to the NH in the MSL corridor

Table 11: Number of locations and number of photo captures of elephants during the current study, Figures in the parentheses shows number of sampling points

Season	Points	No. Of photo captures
Pre-Monsoon	80 (325)	396
Monsoon	46 (196)	237
Post-monsoon	14 (190)	112

Table 12: Photo capture details of elephants from the two intensively sampled corridors

Division	Pre-Monsoon	Monsoon	Post-monsoon	Total
AchanKovil	57	40	07	104
Konni	93	39	0	132
Punalur	100	39	3	142
Shendurney Wildlife Sanctuary	09	51	0	60
Thenmala	137	68	101	307

Photographic evidence of elephants from across the study area helps in understanding their general distribution. However, to gain insights on the habitat connectivity between Periyar and Agastyamalai landscapes, we focused on potential crossing points at the two corridors, which were intensively monitored using a dense network of camera traps. These findings have been summarized in Tables 13 and 14.

In the MSL corridor, we have recorded elephant presence on both sides of the NH – Railway line barrier in the potential crossing point. Elephant presence was recorded in more camera trap locations in MSL (47% of sampled camera trap locations) in comparison to the Kottavasal corridors (Table 13).

Table 13: Photo capture details of elephants from the two intensively sampled corridors

Corridor	No. of permanent sampling locations	No. of locations with photo captures	Percentage
MSL	38	18	47.36
Kottavasal	31	03	09.67

Table 14: Dates and seasonal patterns in photo captures of elephants from the two intensively sampled corridors

	Pre-monsoon	Monsoon	Post-monsoon
MSL	15/01/2014	16/04/2014-19/04/2014	04/12/2013-10/12/2013
	15/04/2014-30/04/2014	11/05/2014-14/05/014	04/01/2014-15/01/2014
	18/05/2014-26/05/2014	01/06/2014-27/06/2014	05/02/2014-21/02/2014
	17/08/2014	06/07/2014-27/07/2014	23/05/2014-26/05/2014
	09/12/2014	04/09/2014-25/09/2014	05/06/2014-10/06/2014
		10/11/2014-27/11/2014	08/07/2014-23/07/2014
		08/04/2015	17/10/2014
		05/05/2015-13/05/2015	27/11/2014
			04/12/2014-24/12/2014
			07/02/2015
			09/03/2015
			20/04/2015
			01/05/2015-22/05/2015
Kottavasal	20/05/2014	10/07/2014-14/07/2014	13/11/2014
		06/06/2014	

Elephants show social hierarchy and associations, adult males are usually solitary or form loose association with other males and range widely. On the other hand females are matrilocal and mostly stick to the family comprising related individuals (females, calves and young males) of different age classes. Negotiating barriers has potential risks, especially for family herds with young calves. Therefore, it can be expected that male elephants would be recorded in more locations closer to the barrier in comparison to family units. However, in the potential crossing locations where we sampled, we observed family units in more locations as compared to solitary males (Figure 15). In the MSL corridor, family herds have been found <200m from the National Highway.
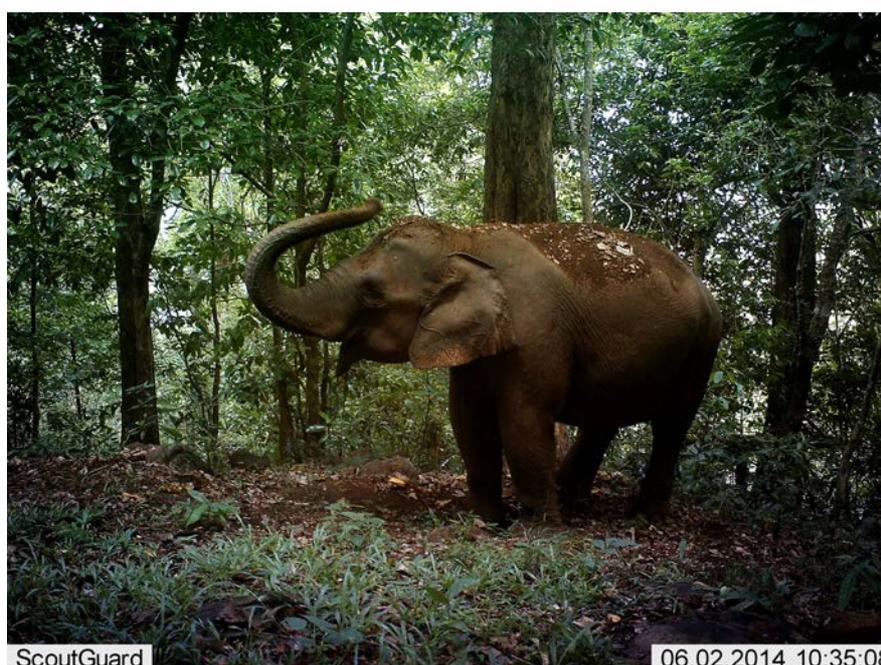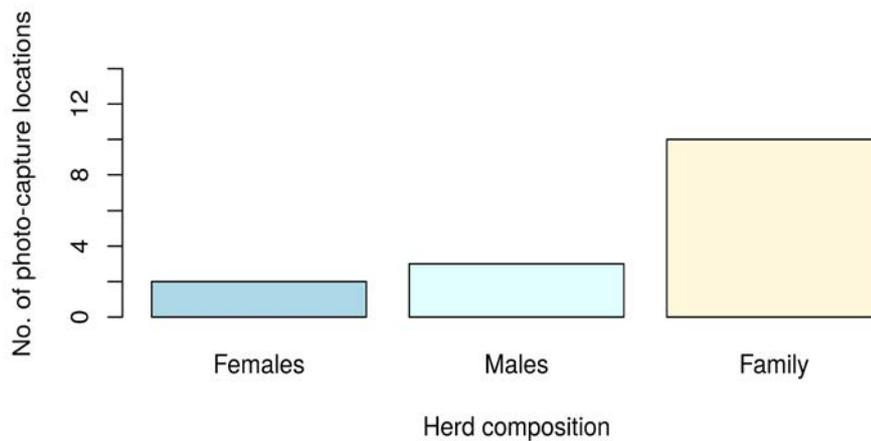
Figure 15: High number of family units of elephants observed in the MSL corridor

