A Study of Reptile Road Mortalities on an Inter-state Highway in The Western Ghats, India and Suggestion of Suitable Mitigation Measures

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Abstract:

Western Ghats, a global biodiversity hotspot, provides habitat for several endemic species that may be threatened due to high numbers of road mortalities because of vehicular collisions. Several studies have shown that amphibians and reptiles, grouped together, experience the highest number of road mortalities as compared to all other animal groups, thus affecting their populations worldwide. I studied animal road mortalities in Western Ghats along an interstate highway that connects the states of Kerala and Karnataka, and had previously been opportunistically recorded to have several snake road mortalities. This study shows that reptiles experienced the highest number of road mortalities as a group, followed by mammals. Within the class of reptiles, snakes were the most affected with several endemic species being killed within a duration of eight days. I henceforth identified four locations with higher numbers of snake road mortalities along the study route. In this study, I also thoroughly review the mitigation strategies for reptile roadkill and suggest suitable ones for the study site. Implementation of these strategies by the forest department and local NGOs can help reduce roadkill to a great extent and help retain viable populations of several endemic reptile species in the Western Ghats. These strategies can help mitigate reptile road mortalities in other regions as well by adopting a few, simple, cost-effective measures post road construction.

Key Words.—biodiversity hotspot; endemic; herpetofauna; roadkill; snakes; Kodagu

Introduction:

The ever-expanding human population and consequent development has led to an increased number of roads cutting through forested areas and impacting the ecosystem as a whole. Roads can have several ecological effects on flora and fauna of the region (Trombulak and Frisell 1999). They can lead to the formation of a barrier to dispersal of animals due to habitat fragmentation (Seshadri and Ganesh 2011). This can eventually subdivide their populations and lead to inbreeding depression or other demographic and genetic effects (Forman and Alexander, 1998). Habitat fragmentation has also increased the susceptibility of animals to roadkill due to vehicular collisions (Langton 1999; Glista 2009). A study on *Felis pardina* (Iberian Lynx) found that road mortality can exceed mortality due to natural causes (Ferreras *et al*. 1992). But some researchers believe that the barrier effect due to roads is more important than direct vehicular collisions when considering the impact of roads on animals (Forman and Alexander 1998). Apart from habitat fragmentation and road mortality, roads also impact animals by causing changes in their physical and chemical environment, and changing their behavior and dispersal patterns (Trombulak and Frisell 1999; Karunarathna 2013).

There have been numerous studies on the number of roadkills in different parts of the globe (Vijayakumar *et al*. 2001; Glista *et al*. 2008; Hartmann *et al*. 2011; Samson *et al*. 2016) and it has been found that millions of animals are killed annually due to expansion and construction of roads around the world (Narayanan *et al*. 2016; Bujoczek *et al*. 2011), making the need to address road mortality an integral part of conservation.

Some animal populations face major levels of mortality due to direct vehicular collision (Trombulak and Frisell 2000; Glista 2008, 2009). Although animals with higher population abundance and high reproductive rates may not be significantly affected by roadkill (Forman and Alexander 1998), threatened or endangered species with small population sizes, and endemic ones may get affected severely leading to their local and global extinction (Spellerberg 1998; Glista *et al*. 2008; Row *et al*. 2007; Seshadri and Ganesh 2011). Examples of such studies include the study on the American Crocodile (*Crocodylus acutus*) by Kushlan, 1988 and another one on the Florida Panther (*Felis concolor coryi*) by Foster and Humphrey, 1995.

Most roadkill studies were initially focused on large animals such as carnivores and ungulates (Glista *et al*. 2008) but now there is increasing awareness about herpetofauna (reptiles and amphibians) being a major group impacted by roadkill (Ashley and Robinson 1996; Glista *et al*. 2008; Selvan *et al*. 2011; Arévalo *et al*. 2017).

This has also been made evident in the Indian subcontinent by multiple studies in the past which recorded mortalities of animals, especially herpetofauna, due to roadkill in the Western Ghats region (Gokula 1997; Samson *et al*. 2016; Narayanan *et al*. 2016). The Western Ghats region of India, considered as one of the 'hottest hotspots' of biodiversity in the world (United Nations Educational, Scientific and Cultural Organization [UNESCO] World Heritage Centre. 1992. Available from https://whc.unesco.org/en/list/1342 [Accessed 18 December 2018]), is home to a large number of endemic plant and animal species (Myers 2000) especially reptiles and amphibians (Inger and Dutta 1986;

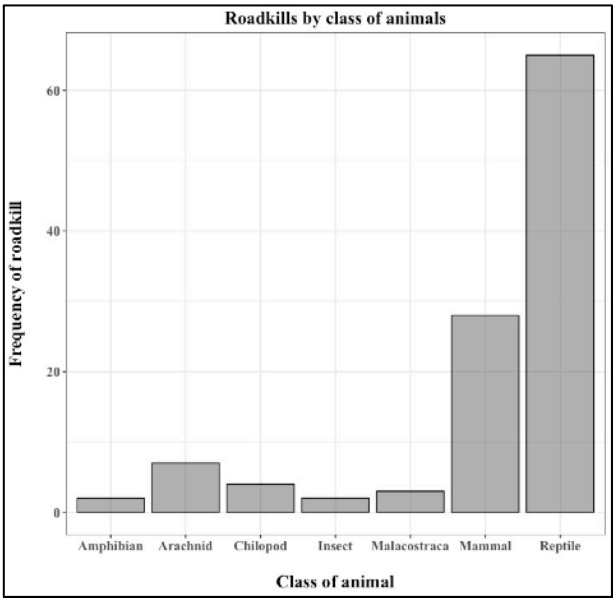

Figure 1. Frequency of roadkill by taxonomic class of animals during an eight-day period from 31 August 2017 to 07 September 2017 on an 18.3 km stretch [Perumbadi lake (12.142243N, 75.795335E) to Kerala RTO check post (12.073331N, 75.723526E)] of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India.

