WILD ANIMAL ROAD KILLS ON THE MANANTHAVADY - KUTTA HIGHWAY PASSING THROUGH THOLPETTY RANGE, WAYANAD WILDLIFE SANCTUARY

Dissertation submitted to the Kannur University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN APPLIED ZOOLOGY

DHANEESH BHASKAR

DEPARTMENT OF ZOOLOGY
KANNUR UNIVERSITY
MANANTHAVADY CAMPUS
KERALA, INDIA

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ACKNOWLEDGMENT

Mr. Shybu Jacob, Lecturer, Department of Zoology, Kannur University, Mananthavady Campus was a source of encouragement, support, inspiration and guidance throughout my course and the dissertation work.

Dr. P. S. Easa, Scientist, Wildlife Department, Kerala Forest Research Institute is remembered for the excellent guidance, support, constructive criticism and creative suggestions for the successful completion of this work.

Dr. Johny Joseph, Course Director and former Course Directors Dr. P. K. Prasadan and Dr. P. Sreekumar, and to all my teachers in the Department of Zoology Kannur University Mananthavady Campus extended their support, throughout the course.

My beloved mother and sister were always with me with their moral support, patience and encouragement in completing this study and throughout my life.

Shri Gopinathan Vallil, Chief Wildlife Warden of Kerala was very helpful by providing necessary permissions on time and Shri Roy P. Thomas, Wildlife Warden of Wayanad Wildlife Sanctuary extended field support along with his staff.

I express my heartfelt thanks to Mr. K. Sunil Kumar (former Wildlife Warden), Mr. V. Rajan (Asst. Wildlife Warden, Tholpetty Range), Mr. Anoop Kumar (former Asst. Wildlife warden), Mr. Sudhakaran (Dy. Range Officer), Mr. E. Baijunath (Section Forest Officer), Mr. P. Jithesh, Mr. K. A. Kunhiraman, Mr. P. K. Noufal, Mr. V. C. Rajesh of the Department of Forests and Wildlife, Kerala for their support and encouragement throughout my field work.

Dr. M. Balasubramaniam, Conservation Biologist of Periyar Tiger Conservation Foundation helped in analyzing the data and also in mapping. Mr. M. Ramith, Wildlife Trust of India assisted for providing necessary facilities, guidance and support throughout my study. Mr. Sandeep Das, Research Fellow in the Wildlife Department of KFRI identified some of the road kills to the species level.

My friends, especially Divin Murukesh, Muhammed Sabith and K. Prijesh were with me throughout in the field and while preparing the dissertation.

DHANEESH BHASKAR

SUMMARY

A study was conducted for evaluating the number of wild animal road kills on the 13 km long Mananthavady – Kutta highway passing through the Tholpetty Range of Wayanad Wildlife Sanctuary in Kerala. The road was having moist deciduous forests along most of its stretch and a few places with plantation of teak and eucalypts. The work was carried out from April to November, 2013 covering the entire stretch on foot recording the road kills from 06.30 to 09.30. A total of 2426 animal kills were recorded of which 2213 were of amphibians, 153 reptiles, 3 birds and 57 were of mammals. The total number of species was 42 where 19 species were reptiles followed by 13 species of mammals, 8 species of amphibians, 2 species of birds. Monthly distribution of the animal kills indicated that the largest number of animal mortality was in September and then August and October.

Common Indian Toad with 1000 individuals, Bi-colored Frog (991) individuals, Indian Bull Frog (130), Warty Frog (49), Bronzed Frog (28) and 12 unidentified caecilians were the most affected among the amphibians. Among the reptiles, 94 individuals of Hump-nosed Pit Viper were observed to be killed followed by 14 Green Keel Back. Indian Black Turtle (6) and Travancore Wolf Snake (6) were also seen killed. Twenty seven individuals of rats, 14 individuals of bats and4 of Indian hare were observed among the amphibians. Porcupine (2), small Indian civet, grey Mongoose, Bonnet Macaque, Hanuman langur, Malabar Giant Squirrel and three striped Squirrel were the other mammals seen killed on the road. Monthly distribution of the kills of almost all the groups of animals indicated larger numbers in September though there were minor variations as in the case of Green Keel Back, where the kills were in June and September.

Most of the killed animals were nocturnal and the kills were at night time. The food habit of the animals, breeding season congregations in the case of frogs and the slow movement of certain species contributed to their mortality on the road. The heavy vehicular traffic at night along with no speed regulation like speed breakers add to the problems.

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CONTENTS

Chapter I

INTRODUCTION

Impact on habitat and wildlife due to transport infrastructure is receiving growing concern among conservationists (Van der Zande *et al.*, 1980; Ellenberg *et al.*, 1981; Bernard *et al.*, 1987; Andrews, 1990; Bennett, 1991; Reck and Kaule, 1993 and Forman, 1995; Seiler, 1996; Evink *et al.*, 1996; Canters *et al.*, 1997; Jalkotzky *et al.*, 1997; Prillevitz, 1997; Evink *et al.*, 1998; Spellerberg, 1998; Forman and Alexander, 1998; Clevenger, 1998; Pierre-LePense and Carsignol, 1999; Evink *et al.*, 1999; Glitzner *et al.*, 1999; Trombulak and Frissell, 2000; Holzang *et al.*, 2000). Possible consequences to wildlife have been recognised and evidences brought in on the effects on both the species and ecosystems at different spatial scales (Canters *et al.*, 1997).

The natural environment is affected by infrastructure in both direct and indirect ways. The physical presence of roads and railroads in the landscape creates new habitat edges, alters hydrological dynamics, and disrupts natural processes and habitats often leading to degradation of the habitat. Road maintenance and traffic contaminate the surrounding environment with a variety of chemical pollutants and noise. In addition, infrastructure and traffic impose dispersal barriers to most nonflying terrestrial animals and vehicle traffic causes the death of millions of individual animals per year. The various biotic and abiotic factors operate in a synergetic way across several scales and cause not only an overall loss and isolation of wildlife habitat but also splits up the landscape in a literal sense.

Effects of roads on nature and wildlife can be included as **p**rimary and secondary. Primary effects as per Van der Zande *et al.* (1980), Bonnet (1991) and Forman (1995) include habitat loss, disturbance, mortality and as a barrier. These are represented in Figure 1.

Habitat loss: Construction of roads and railroads always implies a net loss of wildlife habitat. The physical encroachment on the land gives rise to disturbance and barrier effects that contribute to the overall habitat fragmentation due to infrastructure.

Disturbance: Roads, railroads and traffic disturb and pollute the physical, chemical and biological environment and consequently alter habitat suitability for many plant and animal species for a much wider zone than the width of the road or railroad itself.

Corridor: Road verges and roadsides can however provide refuges, new habitats or serve as movement corridors for wildlife. These beneficial effects of infrastructure are a major challenge to planners and biologists as management and design must be adapted to a wider landscape context. **Mortality:** Traffic causes the death of many animals that utilize verge habitats or try to cross the road or railroad. Traffic mortality has been growing constantly over the years, but is considered as a severe threat only to a few species. Collisions between vehicles and wildlife are also an important traffic safety issue.

Barrier: For most non-flying terrestrial animals, infrastructure implies movement barriers that restrict the animals' range, make habitats inaccessible and can finally lead to an isolation of populations. The barrier effect is the most prominent factor in the overall fragmentation caused by infrastructure.

Secondary effects include changes in land use, human settlement or industrial development, or resource exploitation, which may be induced by the construction of new roads or railroads, etc.

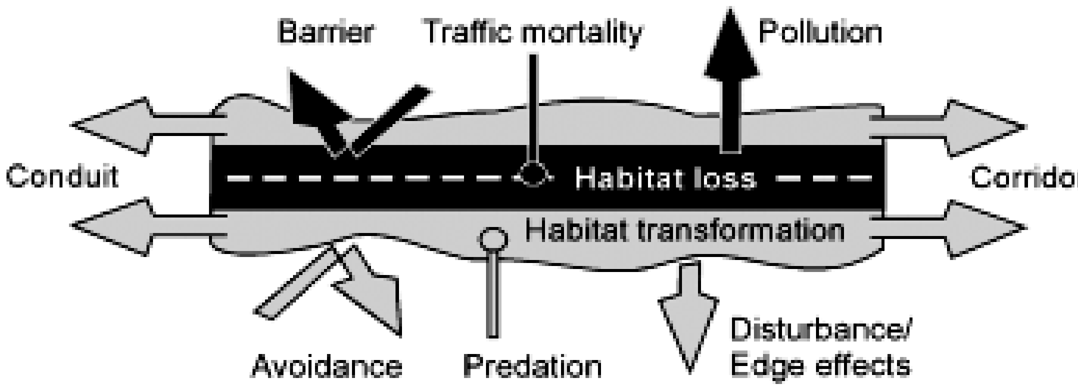


Figure 1: Schematic representation of the five primary ecological effects of infrastructure: Habitat loss and transformation, disturbance due to pollution and edge effects, barrier and avoidance, mortality due to traffic and predation, and the conduit or corridor effect. Together, the various primary effects lead to a fragmentation of habitat. Modified after Van der Zande *et al.* (1980).

There had been a few studies on the complex impact of the rail lines and roads on wildlife and landscapes and even on the ecological processes. Seiler (2001) reviewed the ecological effects of roads. Five major categories of ecological effects have been recognised by various workers (Van der Zande *et al.*, 1980; Bennett, 1991; Forman and Alexander, 1998). These include the loss of wildlife habitat, disturbance and pollution of physical, biological and chemical environment thereby altering the habitat suitability for organisms, death of animals, acting as a movement barrier restricting the animal's range and isolating the populations due to fragmentation. Seiler (2001) also described the different views where the road sides and verges are argued to be refuges, new habitats and movement corridors thereby benefiting the wildlife.

A number of studies abroad have shown the impact of road infrastructure on the wildlife in the surroundings (Hodson, 1966; Van den Tempel, 1993; Rodts *et al.,* 1998; Shepard *et al.*, 2008). Amphibians have been considered as one of the most affected due to transport infrastructure (Vestjens, 1973; Blaustein and Wake, 1990; Reh and Seitz, 1990; Fahrig *et al.*, 1995). The roads would kill a constant proportion of a population and therefore can have a significant impact on rare species. In general, species that occur in small isolated populations, require large extensive areas for their home ranges, or exert long migratory movements, are especially sensitive to road mortality. The larger their home range, the more often individuals will encounter roads. The smaller their populations, the higher the relative importance of each individual. This could be the case of elephants in its Ranges, where elephants are often confined to several fragments of natural areas and finding difficulties to roam freely in the range. Naturally, collisions with wildlife can only occur where a road or railroad dissects a species' habitat, but local factors can alter the relationship considerably. Road kills seems to increase with traffic intensity, but very high traffic volumes, noise and vehicle movement seem to repel many animals and mortality rates may not further increase with traffic.