We also considered the number of days elephants have been recorded in each of the camera trap locations. Visitation rates can be used to understand the intensity with which a location is used. We reasoned that the probability of elephants using potential crossing points to move between Periyar and Agastyamalai could increase with increase in visitations. The camera trap locations that are very close to the National Highway did not have higher visitations during the study period, even though elephants visited these locations occasionally (Figure 16).

We identified individual elephants, using distinct ear characteristics such as, folds, lobe, cuts, and overall shape of the ear to identify females. For males, we used the combination of tusk arrangement and ear characteristics to identify individuals. Young elephants are difficult to distinguish from one another without sufficient good quality photos. Therefore, we limit the identification to adults and sub-adults within the intensively sampled areas in the two corridors. From the photographic records of identified elephants, none of the elephants have managed to disperse across the linear intrusions in the Shencottah gap. A detailed status report on the current status of elephants and the need to restore connectivity is available online[1].

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1   www.feralindia.org/files/cepf/linearbarriers/JUL2015/Report_AriyankavuCorridor.pdf
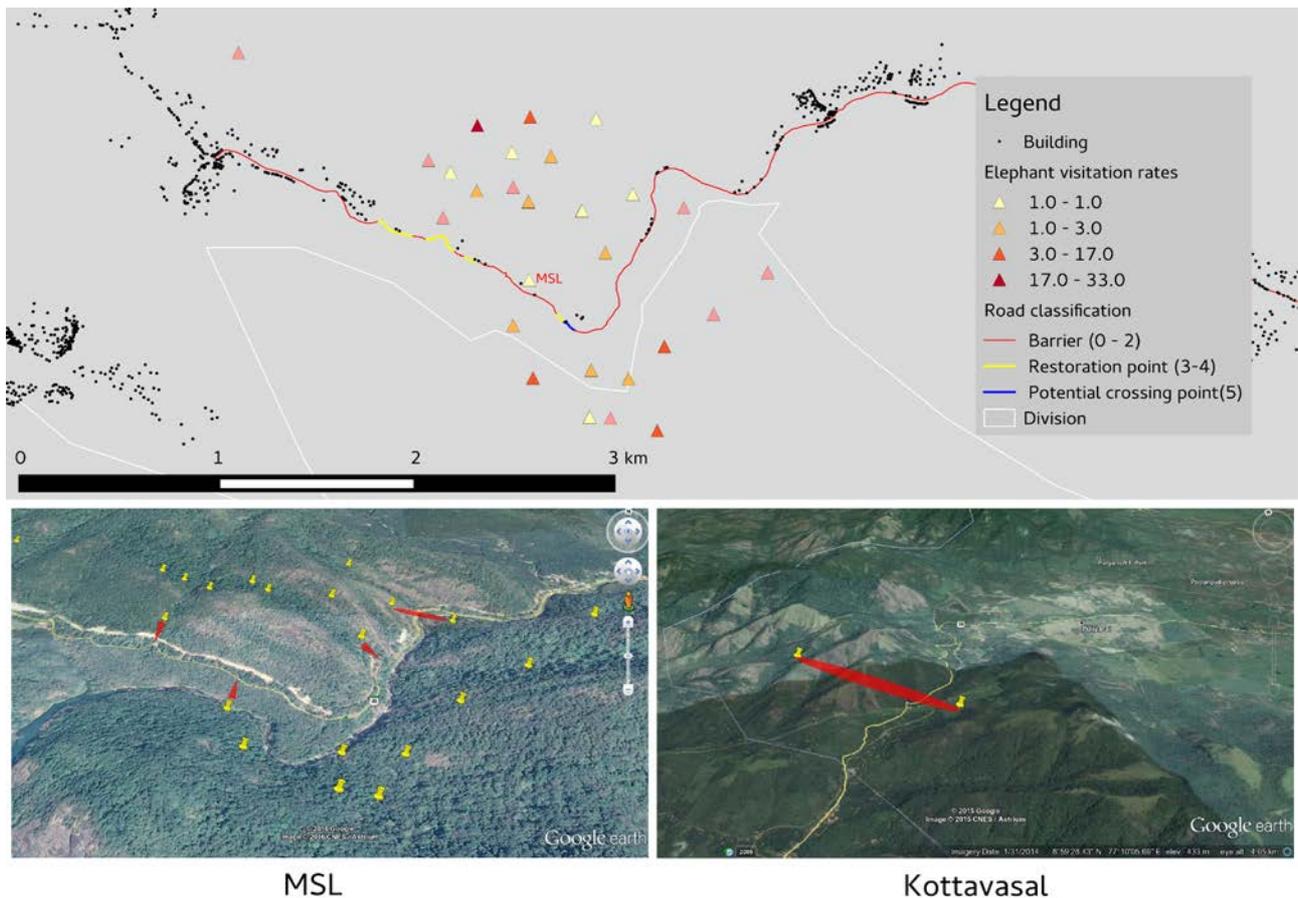
Figure 16: Visitation rates by elephants in the MSL corridor and minimum separation distance within the two intensively sampled corridors