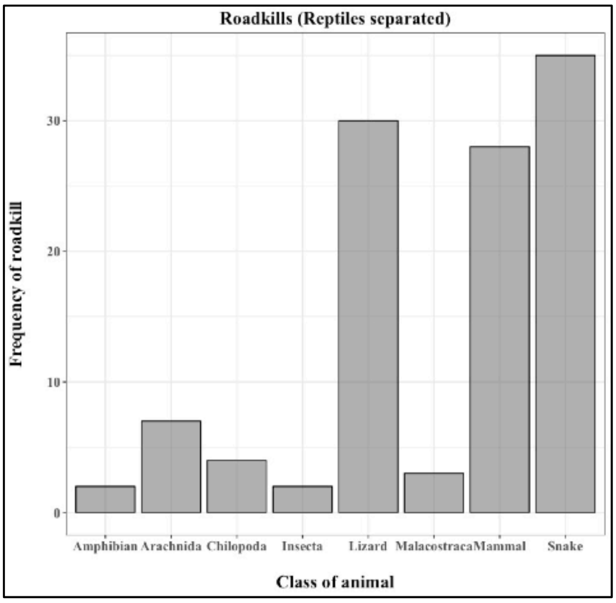

Figure 2. Frequency of roadkill of lizards and snakes separated compared to other taxonomic classes of animals during an eight-day period from 31 August 2017 to 07 September 2017 on an 18.3 km stretch [Perumbadi lake (12.142243N, 75.795335E) to Kerala RTO check post (12.073331N, 75.723526E)] of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India.

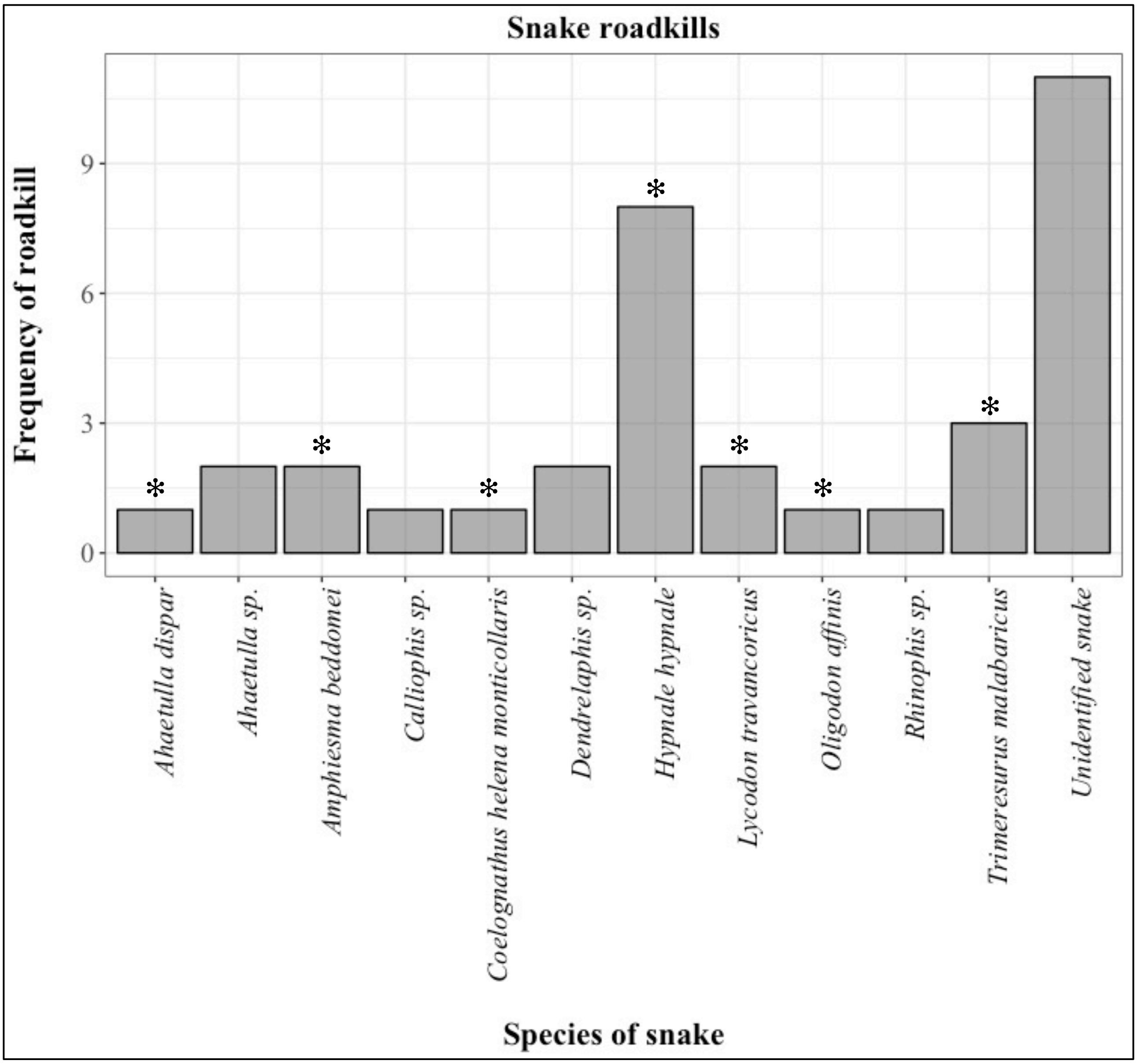

Figure 3. Frequency of roadkill of different species of snakes during an eight-day period from 31 August 2017 to 07 September 2017 on an 18.3 km stretch [Perumbadi lake (12.142243N, 75.795335E) to Kerala RTO check post (12.073331N, 75.723526E)] of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India. The asterisk denotes endemic species of the Western Ghats. It is worth noting that all snake carcasses identified to the species level in this study are endemic to the region.