Unfortunately, there is no clear understanding on the impact of roads on any of the ecological aspects including ecological quality of the areas in India. A number of factors such as road characteristics, landscape topography and hydrology, wind and slope and vegetation influence the impacts. The impact on wildlife is also a factor of the sensitivity of the species. Road construction in an area amounts mostly to clearing of vegetation leading to opening up of closed canopy thereby with a direct impact on the vegetation especially at the edges. This could also affect the arboreal animals in the area. The possible changes in soil density, landscape relief, surface and ground water flows will affect ecosystems, vegetation and fauna in the wider landscape. There would be a definite change in the micro-climatic conditions and wind and light intensity, which would ultimately change the species composition favouring the light demanding ones. The microclimate alterations will have a direct impact on the species such as lichens or mosses. Effects on vegetation and fauna due to edge effects have been reported up to several tens of meters away from the road (Ferris, 1979; Ellenberg *et al.*, 1981; Mader, 1987).

Road maintenance and traffic aggravate edge effects on the surrounding environment by noise and pollution. Most of the pollutants accumulate in close vicinity to the road, but there are possibilities of long distance spread of these pollutants and dust. Traffic mobilises dust from the road surface that deposits along verges and in the nearby vegetation. A number of impacts due to various pollutants have been recorded from elsewhere (Scanlon, 1987; Reck and Kaule, 1993; Bauske and Goetz, 1993; Auerbach *et al.*, 1997; Blomqvist, 1998). Traffic exhaust contains polycyclic aromatic hydrocarbons, dioxins, ozone and many fertilizing chemicals, which in high concentrations can cause physiological distress to animals and plants (Reck and Kaule, 1993; Scanlon, 1991). Changes in plant growth and plant species diversity induced by traffic exhausts have been observed as in lakes (Gjessing *et al.*, 1984) and in heath land more than 200 m distant from the road (Angold, 1997).

Traffic noise is another agent of disturbance that spreads far into the environment. Disturbance effects by noise are comparatively less understood. Traffic noise is reported to be annoying to most humans with long term exposure inducing psychological stress and eventually lead to physiological disorder (Stansfeld *et al.*, 1993; Lines *et al.*, 1994; Job, 1996; Babisch *et al.*, 1999). Though there had been questions on stress among animals, timid species might consider traffic noise as a token for the human presence and consequently avoid noisy areas. Birds seem to be especially sensitive to traffic noise, as it directly interferes with their vocal communication and thereby affects their territorial behaviour and mating success (Reijnen and Foppen, 1994). Various studies have documented reduced densities of birds breeding near trafficked roads (Veen, 1973; Räty, 1979; Van der Zande *et al.*, 1980; Ellenberg *et al.*, 1981; Illner, 1992; Reijnen and Foppen, 1994). Reijnen *et al.* (1995) observed that bird densities in open grasslands declined where the traffic noise burden exceeded 50 dbA. Environmental factors such as the structure of road side vegetation, the type of adjacent habitat and the relief of the landscape and the traffic volume will influence both noise spread and bird densities and thus alter the amplitude of the noise impact (Reijnen *et al.*, 1997; Kuitunen *et al.*, 1998; Meunier *et al.*, 1999). There are also possibilities of mammalian vocal and chemical communication getting affected due to the roads and the related factors. Though empirical studies are scarce, the National Tiger Conservation Authorities' guideline on inviolate area for tiger conservation is also based on disturbances of all types which are detrimental to wildlife in all respects.

In addition to the reports indicating negative impacts of roads due to various reasons, there are observations suggesting great potential of roadsides to support a diverse plant and animal life (Hansen and Jensen, 1972; Way, 1977; Mader *et al.*, 1983; Van der Sluijs and Van Bohemen, 1991; Sjölund *et al.*, 1999). The surface of roads (mainly small roads with little traffic) may be used as pathways by larger mammals. Vehicles and humans may serve as vectors for plants, seeds or small, less mobile animals (Schmidt, 1989; Bennett, 1991). This may offer an explanation for the high proportion of exotics and weed species found along roadsides (Mader *et al.*, 1983; Tyser and Worley, 1992; Ernst, 1998). The spread of weeds and alien plant species along roads is considered as a severe threat to the native flora in many nature reserves (Usher, 1988; Spellerberg, 1998).

For larger animals, roads and railroads hardly comprise any physical barrier. Most mammals, however, are sensitive to disturbances by humans. Smell, noise and vehicle movement as well as experiences with human encounters may repel the animals from approaching the road corridor.

Wild animal road kills is the major impact of roads that passing through Protected Areas (Coffin, 2007). Animals with slow moving ability such as amphibians, reptiles are the major victims of tyres. Amphibians have been considered as one of the most affected taxa due to transport infrastructure (Vestjens, 1973; Blaustein and Wake, 1990; Reh and Seitz, 1990; Fahrig *et al.*, 1995).

Chapter II

REVIEW OF LITERATURE

Roads represent one of the most widespread forms of modification of the landscape (Trombulak and Frissell, 2000; Smith, 1990). The impact of roads on the natural environment was a matter of debate in the early days (Stoner, 1925).There had been studies on the impacts of roads on wildlife and ecological effects of roads (Hodson, 1966; Van den Tempel, 1993; Rodts *et al.,* 1998; Shepard *et al.*, 2008; Vestjens, 1973; Blaustein and Wake, 1990; Reh and Seitz, 1990; Fahrig *et al.*, 1995). Roads are major features of most landscapes that impose an array of ecological effects. Road developments affect and modify the habitat conditions, which in turn influence the abundance and distribution of plant and animal species, i.e. biodiversity of the impacted areas (Nevena Kambourova-Ivanova *et al.,*2012).

Studies by Mader (1984) observed that human encroachments and developmental activities continue to threaten the wildlife by fragmenting their habitat and isolating the residential animals. The loss and change in habitat extent beyond the road (Spellerberg, 1998). Research indicates that the combined ecological effects may extend outward from the road edge beyond 100 meters, delineating a "road-effect zone." (Jochimsen *et al.*, 2004).

Roads have become one of the growing threats to animal and plant populations (Forman and Alexander, 1998; Trombulak and Frissell, 2000). Jochimsen, *et al.* (2004) suggested that when interpreting road effects on the surrounding wildlife, it is important to consider the history of a particular road, including opening date and any changes concerning vehicle access.

Coffin (2007) assessed ecological effects of transportation systems and more specifically roads. According to Coffin (2007), the roads have a wide variety of primary, or direct, ecological effects as well as secondary, or indirect, ecological effects on the landscapes that they penetrate. Ecological effects include the loss of wildlife habitat, disturbance and pollution of physical, biological, and chemical environment, death of animals and acting as a movement barrier (Van der Zande *et al.*, 1980; Bennett, 1991; Forman and Alexander, 1980).

Litvaitis and Tash (2008) considered vehicle-related mortalities of wildlife as the most conspicuous environmental effects of roads. The factors that are contributing to wildlife-vehicle collisions are vehicle speed, traffic volume, road width, animal abundance and roadside vegetation, time of day / year, and habitat diversity along the road. The respective widths and densities of roads, in addition to associated traffic levels and speeds, affect road-kill rates (Forman and Alexander, 1998). Research indicates that more vagile (i.e., tending to change location over time) species are more likely to suffer from road mortality. Carr and Fahrig (2001) suggest that as dispersal distances increase so does the likelihood of road encounter and consequently mortality risk for a given anuran species.

Through direct mortality on the roads (Ashley and Robinson, 1996), or indirect effects such as the modification of adjacent aquatic and terrestrial communities through vehicle exhaust or runoff (Turtle, 2000), or barriers for movement (Oxley *et al.*, 1974), or increased predator activity near (Ortega & Capen, 1999) roads contribute to reduced average heterozygosity and genetic polymorphism (Reh and Seitz, 1990). Increased mortality and barriers to movement may influence species demography and gene flow, consequently having an impact on overall population stability and persistence (Jochimsen *et al.*, 2004).

Roads play major role in killing animals by collision with vehicles (Trumbulak and Frissell, 2000), which is mainly dangerous to small mammals, reptiles, amphibians (Adams and Geis, 1983; Ashley and Robinson, 1996; Fahrig *et al.*, 1995; Hodson, 1966), birds and other animals. Studies suggest that low traffic volumes may be sufficient to cause high levels of amphibian mortality, but generally the mortality rate increases with traffic volume (Jochimsen *et al.*, 2004)

Impact on Amphibians and Reptiles

Species with a metapopulation structure are considered vulnerable to habitat fragmentation because their subpopulations periodically go extinct locally and must be re-established through dispersal from neighboring sources (Lehtinen *et al.,* 1999). The characteristics of the roads themselves (i.e., construction activities, road type, the overall road density in an area, and traffic level and patterns) are considered independent variables that potentially affect amphibians and reptiles, both directly and indirectly. Direct effects are considered to involve injury or mortality during road construction (e.g., inadvertent burial or death from blasting) or subsequent physical contact with vehicles. Indirect effects include habitat loss, fragmentation and alteration (e.g. changes in temperature, moisture, light, noise, pollutants, or quality of available habitat). Such changes may influence the behavior, survival, growth and reproductive success of individual animals (Jochimsen *et al.*, 2004).

Increases in the noise and light levels may disorient an animal preventing them from crossing a road by posing a risk or obscuring cues necessary to follow certain paths, thus interfering with access to cover, food and mates (Jochimsen *et al.*, 2004).

Amphibians and reptiles possess a variety of biological characteristics that influence their vulnerability to road effects. Factors influencing the frequency, speed, distance and timing of movements can increase susceptibility to direct road mortality. Characteristics such as ectothermy (body heat derived primarily from external sources), skin permeability (esp. amphibians) and behavioral responses to light and noise can increase susceptibility to indirect effects (Jochimsen *et al.*, 2004).

The habitat requirements of amphibians and reptiles vary seasonally. Therefore the distribution of resources across the landscape relative to roads can influence mortality. These resources are associated with refuge, mates, and prey that tend to be concentrated in distinct habitats that are patchily distributed (Jochimsen *et al.*, 2004). Amphibians migrate in mass numbers between breeding ponds and terrestrial habitats (Holdgate, 1989; Ashley and Robinson, 1996; Semlitsch, 2000). A flow of 10 vehicles per hour resulted in 30% mortality of females in a population of common toads (*Bufo bufo)* migrating across a road to and from a breeding pond in the Netherlands (van Gelder, 1973). The author estimated that a higher traffic load of 60 vehicles per hour would result in 90% mortality. Similar mortality rates were estimated in Germany, where a flow between 24-40 vehicles per hour may kill at least 50% of the common toad migrants (Heine, 1987; Kuhn, 1987). As reported in Reh and Seitz (1990), the estimated survival rate of toads crossing roads with 24-40 cars per hour varied from zero (Heine, 1987) to 50% (Kuhn, 1987).