Synthesis

From this study we have recorded elephants as close as 100m from the National Highway in the MSL corridor, both adult bulls and females with calves have been photographed. While no evidence of elephant dispersal was collected during the sampling period, our long term data (2010 -2015) from this landscape shows that the MSL corridors has a high potential to facilitate elephant dispersal. Currently the elephant population in the landscape are separated by a short distance of ~300 meter by the National Highway and Railway line and with associated human settlements. Restoring connectivity across the Shencottah Gap at MSL should be easier and is easily achievable to facilitate elephant dispersal. Additionally, strengthening mitigation structures at Kottavasal will provide connectivity for occasional dispersal across the Shencottah Gap.

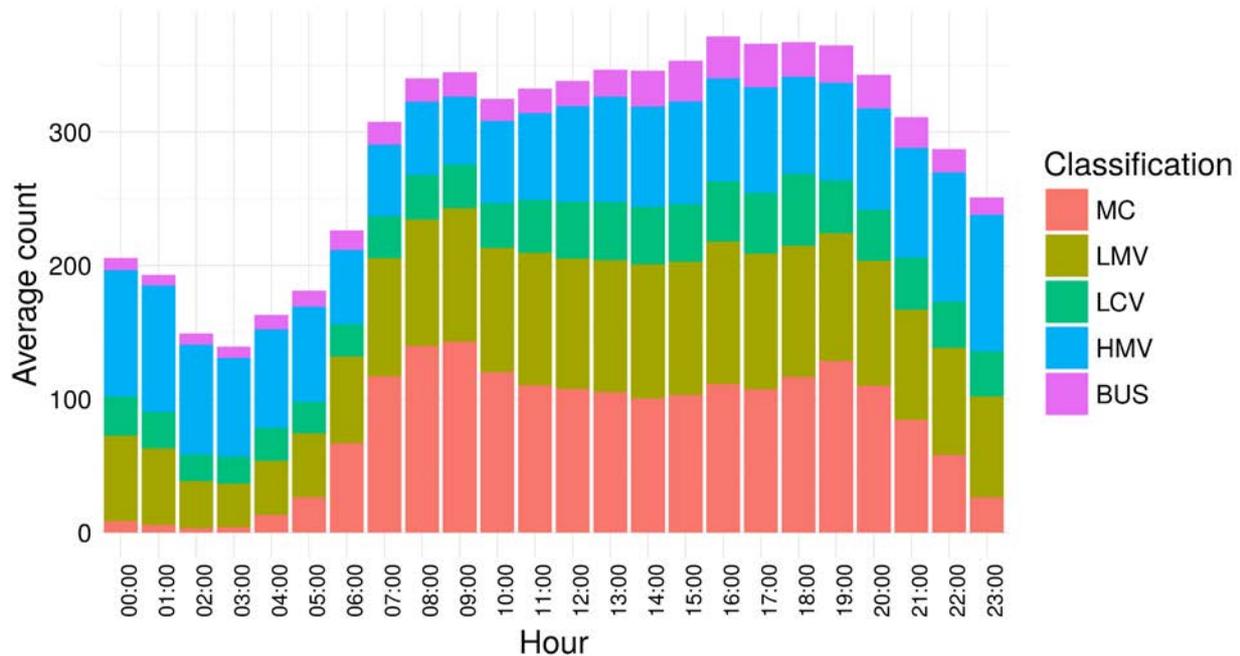## Impact of Linear Intrusions
Effect of Traffic

Figure 17: Hourly average of traffic count and vehicle classification, indicates a high volume of traffic on the NH-208 during daytime

Traffic volumes along the NH-208 is fairly high, with an average of about 290 vehicles per hour. Traffic reduces between 00:00 – 06:00 hours and remains high throughout the day (Figure 17). Day time traffic is dominated by two-wheelers and Light Motor Vehicles (cars) whereas late night traffic is predominantly comprised of Heavy Commercial vehicles Figure 17.

To understand the response of wildlife to traffic we used cross correlation plots. We did not have sufficient incidences of tigers within 500m to carry out analysis, we only present results of vehicular traffic on the occurrence of elephants and leopards within close proximity to the National highway.