Vijayakumar *et al*. 2007). It provides shelter to about 325 or more globally threatened species and is also identified as a World Heritage Site by UNESCO (UNESCO World Heritage Centre. 1992. *op. cit*.). Such landscapes and the species therein are particularly sensitive to human encroachment, roads being one of the major issues as they improve connectivity leading to higher disturbance.

This study focuses on another area of the Western Ghats where opportunistic data had previously indicated a high mortality of snakes on the road. My study had the following objectives:

(1) To determine the number of herpetofauna mortalities on the Kannur-Mattannur-Coorg Road caused by vehicular collisions.

(2) To find out if reptiles, especially snakes, were particularly affected.

(3) To identify regions of the road with higher density of road mortalities of snakes.

(4) To suggest suitable mitigation strategies along the route for implementation by the

Forest Department.

Materials & Methods:

Survey site - I conducted the survey on an 18.3 km stretch of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka in the Western Ghats, India (refer to Appendix 1). The road connects the two states of Karnataka and Kerala and passes through the Brahmgiri Wildlife Sanctuary. The habitat is mostly tropical evergreen moist rainforest but a few rubber plantations exist in some roadside areas. Sampling was started right after Perumbadi lake (12.142243N, 75.795335E) and carried out up until the Kerala RTO check post (12.073331N, 75.723526E).

Survey method - I surveyed the route from 31 August 2017 to 07 September 2017 starting at Perumbadi lake at 0830. I surveyed on a motorbike with one person riding the bike along the extreme left of the road at the speed of 10±5 km/h while I sat behind and scanned the road. I photographed all dead animals, irrespective of their class, above the size of about 1.5-2 cm, as found on the road and after turning, to aid species identification. I recorded the GPS location (in DMS) and then removed the carcass from the road to avoid repeated counting. Where possible, I identified and recorded the species of the road killed snake on the spot using the field guide by Whitaker and Captain, 2015. When specimens were not easily identifiable in field, I identified them later by referring to an online snake database (Indiansnakes.org. Available from http://www.indiansnakes.org/ [Accessed 20 October 2017]) and the field guide by Whitaker and Captain (2015), using the photographs taken in field. I usually took about four hours to complete the survey each day, which varied depending on the number of dead animals found. The rider also helped in spotting animal carcasses on the road during the survey. As the main focus of the study was on snakes, I identified road killed carcasses for snakes to the lowest taxonomic level possible. For other animals, I usually identified up to the genus level.

Data analysis -

1) *Identifying the group with maximum mortality*

I analysed the collected data using RStudio (Version 1.1.383; R Core Team 2017). To check if a particular class of animals was more affected as compared to others, I plot the number of roadkills for each class and compared their numbers. I also did the same to check if snakes, as a separate group, were affected more than any other animal as had been speculated based on opportunistic data from previous visits to the area.

2) *Identifying regions with higher density of snake road mortality*

I converted the location data for roadkill to decimal degrees (DD) from degree minute second (DMS) format in RStudio (Version 1.1.383; R Core Team 2017). Then I overlaid this data on the road map of the study site using the QGIS software (Version 2.18; QGIS Development Team 2017). Next, I generated a heat map with a radius of 0.0001 map units (10.247–11.132 m) for data on snakes and then detected hotspots by setting a suitable threshold based on the heat map (threshold = 1).

Results:

During this study, I recorded a total of 117 road killed animals over a period of eight days along the 18.3 km route which amounts to a total of 146.4 km.

1) *Group with maximum mortality*

Due to difficulty in assigning any identity for six roadkills, I eliminated them before conducting further analysis. Reptiles faced much higher mortality than any other class of animals (58.04%) followed by mammals (25%) (Fig. 1). When I separated lizards and snakes and plot them along with other classes, snakes showed the highest number of mortalities (31.25%) followed by lizards (26.79%) which is still higher than other classes without any group separation therein (Fig. 2). Of course, these numbers would be truly comparable only amongst the animal classes of comparable body size and having equal detection probabilities which is affected by various factors as discussed later. Figure 3 shows that amongst snakes, *Hypnale hypnale* (Hump-nosed Pit Viper) experienced highest road mortality but several other endemic species such as *Oligodon affinis* (Western Kukri), *Coelognathus Helena monticollaris* (Montane Trinket Snake), *Amphiesma beddomei* (Beddome's Keelback), *Trimeresurus malabaricus* (Malabar Pit Viper) were also killed due to vehicular collision.

Mammalian road mortalities included the *Moschiola indica* (Indian Mousedeer), *Macaca radiata* (Bonnet Macaque) and some unidentifiable rat and bat species.

2) *Regions of high animal road mortality*

The map with overlaid points of all animal roadkills shows that the whole stretch of road surveyed experienced animal road mortalities (refer to Appendix 2). Four regions were found to have more than one snake road mortality which may be due to chance in this study because of low sample size and would need to be confirmed with further observations (Fig. 4).

3) *Detection bias due to cloud cover*

While surveying, one of the factors I thought could affect detection of roadkill was sunlight. Thus, I conducted a Spearman rank correlation test to statistically determine any correlation between cloud cover and number of roadkill found. I found no correlation between the total number of road mortalities and cloud cover within the dataset ($\rho = -0.64$, $P = 0.10$) nor between the number of snake roadkills and cloud cover ($\rho = -0.36$, $P = 0.38$).