For amphibians, road mortality may be proportionally high during pulses of movement related to fluctuations in water level (Smith and Dodd, 2003), breeding (McClure, 1951; Hodson, 1966; Fahrig *et al.,* 1995; Ashley and Robinson, 1996) and dispersal (McClure, 1951; Palis, 1994; Ashley and Robinson, 1996; Smith and Dodd, 2003).

Carpenter and Delzell (1951) observed 873 road killed anurans of 8 species in nine surveys along a 0.9 mile stretch of road in Michigan. In Britain, common frogs (*Rana temporaria*) experienced the greatest number of fatalities (409 individuals) among the 16 species (representing 3 taxa, excluding bird data) recorded during daily surveys along a 3.2 km route (Hodson, 1966). During over 84 nights observation by van Gelder (1973), deaths of 122 common toads were observed along a 1.5 km section of road near breeding ponds in the Netherlands (van Gelder, 1973). Cooke (1989) reported the mean annual mortality of 93 common toads near a breeding site in Ramsey, Cambridgeshire, England over a 21year period. Over the course of one evening, Palis (1994) documented the mortality of 55 southern leopard frog (*Rana sphenocephala*) metamorphs (tadpoles that have recently gone through metamorphosis) emigrating across a 0.3 km segment of road adjacent to a pond in Florida. During the spring mating season in Ottawa (Canada), Fahrig *et al.* (1995) traveled 506km (along three road segments) and counted a total of 1,856 dead frogs over six evening surveys.

Anurans comprised 92.1% of vertebrate road kills (32,000 total individuals representing 100 species) identified along Long Point Causeway in Ontario, with northern leopard frogs (*Rana pipiens*) accounting for 85.4% of the total casualties (Ashley and Robinson, 1996). During one event in July 1996, more than 50 Couch's spadefoots (*Scaphiopus couchi*) were observed killed along a 3.84 km segment of road in Saguaro National Park. Additionally, 279 road killed toads, nearly all Sonoran desert toads (*Bufo alvarius*), were observed following one night of heavy rain (Kline and Swann, 1998). A study conducted over a 33 week period on a motorway in France documented the road mortality of 466 anurans (five species), which accounted for 21% of all vertebrate casualties (Lodé, 2000). In Kouchibouguac National Park (Canada), more than 54% of the 3,975 anurans encountered over eight years of road surveys were dead individuals (Mazerolle, 2004).

Herpetofauna with less dispersal ability and greater sensitivity to habitat alteration than birds and mammal may be more sensitive to barrier effect of roads (deMaynadier and Hunter, 2000) and local populations may become isolated and increasingly susceptible to extinction (Mader, 1984). Reptile examples comprise migratory behavior including movements related to fluctuations in water level (Bernardino and Dalrymple, 1992; Aresco, 2003; Smith and Dodd, 2003), adult males searching for mates (Bonnet *et al.,* 1999; Whitaker and Shine, 2000), nesting migrations of adult females in the spring (Fowle, 1996; Bonnet *et al.,* 1999; Haxton, 2000; Baldwin *et al.,* 2004) and neonatal dispersal during late summer or early autumn (Bonnet *et al.,* 1999; Enge and Wood, 2002; Smith and Dodd, 2003).

Snake movements occurred during periods of increased human visitation to the refuge resulted in higher road mortality during both spring and autumn migrations (Jochimsen *et al.*, 2004). Bernardino and Dalrymple (1992) found that the seasonal migration of snakes in Everglades National Park was significantly affected by the fluctuation of water levels. An increased movement of snakes during the dry season coincided with a greater influx of visitors to the park, resulting in 56% of 10 all annual road casualties. Conversely, several studies suggest that nocturnally active species have reduced susceptibility to road mortality due to lower traffic levels (Dodd *et al.,* 1989; Enge and Wood, 2002).

Few studies have examined the speed of crossing animals, but slow movements of amphibians (Hels and Buchwald, 2001), turtles (Gibbs and Shriver, 2002) and snakes (Andrews, 2004) have been documented. While the speed of amphibians and turtles is likely fairly consistent across species within each group, the crossing speeds of snakes vary significantly interspecifically, insinuating that snakes could suffer a greater range of road mortality rates than other taxa (Andrews, 2004).

Crossing angles across the roads also have some impact on wildlife mortality. Two reptile studies, performed with snakes, reported that individuals consistently move perpendicularly across the road, taking the shortest route possible (Andrews, 2004; Shine *et al.,* 2004). Behavioral characteristics may also increase susceptibility to road related mortality. For example, some species of snakes may be attracted to road surfaces to thermoregulate (Klauber, 1939; Sullivan, 1981; Ashley and Robinson, 1996) or scavenge from carcasses (Smith and Dodd, 2003). Some species of toads may use roads under street lights to forage for insects (Neill, 1950). Migratory behaviors are largely genetically controlled and therefore may limit an individual's ability to readily adapt to a road that interferes with its route (Langton, 1989). McClure (1951) observed peak mortality of snakes (all species included) during May and October, when individuals were frequently observed basking on road surfaces during cooler temperatures.

Studies have provided evidence that road mortality may detrimentally impact populations of species with low reproductive rates (Rosen and Lowe, 1994; Ruby *et al.,* 1994; Fowle, 1996; Kline and Swann, 1998; Gibbs and Shriver, 2002). Individuals that inhabit small home ranges and limited dispersal ability are subject to isolation effects resulting from fragmentation (Andrews, 1990; Boarman and Sazaki, 1996).

A turtle's innate slowness increases the time spent crossing a road and therefore increases exposure to traffic (Gibbs and Shriver, 2002). Turtles made up 4% of the 6,723 wildlife casualties observed along Nebraska's highways with ornate box turtles (*Terrapene ornata*) representing half of those losses and suffering the heaviest on June 22 (McClure, 1951). Ashley and Robinson (1996) recorded the road mortality of 716 turtles representing 5 species along a 3.6 km section of Long Point Causeway.

Jochimsen *et al.* (2004) observed that the road mortality rate of saurians is lower, which is due to their relative high speed and ability to cross roads faster. Furthermore, research indicates that certain species do not migrate seasonally and exhibit high site fidelity within small home ranges, limiting their encounters with roads (Rutherford and Gregory, 2003).

Fitch (1949) encountered a total of seven glass lizards (*Ophisaurus ventralis*) over the 8,480 miles traveled within West Central Louisiana. McClure (1951) documented the road mortality of 95 lizards across Nebraska's highways, with heavy losses during June. An incidental survey conducted over 19,041 kilometers in northern Alabama reported the road deaths of 8 lizards (Dodd *et al.,* 1989). Surveys conducted by Kline and Swann (1998) in Saguaro National Park between 1994 and 1996 documented the road casualties of diurnal lizard species and Gila monsters (*Heloderma suspectum*). Rodda (1990) recorded a total of 65 green iguanas (*Iguana iguana*) killed during a one year survey in the Ilanos of Venezuela.

Impact on Birds

Bird species are likely to be killed on the road while they forage for seeds or carrions. Many road kills of granivorous birds are attributed to grain spillage along road sides and seeding grasses adjacent to roads (Hodson, 1960 & 1962; Vestjens, 1973; Dhindsa *et al.*, 1988).The death of bird species may occur while they are dust bathing or taking grit from the road edge (Hodson, 1960 and1962; Brown *et al.*, 1986) or while hawking (hunting) for insects low over the road (Hodson, 1960). Traffic noise may interfere with breeding birds' ability to hear bird song, which they rely on to attract mates and establish breeding territories. Among the birds, nocturnal birds had the highest mortality since they come to road to prey on amphibians and reptiles. (Selvan *et al.*, 2011). In UK, birds that use roadside verges as a food resource, those that walk rather than fly across the road (such as moorhen, *Gallinula chloropus),* and corvids that scavenge on other road kills, are particularly susceptible (Mead, 1997). Roads are a source of food, salt, macro-and microelements, and gastroliths in winter (Brownlee *et al.*, 2000; Erritzoe *et al.*, 2003). These sources are commonly used by birds (Gollob and Pulich, 1978) making them vulnerable to motor vehicle collisions (Laurence *et al.*, 2009; Russsell *et al.*, 2009; Hoskin and Goosem, 2010; Barthelmess and Brooks, 2010). Birds may be attracted to road verges for foraging, or occasionally for breeding, especially when the surrounding landscape is unsuitable for these purposes. Eighteen different species of birds were recorded as using various sections of the roadside verge in one Danish study (Laursen, 1981). A total of 228 individuals of 32 species of birds were found dead on the roads in Kumbhalgarh Wildlife Sanctuary (KWS) in Rajastan (Anil Kumar 2004).

Impact on Mammals

Globally, many studies have been done on road mortality of mammals (Newmark, 1992; Drews, 1995; Newmark *et al.*, 1996; Richardson *et al.*, 1997). For many endangered mammalian species around the world, traffic is considered as one of the most important reasons of mortality (Harris and Gallagher, 1989). Road mortality is by far the most significant source of mortality in the endangered Florida panther (*Felis concolor*), accounting for more than 50% of all known deaths (Harris and Scheck, 1991; Harris and Gallagher, 1989). Recently in south India, a leopard was killed by vehicular collision (Baskaran and Boominathan, 2010). Traffic casualties in otters are most likely to occur where roads cross over watercourses (Philcox *et al.*, 1999).

Among the mammalian fauna, the Bonnet Macaque and crested grey langur come close to the road to beg from tourists leading to higher incidents of mortality due to highway traffic (Baskaran and Boominathan 2010)**.** Southwick *et al.* (1976) documented in detail the effect of artificial feeding on behavior and ecology of Rhesus Macaques. Artificial feeding alters their diet, home range and primary habitat that further influenced social behavior and the spatial distribution of the animals (Pragatheesh, 2011).

Several authors have recorded the negative effects of artificial feeding and road kill studies on Hanuman langurs, *Semnopitheaus entellus* in India (Mohnot, 1974; Agoramoorthy, 1987; Rajpurohit, 1987; Rajpurohit *et al.,* 1997; Chhangani, 2000, 2001 and 2004). During summer and late winter, individuals of Macaques were attracted towards the road because of food offered by humans. The encounter rate of Macaques on the line and road transects survey showed that the use of roadside habitats in summer and winter was relatively high and gradually decreased towards the forest interior, where no individuals were seen during summer (Pragatheesh, 2011). The highest number of road kills was taking place at a location, where the frequency of feeding (artificial feeding) by passersby was high (Pragatheesh, 2011). Apart from collisions, fire and plastics play major roles in animal mortalities (Selvan *et al.*, 2011).