For elephants, the correlations are negative (Figure 18), indicating that an above average value of traffic volume per hour is likely to lead to a below average value in encounter rates of elephants near the National Highway, and below average traffic is associated with a likelihood of above average encounter rates of elephant.

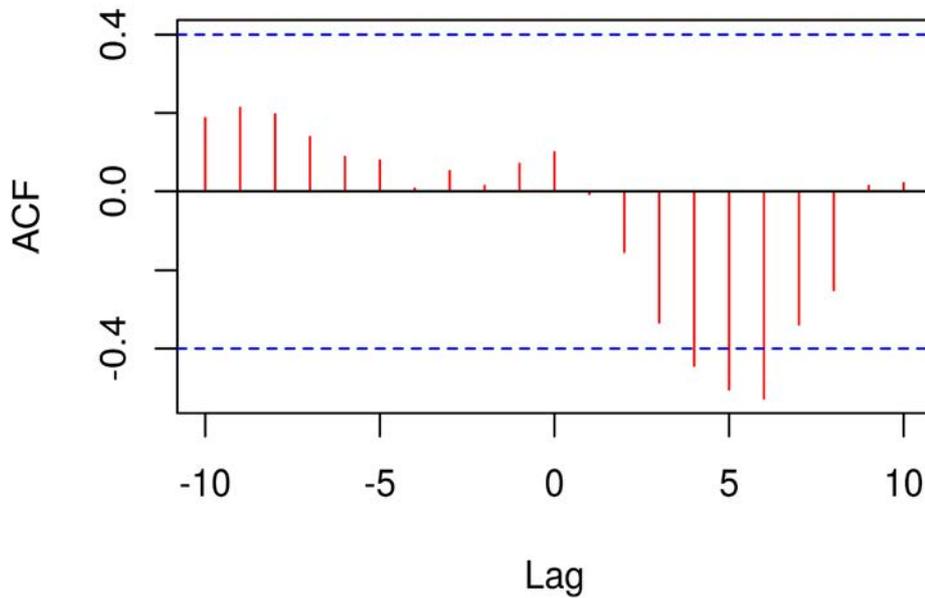## Elephant detections vs Average traffic count

Figure 18: The number of elephants photographed within 500m of NH-208 shows a negative response to vehicular traffic

For leopards, the correlations are positive (Figure 19), suggesting that leopards are more likely to be in proximity to the National Highway 5-7 hours after the traffic volumes reach their peak. Given the nocturnal behaviour of leopards, the plot suggests overlap in peak activity period of leopards and traffic in the Shencottah gap.

Leopard detections vs Average traffic count
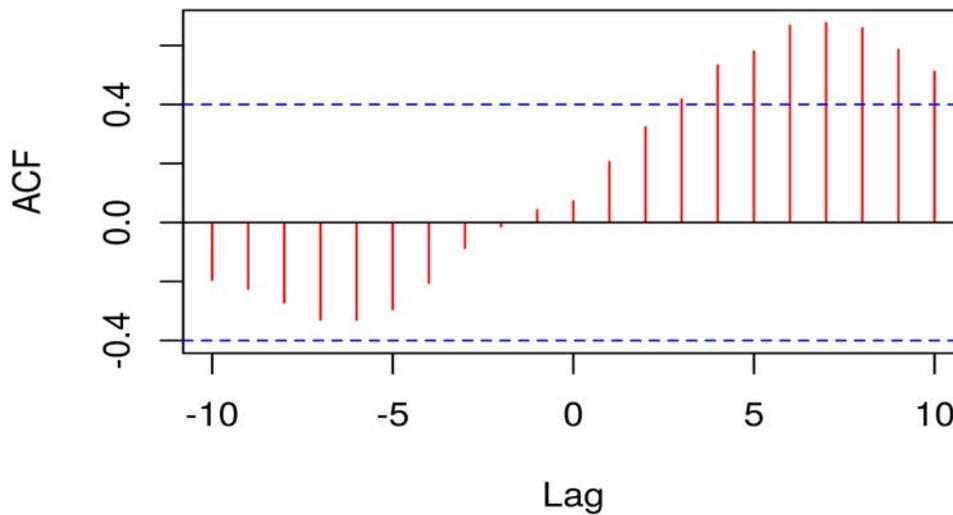
Figure 19: The number of leopards photographed within 500m of NH-208 shows a positive response to vehicular traffic suggesting that leopards are more likely to be in proximity to the National Highway 5-7 hours after the traffic volumes reach their peak

Impact of linear intrusions on elephant dispersal

Overall, across the 15 roads in human dominated landscapes that were sampled, we found that elephants did not cross the roads at all at points with high slope (slope >20 degrees) even when the human presence (number of houses and buildings) at these points were low (<24 houses). They also did not cross at locations with high human activity (number of houses >24). The elephants showed very high propensity (90%) of crossing at a point along the road with low human activity (number of houses <24), low slope (<20 degree) and high vegetation cover (>19.12%). Their propensity to cross however dropped with lowered vegetation cover (<19.12%) from 90% to ~55% (Figure 20).