Discussion

This study found that the study route has a substantial number of road mortalities. There were 117 road mortalities in 8 days. If the average rate of road mortalities remains the same throughout the year, the total number of mortalities each year would reach more than 5000.

Reptiles had the highest road mortalities followed by mammals. This result can be explained using several reasons. Reptiles being ectothermic animals often use behavioral thermoregulation. The tar roads heat up during the day and the heat is released slowly at night. This attracts nocturnal reptiles to the roads for thermoregulation of their body temperatures (Bernardino and Dalrymple 1991; Bamabaradeniya *et al*. 2001; Selvan *et al*. 2011; Karunarathna *et al*. 2013). Many of the road killed snakes found during my study were in a coiled position instead of being stretched out like some others, which may suggest that some were thermoregulating on the road while others were probably just crossing it. It has also been suggested that reptiles may be laying eggs along road edges for similar reasons (Karunarathna *et al*. 2013). Roads in dense canopy forests can provide gaps where sunlight penetrates well to the ground during the day. This could be the reason for diurnal reptiles to be seen basking on the road and for their higher mortality. Numerous individuals of the genus *Calotes* observed along the sides of the road during the survey may provide one such example. The small size of the reptiles compared to large mammals which can be easily seen by approaching vehicles could be another reason. Since the route studied had been renovated such that there is high speed traffic now, the reptiles would go unnoticed most of the times and be run over.

TABLE 1: Summary of suggested roadkill mitigation strategies

Category	Mitigation strategy	Importance	References
Animal behaviour modification	Culverts/Underpasses/Hose-bridges • At identified hotspots • 0.5m diameter • 0.6-0.9 m high drift fences • Light source	Safe crossing by animals	Brehm 1989; Bernardino and Dalrymple 1991; Aresco 2005; Glista et al. 2008, 2009; Woltz et al. 2008
Animal behaviour modification	Metal cover boards Place metal cover boards at regular intervals (100 m) along road-side.	Refuges for thermoregulation	James Warren, pers. comm.
Animal behaviour modification	Strumming of vegetation Push the forest edge away from road by clearing vegetation up to 5-10 m on either side of road.	Non-road open canopy areas for basking	James Warren, pers. comm.
Human behaviour modification	Reduction in traffic volume Restriction on number of vehicle entry per day, especially on festival days and holidays.	Less traffic faced by animals	Seshadri and Ganesh 2011
Human behaviour modification	Temporary road closure During breeding season of snakes and at night when roads are hotter compared to the surrounding areas, the roads should be completely barricaded.	Less traffic faced by animals	-
Human behaviour modification	Speed limit Reduction and strict implementation of speed limit which can be aided by sign boards and speed bump construction.	Time to escape	Glista et al. 2009; Seshadri and Ganesh 2011; Samson et al. 2016

Within reptiles, the highest road mortalities in snakes can be explained by additional reasons. When crossing roads to move between fragments of habitats (Langton, 2002; Karunarathna *et al*. 2013) they have lesser mobility as compared to lizards which tend to escape from approaching vehicles (Bambaradeniya *et al*. 2001; Karunrathna *et al*. 2013). Snakes tend to coil up on detecting vibrations of vehicles and hence get killed (Bambaradeniya *et al*. 2001; Karunrathna *et al*. 2013). In India, snakes are often resented by the general public due to the extremely high number of snake bite cases leading to injuries and deaths and thus many people can be seen riding over the snakes, intentionally, on detection. Aggressive behavior of drivers towards snakes on roads has also been documented before (Bambaradeniya *et al*. 2001; Karunrathna *et al*. 2013).

Although, this study does not support many other studies which have found amphibians to be the major group of impact (Vijayakumar *et al*. 2001; Arévalo *et al*. 2017), it does provide support to some studies which found reptiles to be the major group of impact (Selvan *et al*. 2011; Karunarathna *et al*. 2013). The differences could be explained by local abundance of reptiles in the study area and the extremely small size of some amphibians. Uncertainty in identification of completely destroyed animal carcasses on the road could also have played a major role in leading to this bias. Some studies suggest that carcass persistence on roads is the major factor in estimate biases during roadkill surveys (Coelho *et al*. 2008; Santos *et al*. 2011) where persistence is higher for larger animals as compared to smaller animals (Balcomb 1986; Wobeser and Wobeser 1992; Santos *et al*. 2011). The above-mentioned studies also suggest that carcasses for smaller animals usually persist for a day. This study was designed to maximise detection of smaller animals because of their previously known local abundance and thus the survey was conducted every 24 hours, eliminating most possibilities of missing carcasses. Hence, lower persistence of smaller carcasses could not be a possible cause of lower amphibian road mortalities as found in this study. But a study by Aresco *et al*. (2005) suggests that detecting some small anuran species road kills may be difficult due to their tendency to get stuck on tyres or get completely destroyed. Therefore, the low abundance of amphibian mortality data either indicates their low abundance in the area, avoidance of roads, mortality of only very small anuran species or some other reason which would need further investigation.

Since the ecology and behavior of each taxon varies, a generalized analysis of road kill hotspots would not help devise meaningful mitigation strategies. A heat map analysis for reptiles showed a somewhat uniform spread of the road kills and hence did not reveal significant values for identification of hotspots (refer to Appendix 3). This study was thus focussed on snakes due to expertise in the field and their local abundance. The regions with more than one snake road mortality were marked. Even though four such regions were identified using GIS heat map analysis, the data is insufficient to draw proper conclusions since the threshold used in the analysis for calculating hotspots was low (threshold = 1). Eberhardt *et al*. (2013) also suggest the unreliability of hotspots analysis. They suggest that often areas with highly suitable habitat for a species may have seen a population decline due to road kills in the past and hence may not appear as a hotspot in the analysis of a more recent dataset for road mortalities in the region (Eberhardt *et al*. 2013). Such regions still need to be taken into account when suggesting mitigation strategies and hence not much focus should be placed on hotspot analysis. Nevertheless, a long-term monitoring study or additional short-term studies carried out during different seasons may help confirm the locations of hotspots identified in this study for snake road mortalities. A similar analysis with more data could also reveal certain areas with higher *Macaca radiata* (Bonnet macaque) deaths since they were often observed in groups around areas of higher human disturbance.