Studies in India

In India, unfortunately, there had been only very few observations on the impact of roads on landscape and the behaviour of animals in terms of changes in activity, feeding habits, breeding and other aspects. Most of the studies, mostly of short term nature, have been on the impact on selected groups of animals or species. These were also on the mortality. Presence of road and their impact on elephants have been described by Desai and Baskaran (1996), Menon *et al.* (2005) and Vidya and Thuppil (2010). There are a number of studies in India on the road kills along the highways. Sharma (1988) reported animal deaths on NH 11 in Bharathpur. Based on one year long observations, he recorded 439 casualties, which included amphibians, reptiles, birds and mammals. Gokula (1997) reported mortality in snakes due to highway traffic in the dry deciduous forests of Mudumalai Wildlife Sanctuary, Tamil Nadu.

Kumara *et al.* (2000) reported road kills in Indira Gandhi Wildlife Sanctuary. A month long study by Vijayakumar *et al.* (2001) reported mortality of herpetofauna from the highway segments passing through rainforest fragments and tea gardens in the Anamalai hills, where more amphibians were killed. Seventy three reptiles were seen killed against 311 amphibians. Chhangani (2004) recorded 228 birds of 32 species in the highways passing through Kumbhalgarh Wildlife Sanctuary in Rajasthan. Parasharya and Tere (2007) reported their observations of road kill in the Anand – Ahmedabad road. Das *et al.* (2007) reported the reptile mortality along the NH 37 passing adjacent to Kaziranga National Park. The five month long study recorded 68 instances of road kills. The four day survey of amphibian mortality on roads in the Sharavathi river basin recorded 144 individuals of 13 species (Seshadri *et al.,* 2009). About 50 kills, mostly of herpeto-fauna and also birds and mammals, were recorded in a one month long observation along the NH 220 in Kambam - Kumily road (Selvan, 2011).

There had not been any study on the road kills in Kerala except the long term ongoing ones in Chinnar and Sholayar (Easa, Pers. Commn.). The roads passing through Wayanad and parts of Karnataka have been in the centre of a debate because of the night traffic ban along the roads.

There are three major roads that connect Wayanad with Karnataka and Tamil Nadu; Sulthan Bathery – Gundulpet, Mananthavady – Mysore and Mananthavady – Kutta. These roads pass through Wayanad Wildlife Sanctuary. People in Wayanad and other districts of Kerala depend on these highways and hence the number of vehicle through these roads is also higher. Because of high vehicular intensity there were also reports of many wild animal road kills.

Increasing number of wild animal road kills in the National Highway 212 between Gundulpet and Sulthan Bathery was cited as the reason for the Government of Karnataka to prohibit traffic of all kinds of motor vehicles along this NH between 9.00 p.m. and 6.00 a.m. This ban was to avoid disturbance to the wildlife of Bandipur Tiger Reserve. At the same time, night traffic through Nagarahole Tiger Reserve was also banned. During the course of various debates on the subject, suggestions were made by the Karnataka Forest Department that alternative road leading to Wayanad from Mysore via Hunsur – Gonikkuppa – Kutta – Mananthavady is in existence and join NH 212 at Kalpetta and that this would be lengthier by 60 km than the existing route. However, there was no quantitative data to show that the traffic through this road is safe for animals.

Objectives

The present study was aimed at evaluating the number of wild animal road kills on Mananthavady – Kutta highway passing through Wayanad Wildlife Sanctuary.

CHAPTER III

STUDY AREA

Wayanad, consisting of the forests under the administration of North Wayanad, South Wayanad and Wayanad Wildlife Divisions form a major portion of Nilgiri Biosphere Reserve and is a part of larger contiguous landscape consisting of Wayanad, Bandipur, Mudumalai, Sathyamangalam, BRT Hills and up to the Eastern Ghats. The sanctuary also falls within the notified Elephant Reserve VII and the Nilgiri Biosphere Reserve. Wayanad Wildlife Sanctuary, notified in 1973. This also forms a part of the Elephant Reserve No. 7 comprising elephant habitats in Kerala, Tamil Nadu and Karnataka. Wayanad sanctuary is contiguous with Bandipur Tiger Reserve and Mudumalai Wildlife Sanctuary in the South and Southeast and Rajiv Gandhi National Park in the North and Northeast (between 11^0 20' and 12^0 7' N latitude and between 75^0 28' and 76^0 36' E longitude). The total extent of area is about 520.78 km^2, of which 344.44 km^2 form the Wayanad Wildlife Sanctuary (Fig.2). Out of this, 242.954 km^2 are natural forest and 101.437 km^2 are plantations, mainly of teak.

Wayanad – a history

Easa and Sankar (2001) has given a brief history of the area. 'Wayanad' derives its name from the numerous swamps (locally called as *vayals*). Francis (1994) described the political history, forest, agriculture and wildlife in Wayanad in earlier days. According to Francis (1994), the forests of Wayanad were *being almost interminable subtropical jungle in which grow trees and plants unknown to the higher levels and its* *animal, bird and insect life (not forgetting its leeches) being more in evidence and more varied. It is in short a botanist's paradise and a naturalist's El Dorado.*

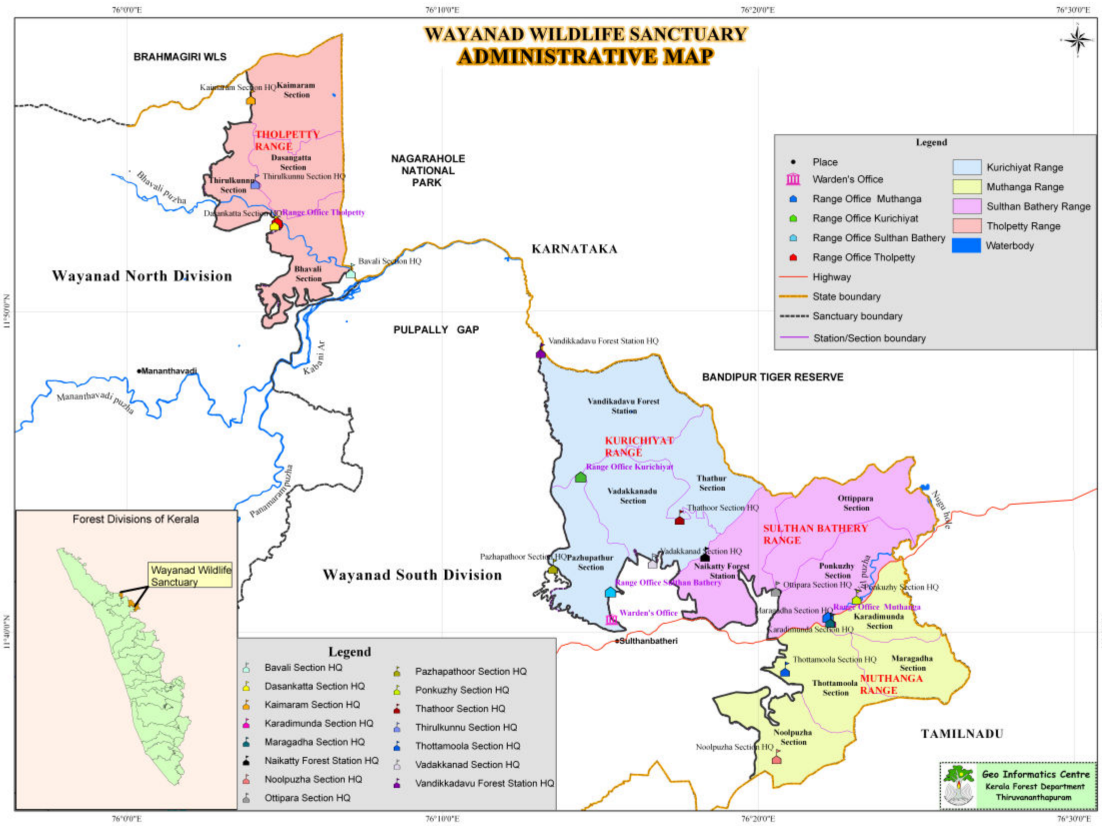


Fig. 2 Location map of Wayanad Wildlife Sanctuary

Paddy was the commonest crop mostly cultivated in the swamps. The dry higher grounds were cultivated with crops such as ragi and chama. These were often grown on the shifting system. Wildlife was so numerous that crop raiding was frequent. Fencing or continuous watching were the methods to prevent wild animals from damaging the crop. According to Francis (1994) *one of the characteristics of Wayanad fields is the large number of watchers or raised platforms (machans) which are dotted about them.*

Coffee was probably the first plantation crop to be introduced into Wayanad in 1828 and by 1839, its cultivation became an enterprise. This was the beginning of a series of monoculture plantations such as tea and then extensive deforestation for raising teak. The plantations are considered to be the actual start of deterioration of the habitat.

The human population was so low that labour was a problem and the Britishers once even thought of encouraging or forcing the Badagas of Nilgiris to migrate to Wayanad to make agriculture extensive and profitable. The tract was feared for its malarial fever that people were reluctant to move to the area. But in the fifties, after the state reorganization, there was a mass invasion of the forests of Wayanad by the settlers.

An increase in the labour requirement due to commercial plantations lead to the replacement of 'Kurumban' tribals with coolie labourers brought from elsewhere and the number of settlements increased. The commercial activities and the increased settlements had its effects on the once continuous stretch of thick forests. As the population increased, the settlements began to intrude the neighbouring forests thus fragmenting the wildlife habitat. The developmental programmes that followed contributed further to the deterioration of the remaining forest areas.

During the dawn of the century, the area was protected as Reserved Forests under the jurisdiction of Chedleth Range. Subsequently, Sulthan Battery Range was formed in 1924. After 1958, South Wayanad was managed under Kozhikode Forest Division and North Wayanad under Wayanad Forest Division. The area was declared a Sanctuary in 1973 and brought under the Wildlife Division in 1985. Gopinathan (1990) has given a detailed description and history of the Sanctuary.

The forest of Wayanad could be considered as three Regions based on the contiguity of forests.