When the terrain was flatter (Eg. Eastern Ghats landscape and in plains), availability of adequate vegetation cover (>19.12%) and low levels of human presence (<19 houses) alone regulated elephant movement across the roads. As these areas have a flat terrain the influence of topographical features on decision-making by elephants was not expected (Figure 21), we had expected traffic volumes to influence their ability to disperse.
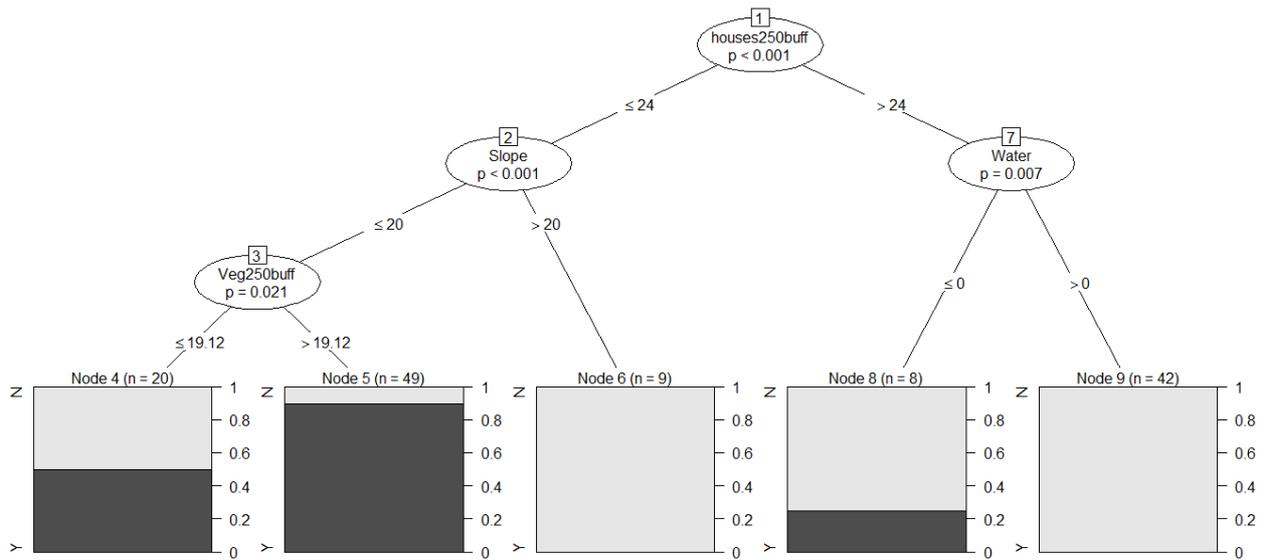
Figure 20: Factors influencing elephant dispersal across different types of roads and across varying topography
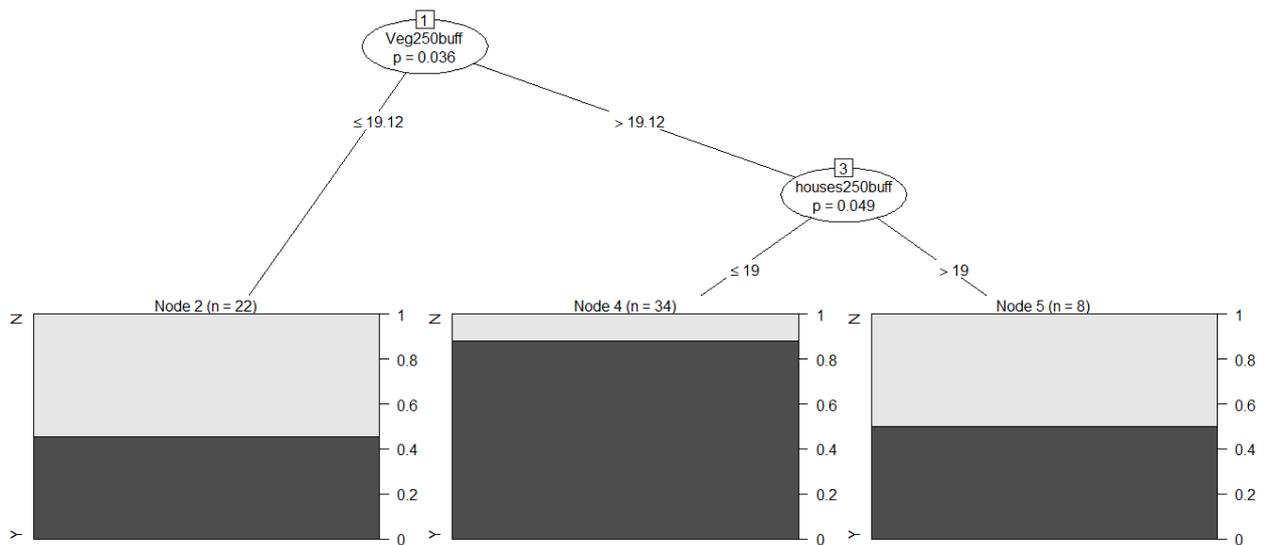

Figure 21: Presence of vegetation and buildings influence the probability of elephants crossing a road in the plains