However, there can be several factors affecting the observations of this study. For example, higher temperatures may lead to drying of the carcasses beyond recognition while high precipitation could wash them away. Thus, these factors need to be taken into account when designing sampling method for a given area.

The correlation between cloud cover and number of road mortalities was checked to ensure that there was no detection bias between shaded and sunny area as was speculated during the survey. Cloud cover does not seem to have had any effect on the number of animal road mortalities detected during the sampling period of this study.

There could still be some other factors affecting the numbers in the survey. Some carcasses may have moved away from the road or been picked up by scavengers before being detected which can cause underestimation of the number of roadkills (DeVault *et al*. 2003; Smith and Dodd 2003; Glista *et al*. 2008) along with the lower efficiency of driving surveys compared to walking surveys (Langen *et al*. 2007). Identification of road killed animals is an extremely daunting task since most specimens are flattened and laden with mud from the vehicle tyres and tar from the road. Thus, it was very difficult to identify several snake specimens, henceforth inhibiting proper interpretation of (Fig. 3). These issues are characteristic of roadkill studies and much cannot be done to resolve them.

Directions for Future Studies in the Area:

Several studies have shown a correlation of number of road mortalities of animals belonging to different taxa with weather variables (Smith and Dodd 2003; Glista *et al*. 2008; Narayanan *et al*. 2016). Glista *et al*. (2008) showed that temperature and precipitation played a major role in determining the number of road mortalities with peaks during highest temperature and precipitation months. Other studies discuss the species specific seasonal variation in number of road mortalities which may be due to mate searching and juvenile recruitment in snakes (Hartmann *et al*. 2011) and distinct life histories of anuran species (Ashley and Robinson 1996; Glista *et al*. 2008) for example. The volume of traffic has been another determinant for the number of road mortalities in some studies which show a positive correlation between the two (Bernardino and Dalrymple 1991; Seshadri and Ganesh 2011; Arévalo *et al*. 2017). The study by Santos *et al*. (2011) also talks about the effect of traffic and weather conditions on the estimation of the number of road mortalities. Traffic can have a positive correlation with the number of road mortalities detected not only due to more animals being run over but also because more traffic results in lesser access of the carcasses to the scavengers (Slater 2002; Santos *et al*. 2011). Similarly, the weather conditions can also increase the number of road mortalities detected due to lower scavenger activity in poor visibility conditions such as fog or rain (Hels and Buchwald 2001; Slater 2002; Coelho *et al*. 2008; Santos *et al*. 2011). Thus, further studies in the area are required to check for any effects of season, weather, species specific behaviors and traffic on the number of road mortalities to be able to suggest better suited mitigation strategies such as temporary closure of the road.

Mitigation Strategy:

The data collected in this study is sufficient to indicate the need for mitigation strategies for road mortalities of animals since the number is astonishingly high for an eight day period and many important, endemic species were also found dead. If roadkills occurred at the same rate, throughout the year, as observed during