Southern Region- comprises the forests of Muthanga, Sulthan Bathery and Kurichiat forest Ranges. The Region starting from Nulpuzha reserve extends through Kerala, Karnataka and Tamil Nadu trijunction to the Kabini riverbank. Its contiguity with the Padiri Reserve of Chedleth Range is lost due to the encroachment in Pulpally forest areas. However, contiguity is maintained through the forest of Padri reserve and a narrow strip in Karnataka side. A major portion of this region is bordered by Kabini river, both sides of which are under cultivation. A major portion of the segment is bordered by the forests of Mudumalai Wildlife Sanctuary and Bandipur Tiger Reserve of Karnataka. There are about 88 settlements in the Southern Region.

The forests in this Region represent one of the best examples of dry deciduous forests in the state. Presence of extensive bamboo break is one of the most important characteristics of the area.

Northern Region- The northern region in Wayanad extends from the Shanamangalam, Kartikulam reserve forests bordering North Padri reserves through the highly fragmented patches of Begur and Tholpetty Ranges of North Wayanad and Wayanad Wildlife Sanctuary division respectively. This has contiguity with Periya, Kottiyur and Mananthavady of North Wayanad and Kannur Forest divisions. Rajiv Ghandi National Park of Karnataka is located on the East. The fragile, unique ecosystem of Kuruva islands falls between this region and the Central region. There are about 26 enclosures in the northern region. The vegetation types in the region vary from evergreen to deciduous types.

Central Region- The central Region comprises the forest of Padri reserve under the administrative control of Chedleth Range of South Wayanad Forest Division. A narrow strip of forest along the Kabini river is bordered by Kabini river. Both sides of Kabini are under cultivation. Electric fencing leaving a gap for elephant movement protects the cultivated areas along the Kabini on one side. A large part of the forest falls under the moist deciduous forest with bamboo break. There are 14 enclosures of which two occupy a vast expanse.

The sanctuary harbours a diverse group of animals. Most of the habitat is moist deciduous type. However, patches of semi-evergreens are also scattered throughout. A substantial portion of the sanctuary is also made up by plantations of teak. As part of a concerted management intervention, attempt is being made to convert them to natural forests. The diverse vegetation, the terrain (gently undulating with Karottimala, 1158 m, the highest peak), the temperature(13º to 32º C) and the rainfall (about 200cm annually) have worked up a synergy which makes this area a home to almost every major Indian wild-animal species.

Wild animals of the sanctuary

The vegetation types and contiguity with the adjacent biodiversity rich areas lead to a diverse fauna. Asian Elephant is the largest in terms of numbers and biomass. The area, which forms a part of the largest elephant habitat of about 12000 km^2 and with a population of about 6500 elephants, is also considered to hold the most preferred elephant habitat (Leimgruber *et al*., 2003) not only a cynosure for the visitor's eyes but also the cornerstone of wildlife management. Among the other herbivores, gaur, sambar, chital, barking deer and wild boar are frequented. Others like the Common langur, Bonnet Macaque and even the very rare slender loris can also be seen.

The herbivores constitute the prey base for variety of carnivores. Tiger population is reported to be about 70. Leopard, wild dog, sloth bear, jungle cat and leopard cat are the other carnivores in the sanctuary.

About 230 species of birds have been reported by Uthaman (1993). About 61 species of reptiles reported from the area include several groups. The thirty five species of amphibians include 8 Western Ghat endemics.

Tholpetty Range

Tholpetty Range with an extent of 77 km^2 is a major wilderness part of Wayanad wildlife sanctuary with rich plant and animal diversity. The animals sighted in other parts of Wayanad Wildlife Sanctuary are reported from the Range. The area is contiguous with the forests of Nagarahole and parts of North Wayanad Forest Division.

There are two highways passing through or through fringe. Mysore – Hunsur – Gonikkuppa – Kutta – Mananthavady road is having a stretch of 13.16 km through the Tholpetty Range. The other road to Mysore via Bavali passes through about 3 km of the Range. During night, Mysore – Hunsur – Gonikkuppa – Kutta – Mananthavady is the major route for all interstate vehicles, because of night traffic ban on the two other roads.

The existing night ban of traffic on the other two highways resulted in increase of interstate traffic intensity on Mananthavady – Kutta road especially during night. In Wayanad, Mananthavady – Kutta highway is linked to major tourist places like Thirunelly temple and Tholpetty part of Wayanad wildlife sanctuary.

A major part of the road passes through moist deciduous forests with small stretches of teak and eucalyptus plantations. There are four bridges across the rivers and streams like Kalindi river and Cheriya Naikatty and Naikatty streams. In addition, there are a few water holes in different locations (Fig. 3). The rain fall data collected by the Forest Department from Srambi at Tholpetty Check post indicate high rainfall in June and July (Fig. 4).

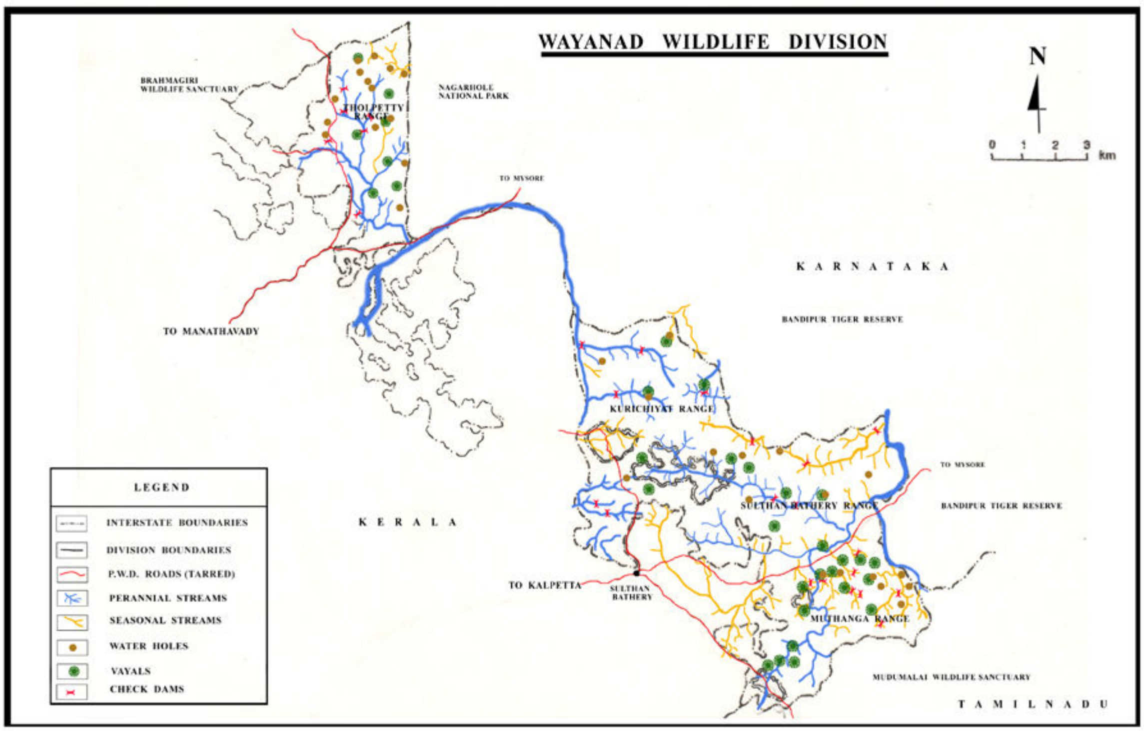


Fig. 3 There are streams and water holes on the road sides

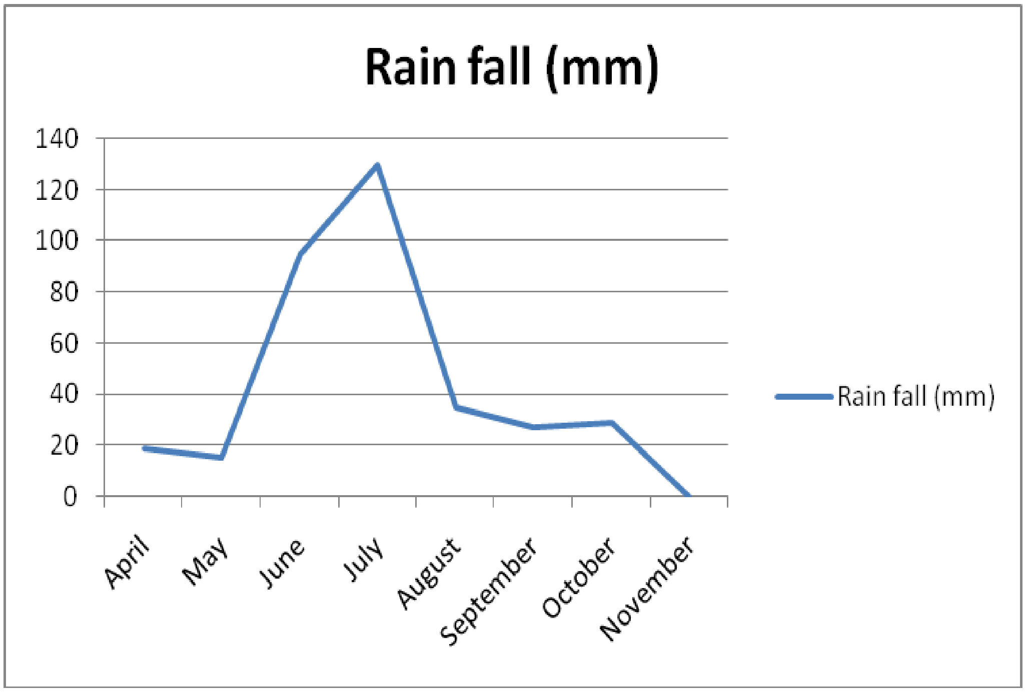


Fig. 4 Rainfall details of the Tholpetty Range area during April – November

CHAPTER IV

METHODS

The Mananthavady – Kutta road passing through Sanctuary was sampled from April 2013 to November 2013. A stretch of 13.16 km of the road were systematically surveyed in the early morning hours. A reconnaissance of the road on foot covering different time periods of the day indicated lack of road kills during day time. Only on two occasions, one of Bonnet Macaque and another of a turtle, kills were seen during day time. Hence the time between 06:30 to 09:30 was selected for observation so that the entire stretch could be covered within three hours. The entire road was surveyed in continuous days within a month. The number of days covered in different months is given in Figure 5. Opportunistic encounter of kills were also recorded. On three occasions, information provided by reliable persons was also considered.