In the hilly areas (Eg. Shencottah region and other parts of the Western Ghats) other than slope, human presence along linear intrusions seems to be of relevance in understanding decision-making by elephants. The propensity of an elephant crossing the roads in the hilly regions is also influenced by the number of houses/buildings in a 250m buffer region around the point. They seem to have a high propensity (~85%) of crossing

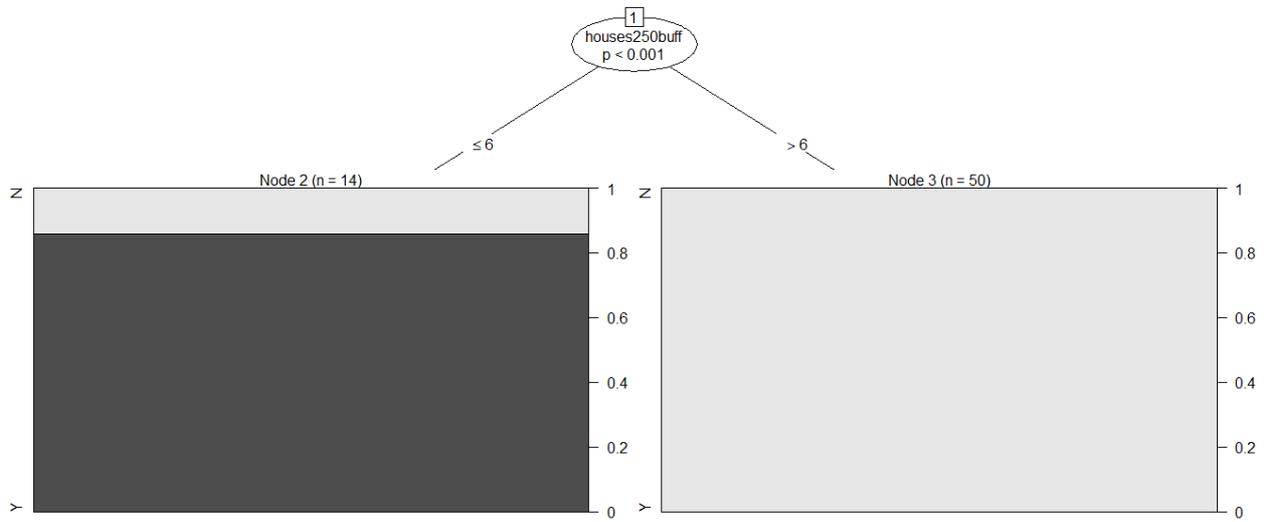at locations with <6 houses which dropped to 0% at locations with more than 6 houses (Figure 22).

Figure 22: Slope and presence of humans influence the probability of elephants crossing a road in hilly terrain

In summary, in southern India, both topographical features (which get modified due to linear incursions) and human presence seems to be influencing elephant crossing road at any given point. In the flatter areas anthropogenic activity such as number of houses becomes a conditional factor to vegetation cover. While in the hilly terrain, the decision is conditioned on a topographical feature such as slope. Slope could also be due to the embankments built while constructing the road. It is interesting to note that vehicular load did not come up as an important factor in the overall model across the region, probably because most road crossing by elephants is at night when the traffic levels are relatively low.

Potential Crossing Points and Mitigation Structures

Using the point locations where we photographed elephants on either side of the road, we developed a kernel estimator based on the photographic captures rates to identify stretches across the linear barriers that need physical intervention to restore connectivity. The Kernel estimator provides an estimate of the intensity of use/unit area by an animal in the landscape. Within this, we identified specific stretches of the road that elephants could potentially use for crossing. For this we used the ranks assigned to each stretch of the road (refer to 'road survey' in methods section) and narrowed down