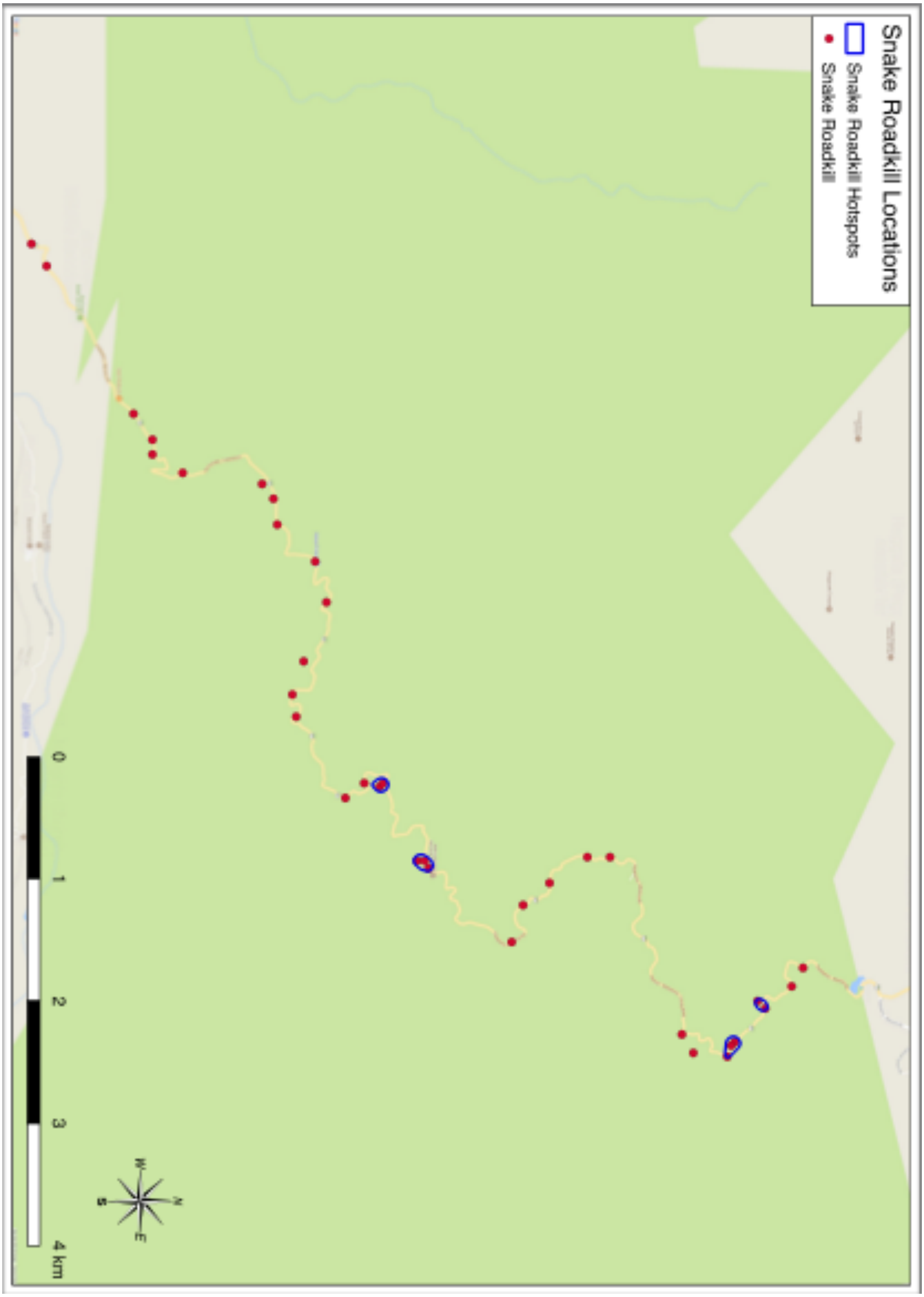

Figure 4. Map showing snake roadkill locations along the 18.3 km stretch of road surveyed [Perumbadi lake (12.142243N, 75.795335E) to Kerala RTO check post (12.073331N, 75.723526E)] of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India. The blue circled areas denote the identified hotspots for snake roadkills (base map used: Google street maps).

Figure 5. Photographs of roadkills taken during the survey. A: *Ahaetulla sp.*, B: *Calotes sp.*, C: *Calliophis sp.*, D: *Dendrelaphis sp.*, E: *Moschiola indica*, F: Bat (species unidentifiable), G: Caecilian (species unidentifiable). (Photographed by Udita Bansal).

the study period for this study, a simple calculation shows that the number of total roadkills would reach 5338 in a single year. As previously mentioned, the effect of roadkill can be drastic for endemic species which can go locally extinct (Vijayakumar *et al*. 2001; Glista *et al*. 2008; Seshadri and Ganesh 2011) due to such unnatural causes of population decline which far exceed the rate of mortality due to natural causes (Ferreras *et al*. 1992). Thus, some mitigation strategies are hereby suggested for reptiles as the main focus group.
Mitigation strategies have been grouped into two categories by Glista *et al*. (2009) based on the modification of the animal or the motorist behavior. The first category can include strategies such as culverts and other animal crossing structures, cover boards and strumming of vegetation. Regulating volume of traffic, temporary closure of roads, enforcing speed limits, putting up sign boards and speed breakers can be part of the second category.

Culverts have been suggested by several authors as means of letting animals move across fragments of habitats on either side of the road (Aresco 2005; Glista *et al*. 2008, 2009; Woltz *et al*. 2008). They may be avoided by some large animals (Glista *et al*. 2009) but since this study shows a majority of small animal road mortality in the study area, they can be adopted effectively in this case. As location of the culverts has been implicated to be a major factor in their effectiveness for herpetofauna and other less mobile, small animals (Glista *et al*. 2009), locations identified as having higher density of snake road mortalities in this study should be further checked and can be installed with medium sized diameter (Woltz *et al*. 2008) culverts.

Underpasses can also be used in place of culverts along with drift fences or barrier walls (Brehm 1989; Bernardino and Dalrymple 1991; Glista *et al*. 2009). These underpasses can have openings on their upper surfaces for penetration of natural light and maintenance of natural temperature conditions to prevent avoidance by animals (Brehm 1989; Bernardino and Dalrymple 1991).

Hose-bridges which are easier to install post road construction as temporary structures are a recent development in this field. They act as speed breakers for vehicles and also allow snakes to pass through safely when directed towards the different sized tunnels using drift fencing (Manka 2016). These structures have an advantage of easy installation, possibility of shifting due to changes in hotspots of roadkills, and natural light conditions due to provisions of slits or holes (Manka 2016). Thus, in regions of the road where snake mortality is the primary concern, these structures can prove to be easy solutions for safe snake crossings.

To prevent reptiles from basking on the road, metal cover boards can be placed along road sides to provide places for thermoregulation. If permissible, the vegetation on either side of the road can be strummed to push the habitat edge inward and away from the road to help keep the animals away from the road (James Warren, pers. comm.).

Apart from modifying animal behavior, an effective solution can be to regulate the volume of traffic on the road by putting restrictions on the number of vehicles allowed to enter the route each day along with promotion of public transport usage on this particular route (Seshadri and Ganesh 2011). The road can be temporarily closed during breeding seasons of snakes and during the night when there may be high number of nocturnal snakes on the road for thermoregulation. Reducing the speed limit and its proper enforcement can help reduce mortalities (Glista *et al*. 2009; Seshadri and Ganesh 2011) since high-speed traffic has been implicated as a major reason for roadkill (Glista *et al*. 2009). It can give animals enough response time to escape (Seshadri and Ganesh 2011) and also the drivers to apply breaks and bring the vehicle to a halt. Speed bumps can be constructed at regular intervals to ensure enforcement of speed limits (Glista *et al*. 2009; Samson *et al*. 2016) and sign boards put up to indicate wildlife crossing areas and remind people about the speed limit (Glista *et al*. 2009; Seshadri and Ganesh 2011; Samson *et al*. 2016).