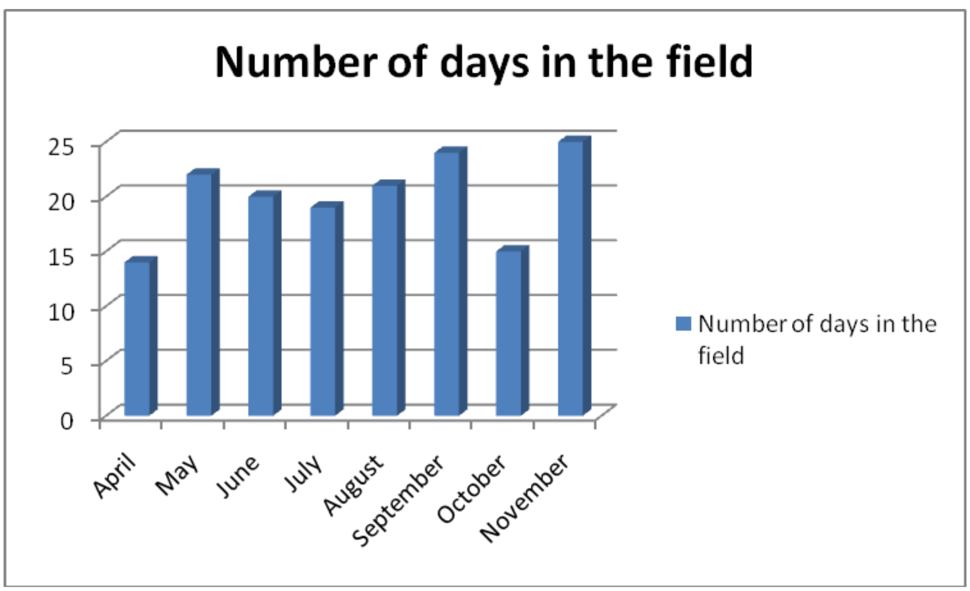


Fig. 5 Number of field days in different months

The sighted road kills were recorded along with habitat and status of the specimen. The kills were photographed separately and with the surrounding habitat. The locations of kills were recorded using GPS. The recorded kills were removed from the road to avoid possible repetitions. The species were identified by referring the books on the subjects (Eg. Grimmet *et al*., 1998; Daniels, 2002; Whitaker and Captain, 2008). The assistance of experts were also sought for identification of some of the species or confirmation of already identified ones.

CHAPTER V

RESULT

The length of the road selected for observations was 13 km (Fig. 6). One hundred sixty days spread over eight months were spent in the field recording the kills observed. The details are given in the Figure 5. The number of days varied from 14 in April to 25 in November.

A total of 2426 road kills were recorded during April – November, 2013. Of these, 2213 kills were of amphibians (Fig. 7). The reptiles accounted for 153 numbers and mammals 57 numbers. Bird kills were only three. The 2426 kills belong to 42 species, which include 8 species of amphibians, 19 species of reptiles, two species of birds and 13 species of mammals (Table 1). Of the species recorded as road kills, reptiles formed about 46%, mammals 29%, amphibians 20% and birds about 5% (Fig. 8). The monthly distribution of animal kills observed during the period is given in Figure 9, which indicates the peak in September.

Among the amphibian kills recorded, the highest number was that of Common Indian Toad, *Duttaphrynus melanostictus* (1000 numbers) followed by Bi-colored Frog, *Clinotarsus curtipes* (991 numbers). Other amphibian kills include Indian Bull Frog, *Hoplobatrachus tigerinus* (130 nos,), Warty Frog *Zakerana sp.* (49 nos.), and Bronzed Frog, *Hylarana temporalis* (28) and Caecilians (12). The highest number amphibian mortality on the road was recorded between August and October with the peak in September (Fig. 10). This is because of the high mortality of Bi-colored Frog, Common

Indian Toad, Indian Bull Frog, Warty Frog, Bronzed Frog and caecilians during the period (Figs. 11 - 17).

Table 1. The details of animal kills observed during April – November on Mananthavady – Kutta Road

Common Name	**Scientific Name**	**Number of road kills**
Amphibians		
Bi-colored Frog	*Clinotarsus curtipes*	991
Common Indian Toad	*Duttaphrynus melanostictus*	1000
Indian Bull Frog	*Hoplobatrachus tigrinus*	130
Winged Gliding Frog	*Rhacophorus lateralis*	2
Warty Frog	*Zakerana sp(keralensis?)*	49
Forest Toad	*Duttaphrynus parietalis*	1
Bronzed Frog	*Hylarana temporalis*	28
Caecilians	Unidentified	12
Reptiles		
Bibron's Coral Snake	*Calliophis bibroni*	3
Common Kukri	*Oligodon arnensis*	3
Large eyed Bronze Back	*Dendrelaphis grandoculis*	1
Common Krait	*Bungarus caeruleus*	3
Green Keel Back	*Macropisthodon plumbicolor*	14
Common Indian Monitor	*Varanus bengalensis*	1
Nilgiri Forest Lizard	*Calotes nemoricola*	5
Travancore Wolf Snake	*Lycodon travancoricus*	6
Hump nosed Pit Viper	*Hypnale hypnale*	94
Skink	*Unidentified*	1
Cat Snake	*Boiga sp.*	2
Russell's Viper	*Daboia russelii*	2
Indian Black Turtle	*Melanochelys trijuga*	6
Checkered Keel Back	*Xenochrophis piscator*	1
Shied-tailed Snake	*Uropeltidae*	1

Striped Keel Back	*Amphiesma stolatum*	3
Montane Trinket Snake	*Coelognathus helena monticollaris*	1
Hill Keel Back	*Amphiesma monticola*	1
Snake	*Unidentified*	1
Aves		
Spotted dove	*Spilopelia chinensis*	2
Orange Headed Thrush	*Zoothera citrine*	1
Mammals		
Three striped Squirrel	*Funambulus palmarum*	1
Indian Porcupine	*Hystrix indica*	2
Small Indian civet	*Viverricula indica*	2
Bonnet Macaque	*Macaca radiate*	1
Hanuman langur	*Semnopithecus entellus*	1
Grey Mongoose	*Herpestes edwardsii*	1
Common Palm civet	*Paradoxurus hermaphrodites*	1
Malabar Giant Squirrel	*Ratufa indica*	1
Indian hare	*Lepus nigricollis*	4
Painted bat	*Kerivoula picta*	2
Rat	*Unidentified*	27
Bat	*Unidentified*	14

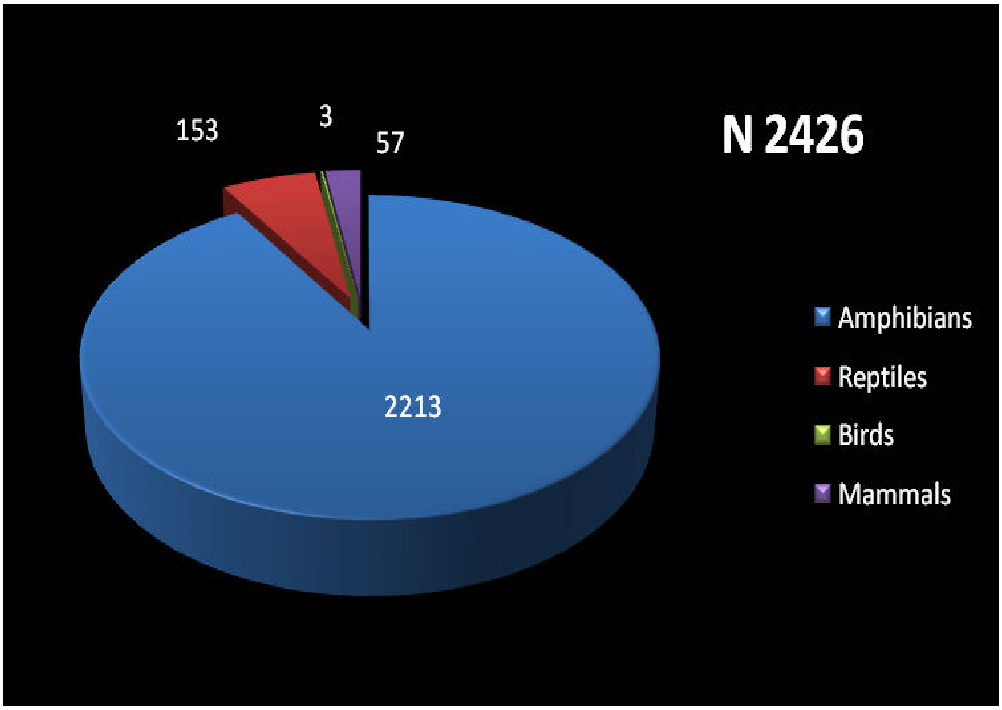


Fig. 7 Number of animal kill in different groups recorded in Mananthavady – Kutta Road

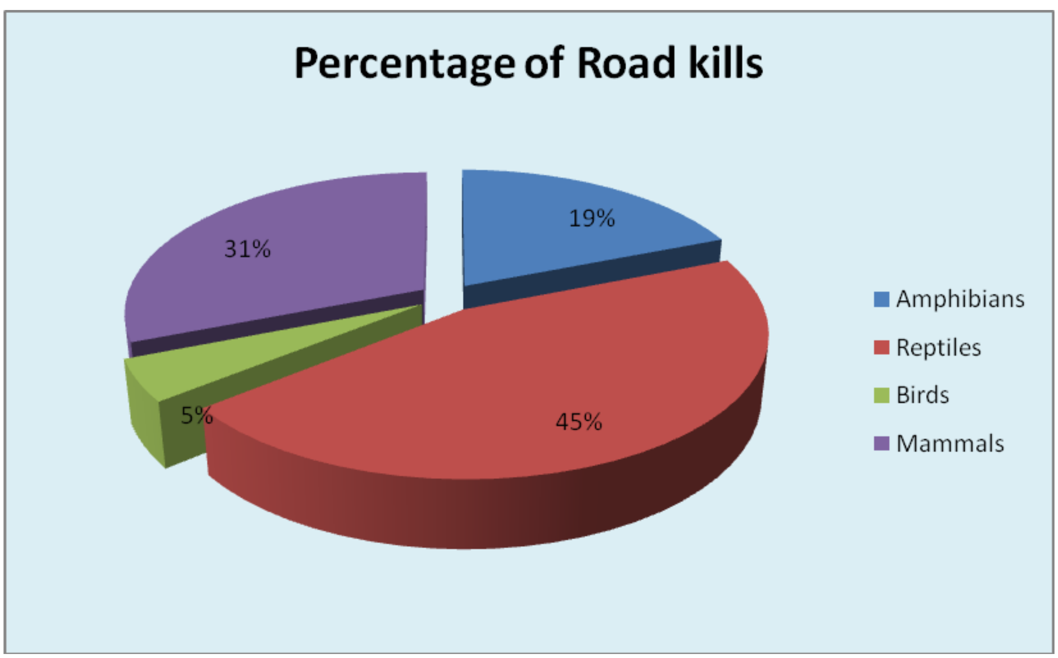


Fig. 8 Percentage of different groups of animals among road kills recorded on Mananthavady – Kutta Road