potential locations (Figure 23). It is important to note that although many individual segments of the road were assigned ranks 4 and 5, we did not consider them as potential crossing locations because large herbivores like elephants require continuous stretch with high rank (ranks>3) within the kernel. Additionally, longer stretches are preferable if mitigation structures have to be constructed.
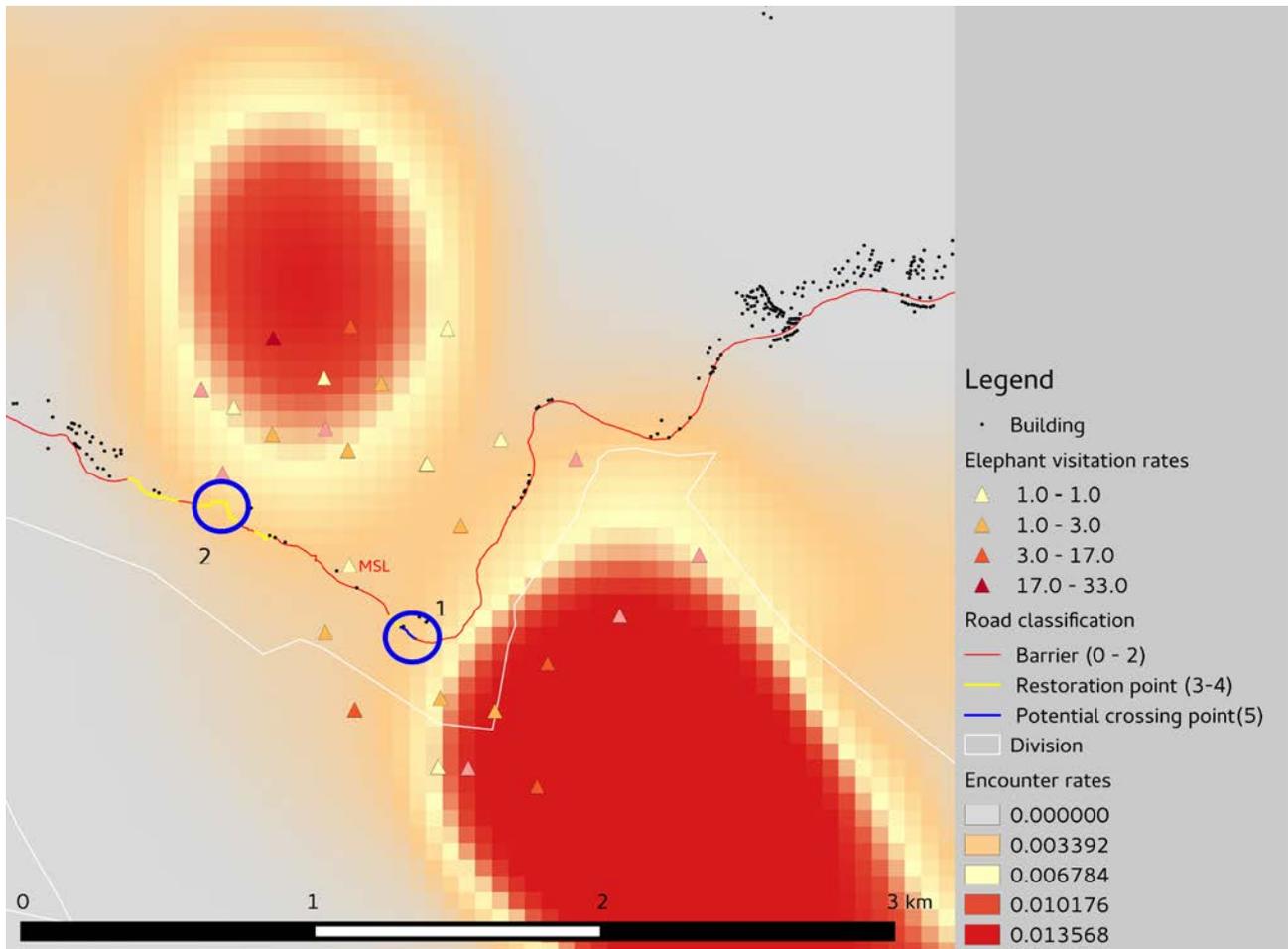

Figure 23: Two potential locations for mitigation structures based on intensity of use by elephant and existing road conditions

Only selected locations (Figure 23) met that criteria and therefore has good potential to facilitate large movement between Periyar and Agastyamalai landscapes. Finally we considered valleys or streams which will provide natural gradients for animals to pass through to identify potential location where mitigation structures can be considered.

Based on the camera trap data and field surveys we short-listed three possible locations within the MSL corridor which could potentially be altered to facilitate elephant movement across linear barriers (Figure 24). However location 1 & 2 were not considered as it was technically unsuitable to construct mitigation structures across the

National Highway and the Railway line. Additionally, to facilitate large carnivore dispersal an overpass has been suggested in the Kottavasal (Figure 25), the location was identified based on topography and frequency of successful leopard dispersal.
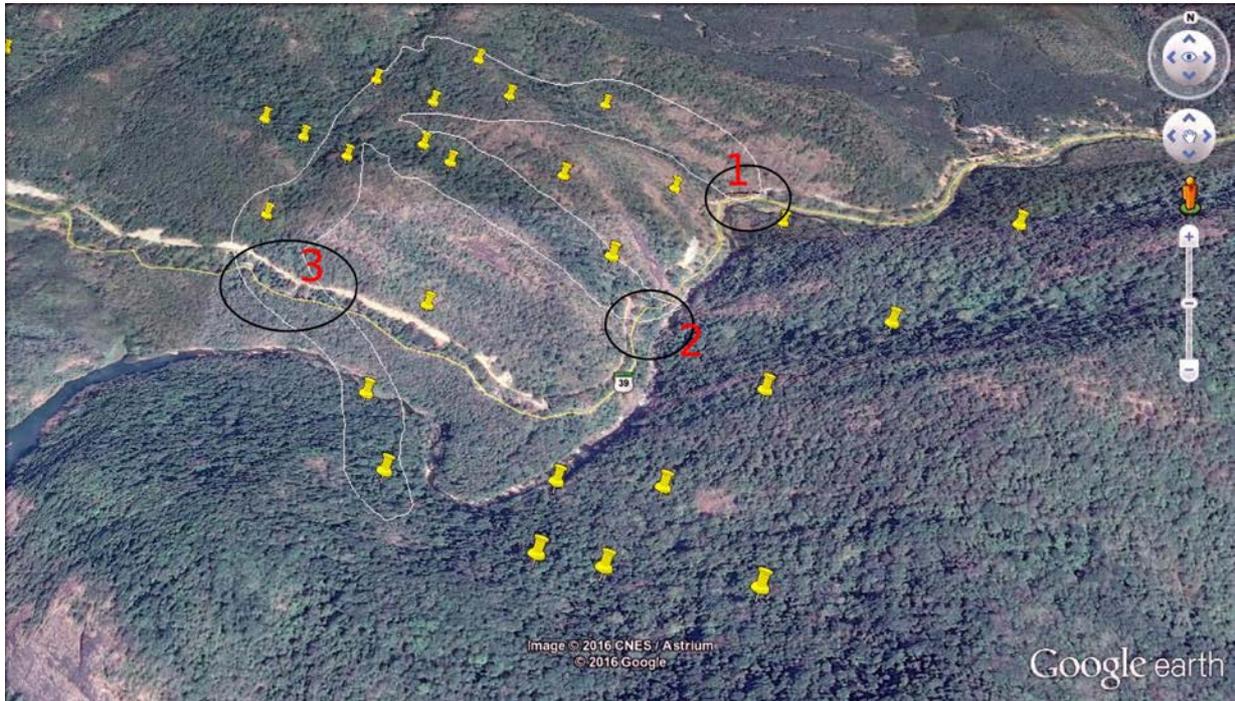