A serious problem observed along the route of the survey was feeding of the Bonnet Macaques by tourists who often stopped on their journeys to take a break and have a meal. This not only created areas of Bonnet Macaque concentration, possibly altering their ecology and behavior, but also resulted in littering of the forest. Such activities should be kept under strict check in protected areas of such high endemic value. Sign boards can be put up in the local languages to spread awareness but regular patrolling by the forest department and placement of fines will be necessary. Halting of vehicles along the 18.3 km stretch should not be permissive and short cemented pillars along the road can help block spaces for parking cars.

All the above-mentioned strategies have been summarized in Table 1.

With massive number of roadkills in India happening by the day there has been an increased awareness about the issue. A recent citizen science initiative has been taken to increase further awareness and get roadkill data from across the country. An Android application, named “Roadkills”, which lets you report roadkill data along with images and location has been launched by Wildlife Conservation Trust. The data is openly available for use by NGOs and the government and hence can reduce the need of carrying out surveys by researchers who can then focus on devising suitable mitigation strategies by analysing the collected data. It is one of the first such applications in India and is a huge step towards reduction of animal road mortalities.

Conclusion:

With substantial number of animal road mortalities along the survey route passing through a protected area in the Western Ghats, it is imperative to take action to prevent local extinction of endemic reptilian species. If preservation of natural forested habitats is not entirely possible, roads should be constructed bearing in mind the consequences animals face. Appropriate strategies should be adopted during and after road construction to allow safe passage of animals across the roads. It has been shown that overall mitigation measures are effective in reducing roadkill by 40% (Rytwinski *et al*. 2016) and hence the strategies suggested here, after careful survey of the roadkill in the region, should be implemented by the forest department. The strategies suggested are all very economical and just require stricter implementation of existing laws in some cases. Further studies may be done in the area to check for seasonal differences and the effect of traffic volume but till then this study shall suffice to suggest the need and the kind of mitigation measures to be implemented to reduce animal roadkill in the region.