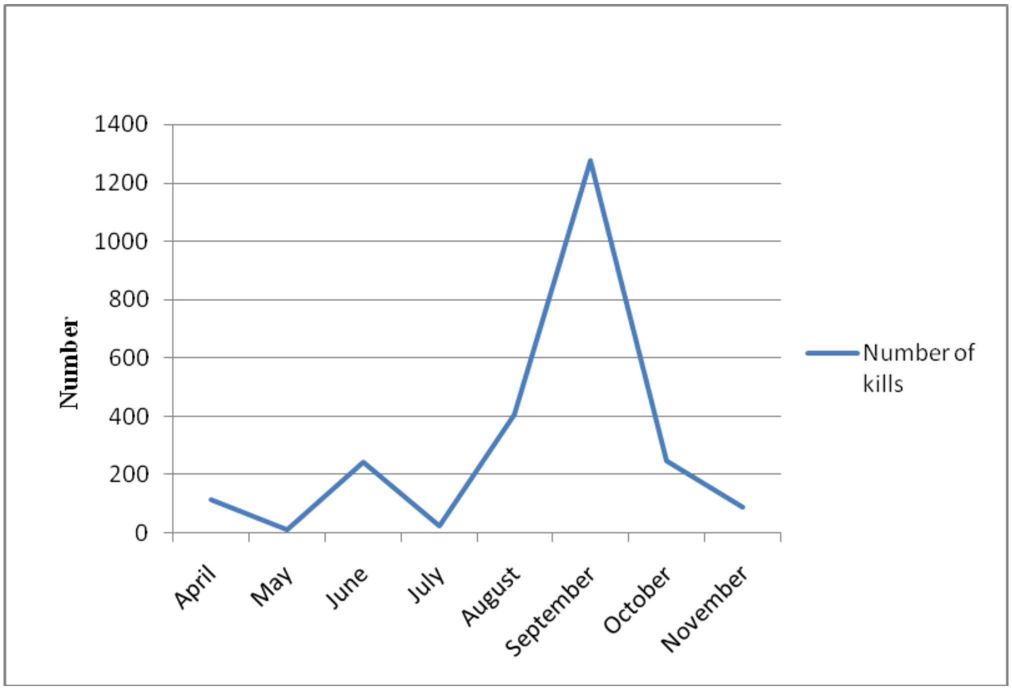


Fig. 9 Monthly distribution of animal kills on Mananthavady – Kutta Road

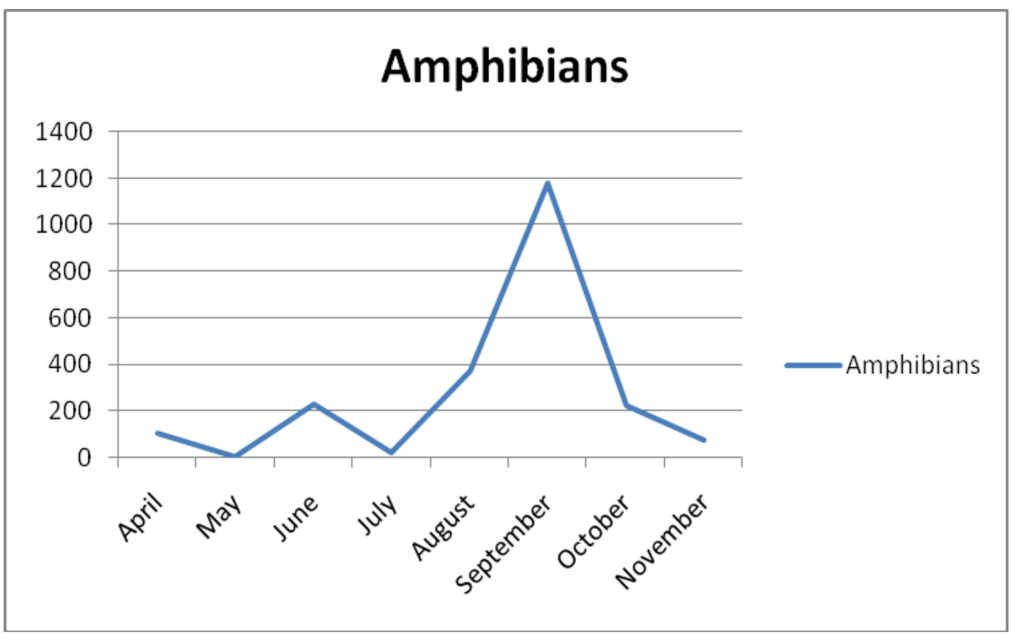


Fig. 10 Monthly distribution of amphibian mortality on Mananthavady – Kutta Road

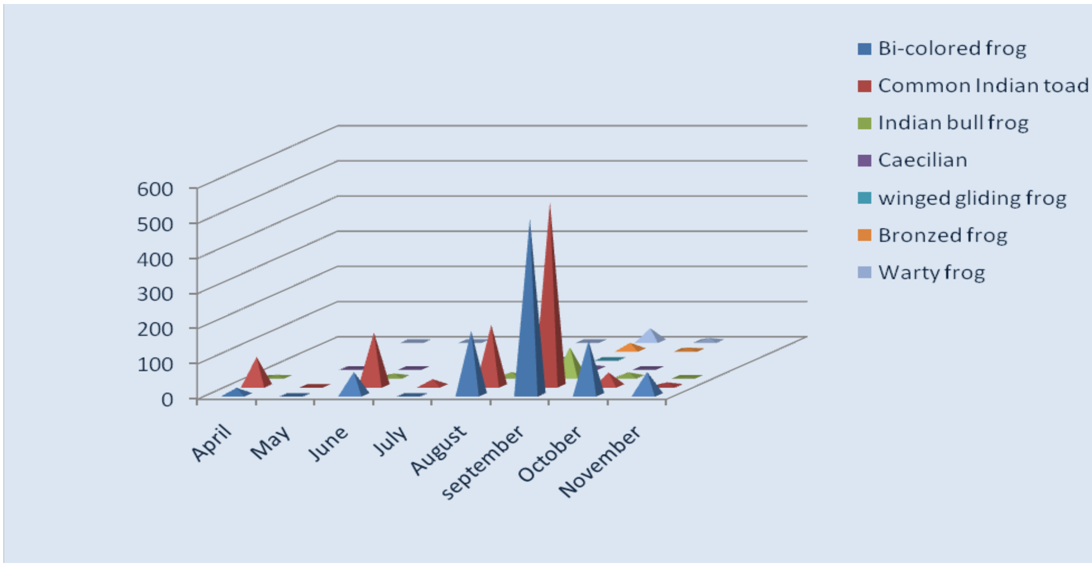


Fig. 11 Monthly distribution of mortality of various amphibian species on Mananthavady – Kutta Road

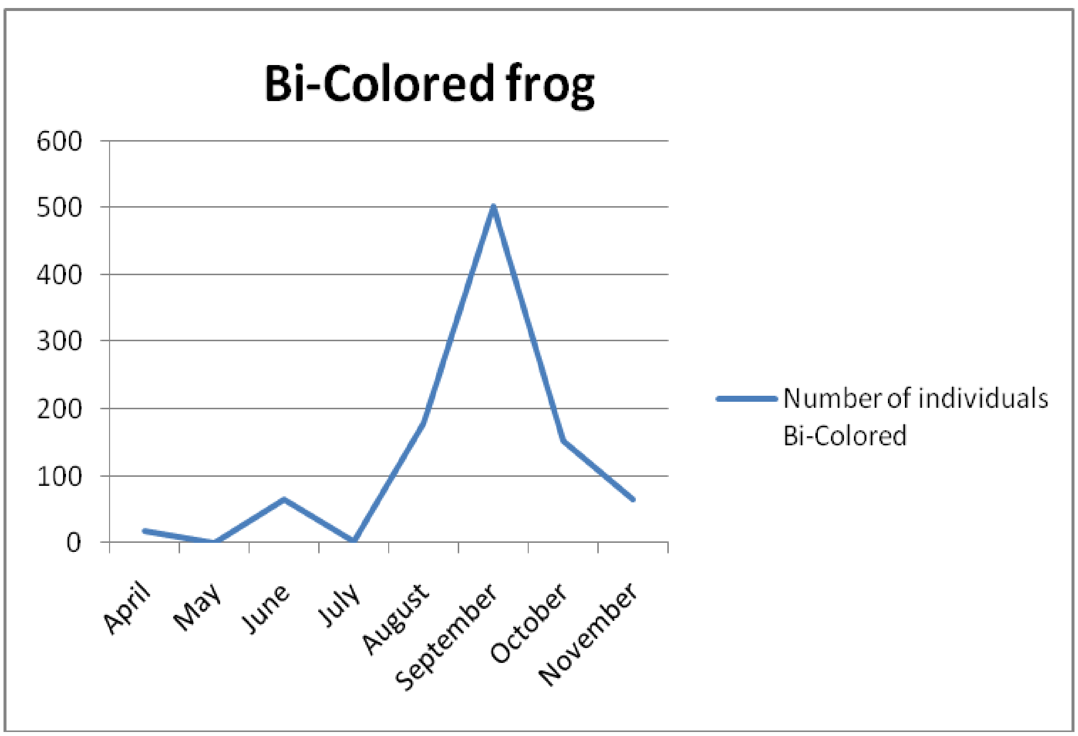


Fig. 12 Monthly distribution of Bi-colored Frog mortality on Mananthavady – Kutta Road

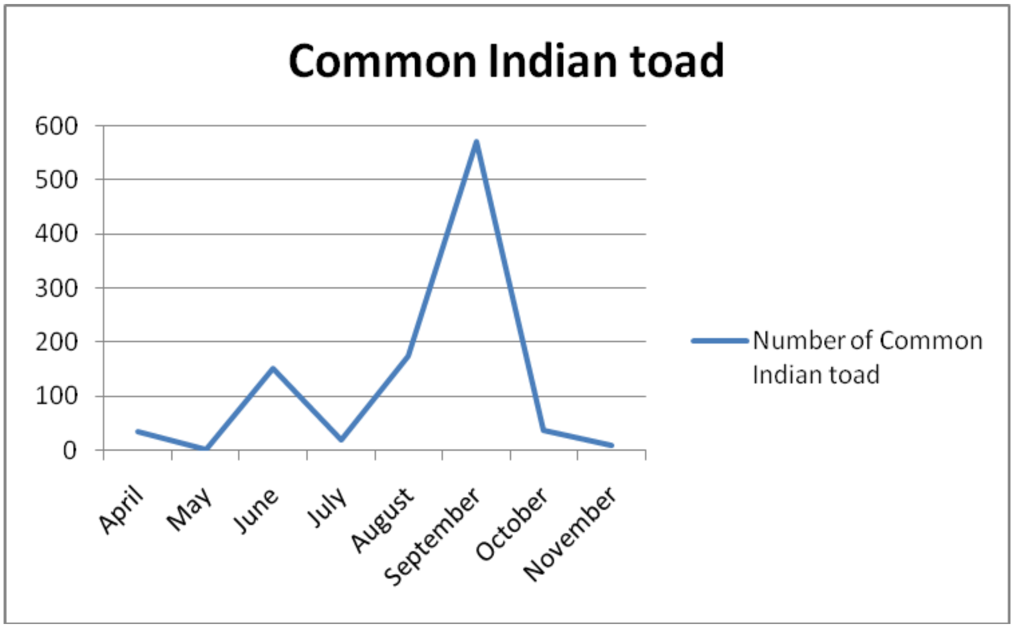


Fig. 13 Monthly distribution of Common Indian Toad mortality on Mananthavady – Kutta Road