Figure 24: Three potential locations within the MSL corridors which were short-listed for engineering surveys. Locations were chosen based on presence of elephants in valleys or streams that cut across the National Highway and Railway line

Figure 25: Location within the Kottavasal corridors which was short-listed for engineering surveys. The location was chosen based on presence of leopards (white pin) and tigers (red pin)

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Recommendations

The findings from this study further strengthen and fine tune the interim recommendations made in December 2013. Moreover, our research provides inputs to the BCRLIP project, which has been initiated by Periyar Tiger Reserve (PTR) and Kalakad Mundanthurai Tiger Reserve (KMTR). We note that the issue of connectivity needs to be jointly addressed by State governments of Tamil Nadu and Kerala. The cheapest and long term ecological solution to addressing issues of connectivity across the Shencottah gap would be to ban night traffic when volumes are low, while maintaining the current restrictions on traffic during night on the Punalur – Achenkovil – Shencottah road. If the Punalur – Achenkovil – Shencottah road is expanded, tunnelling and flyovers for vehicles should be considered to ensure free and safe passage for wildlife. More importantly the corridors identified in this study should be legally notified as "corridors" using the Central or State provisions, to ensure the highest possible protection is provided to facilitate wildlife movement and to ensure restoring connectivity. In the Shencottah landscape and other hilly terrain, any new construction of linear intrusions should consider alternate routing, if none are available then underground structures should be promoted, even if it is at a higher cost to avoid ecological damage. For existing barriers, as in the case of the Shencottah gap, we make specific structural recommendations at both MSL corridor and Kottavasal corridors, a brief summary is provided below:

For the MSL corridor the following steps should to be initiated by the Kerala Forest Department:

1. Construction of a modern flyover (~200m in length) to facilitate vehicular movement to provide a safe underpass for large mammals including elephants and tigers. Encroachments along the highway need to be removed.

2. Once the flyover is constructed the existing stretch of the NH should be dismantled to prevent straying of elephants and also to provide the necessary gentle gradient which will allow them a quick passage.

3. Undertake landscaping to modify existing slopes to facilitate easy movement of animals below the railway line, highway and river course.

4. The hill slopes on the northern side of MSL should be restored with native vegetation such as bamboo to attract the animals to use the corridor area. Encroachments here need to be removed.

5. Encroachments along the highway and railway line near the location identified for construction should be removed by the relevant authorities.

6. The reserve forests within the landscape should be managed as corridors, and all timber operations should be faced out. Timber lots should be replaced with native vegetation to provide natural habitat which will enhance habitat-use by large mammals.

7. A systematic long-term monitoring (camera traps, radio - collars, genetic studies) of the corridor and use of proposed mitigation structures should be initiated prior to construction and should be continued to evaluate the efficiency of the mitigation structures.

For the Kottavasal corridor, the following steps should be to be initiated by both the Kerala and Tamil Nadu forest departments

1. An overpass with a width of 30 m for animals should be constructed at the interstate border between the hills near the Karuppaswamy temple and sufficient vegetation cover should be established on the overpass to facilitate movement of species such as leopard and tiger. Additionally this structure can be further strengthened to facilitate occasional dispersal of elephants.

2. The 5-acre property on the northern side of Kottavasal should be acquired.

3. Encroachment along the Power Grid high-tension line, within reserve forests and those along the railway line should be relocated.

4. Habitat improvement and restoration on the southern side should be initiated.

5. The actual extent of the Puliyarai Reserve Forest needs to be ascertained using land records and cadastral maps to ensure no encroachments further erode connectivity and existing illegal structures should be dismantled.

6. A systematic long-term monitoring (camera traps, radio - collars, genetic studies) of the corridor and use of proposed mitigation structures should be initiated prior to construction and should be continued to evaluate the efficiency of the mitigation structures.

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