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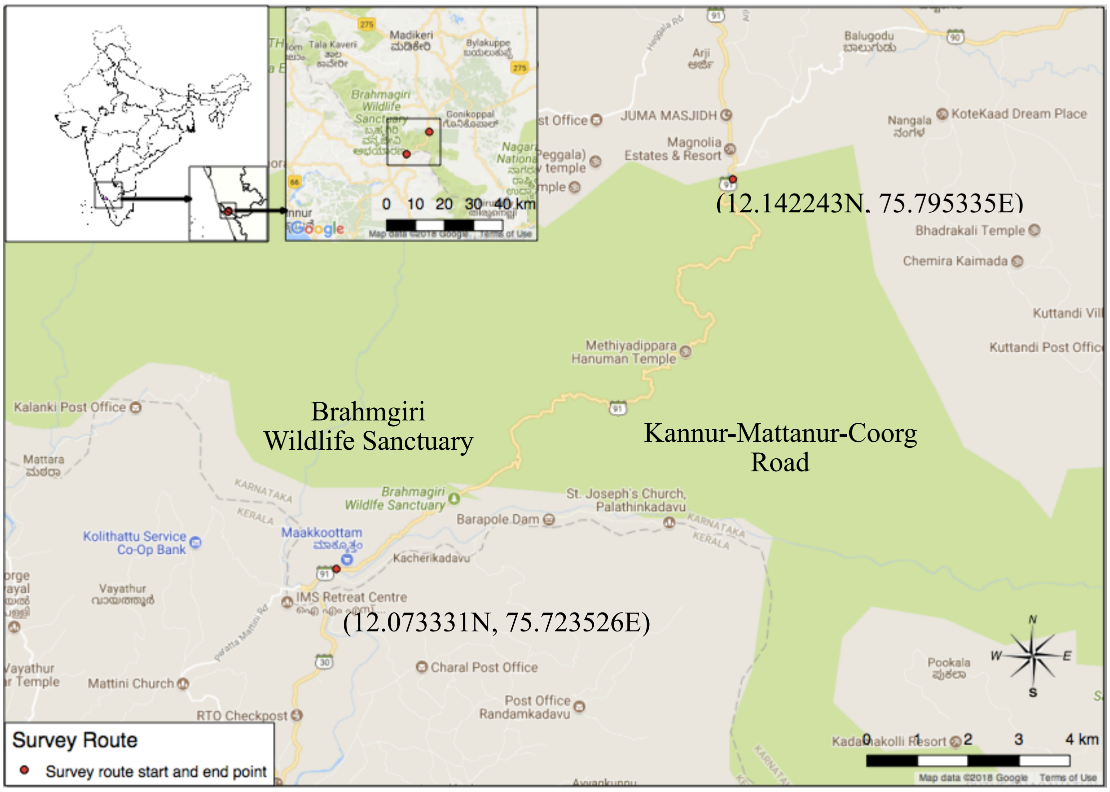
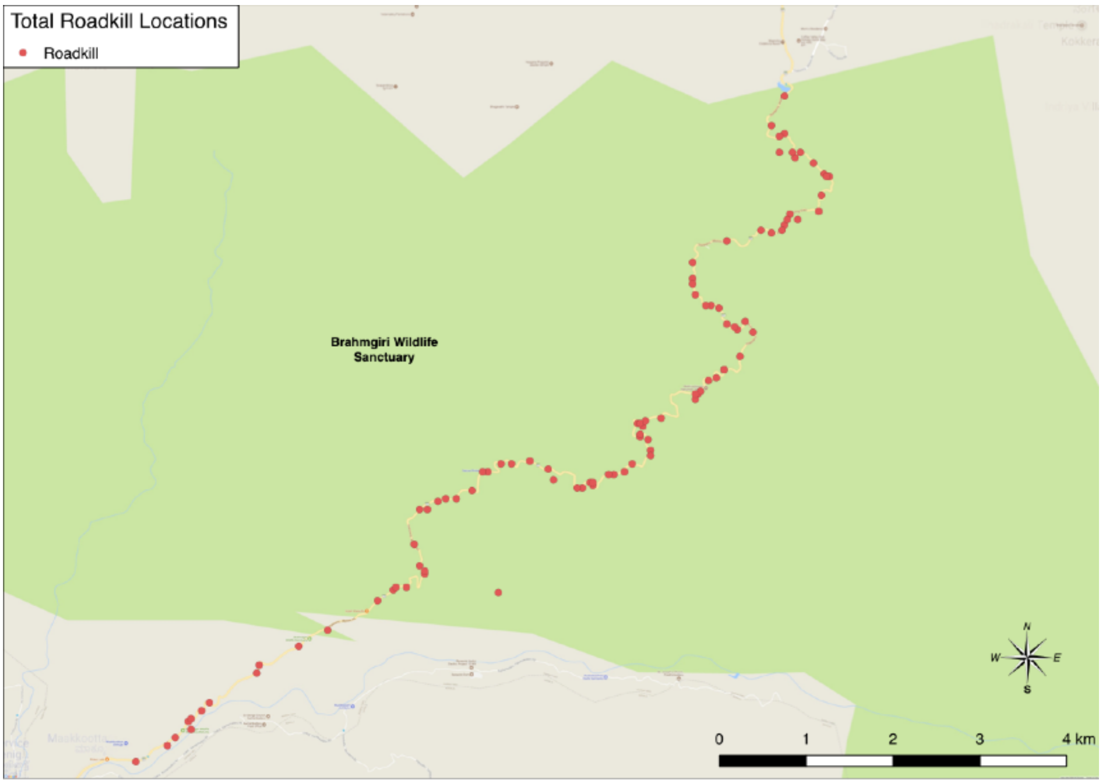
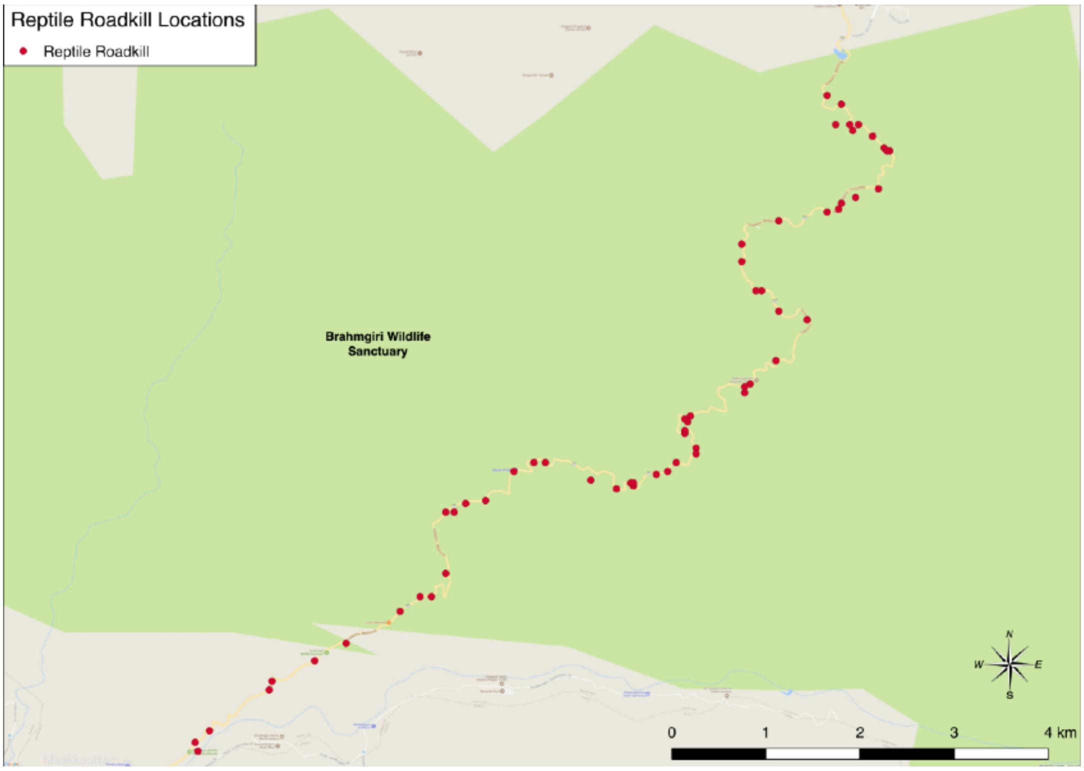
Appendices



Appendix 1. Map of the survey site. The red points demarcate the 18.3 km stretch of the Kannur-Mattannur-Coorg Road that was surveyed from 31 August 2017 to 07 September 2017 in Kodagu, Karnataka, India. The upper red point denotes Perumbadi lake (12.142243N, 75.795335E) which was the survey start location, and the lower red point denotes the Kerala RTO check post (12.073331N, 75.723526E) which was the survey finishing location.



Appendix 2. Map showing location of all roadkills along the survey route during a period of eight days from 31 August 2017 to 07 September 2017. The survey route was an 18.3 km stretch of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India.



Appendix 3. Map showing location of only reptile roadkills along the survey route during a period of eight days from 31 August 2017 to 07 September 2017. The survey route was an 18.3 km stretch of the Kannur-Mattannur-Coorg Road, Kodagu, Karnataka, India.