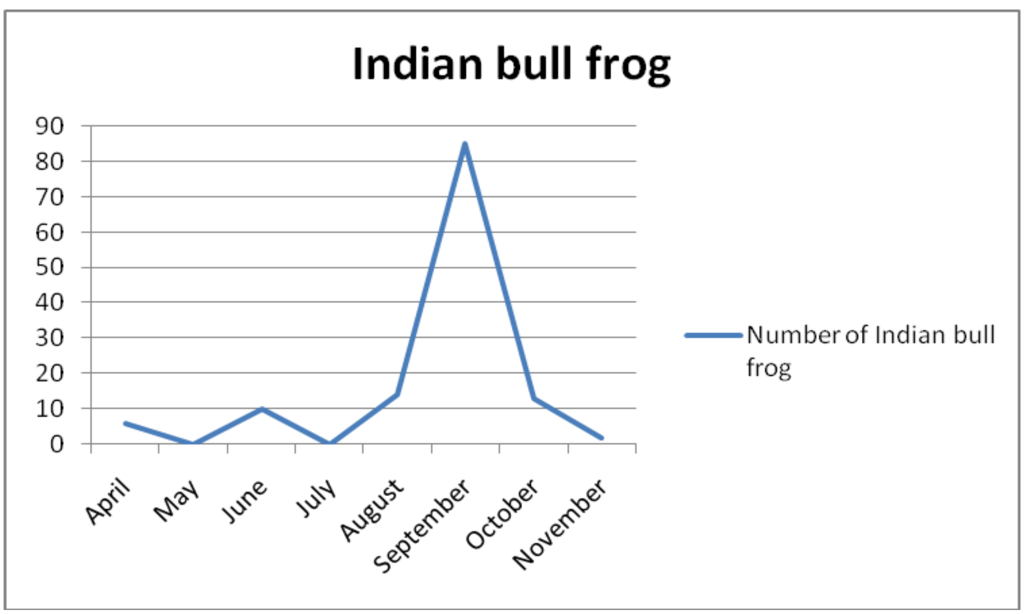


Fig. 14 Monthly distribution of Indian Bull Frog mortality on Mananthavady – Kutta Road

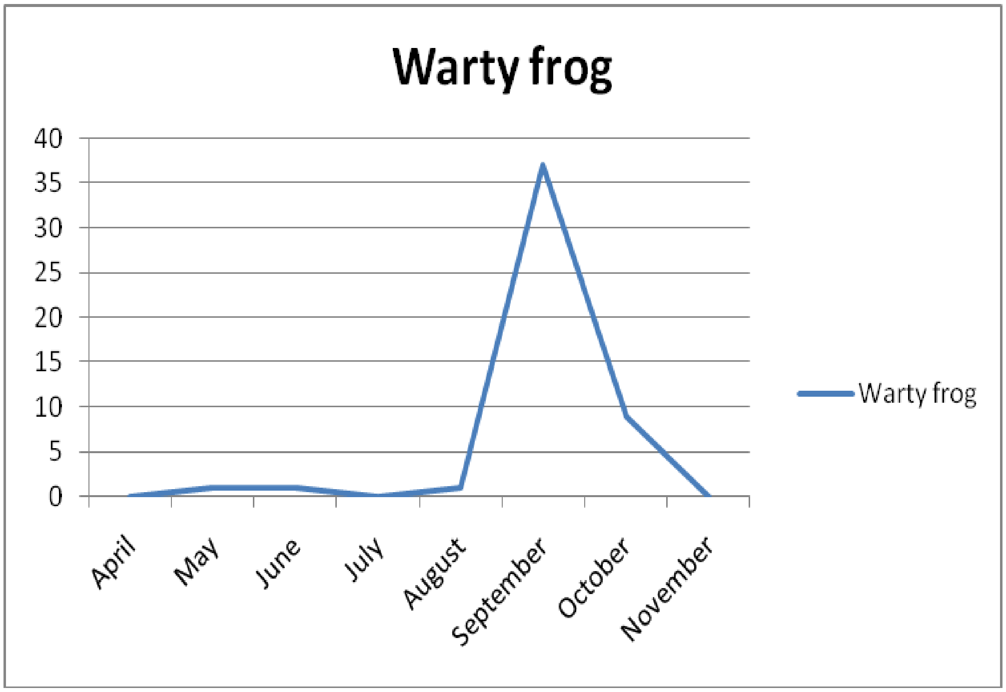


Fig. 15 Monthly distribution of Warty Frog mortality on Mananthavady – Kutta Road

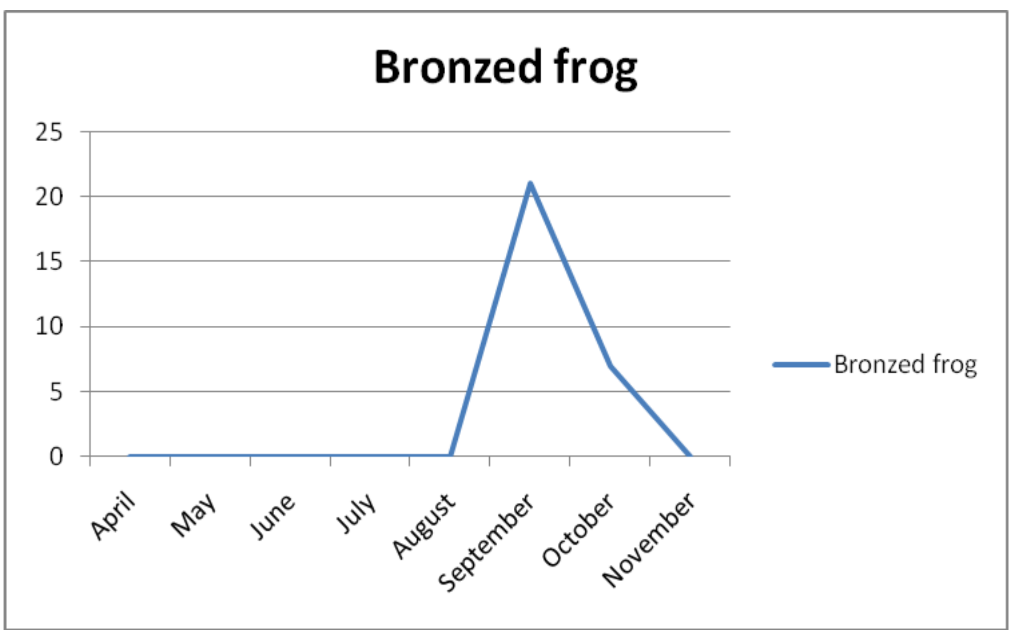


Fig. 16 Monthly distribution of Bronzed Frog mortality on Mananthavady – Kutta Road

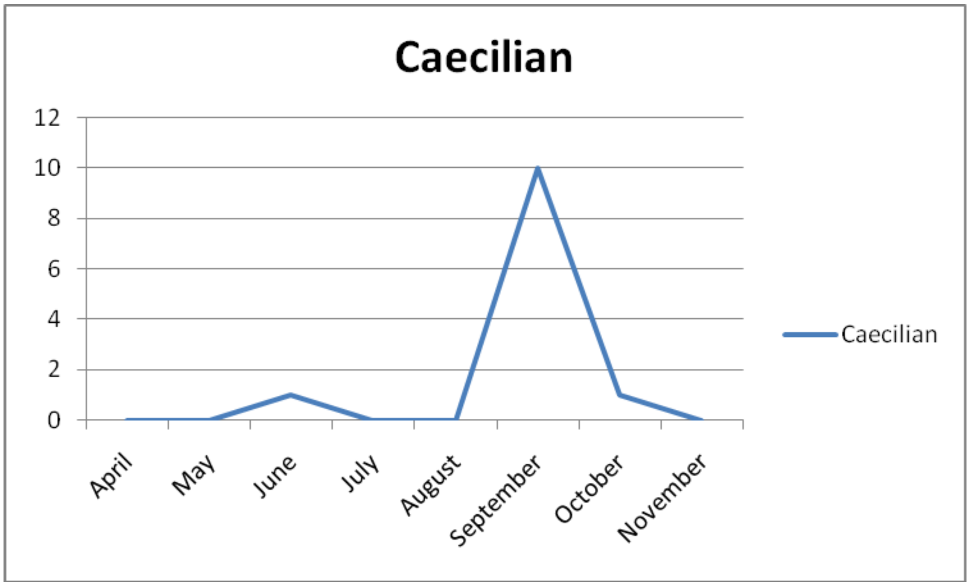


Fig. 17 Monthly distribution of caecilian mortality on Mananthavady – Kutta Road

One hundred and fifty three reptile kills were recorded during the period of observation. Of these, the highest number was that of Hump-nosed Pit Viper, *Hypnale hypnale.* Ninety four individuals of the species were observed to be killed on the road and formed about 62% of the total reptile kills. Green Keel Back, *Macropisthodon plumbicolor* accounted for 14 kills, which was about 9% of the total reptiles killed on the road. Bibron's Coral Snake *Calliophis bibroni* (3 nos), skink (5 nos), Common Indian Monitor *Varanus bengalensis* (1no.), Indian Black Turtle *Melanochelys trijuga* (6 nos) and Nilgiri Forest Lizard *Calotes nemaricola* (4) formed about 29% of the reptile kills recorded.

The monthly distribution of reptile kills during the eight month period indicates a peak in September (Fig. 18). However, unlike amphibians, kills were recorded in all months. The Hump-nosed Pit Viper kills were mostly in October and then in September with a few in November (Figs. 19 - 20). The Green Keel Back kills were mostly in September followed by June and October (Fig. 21).

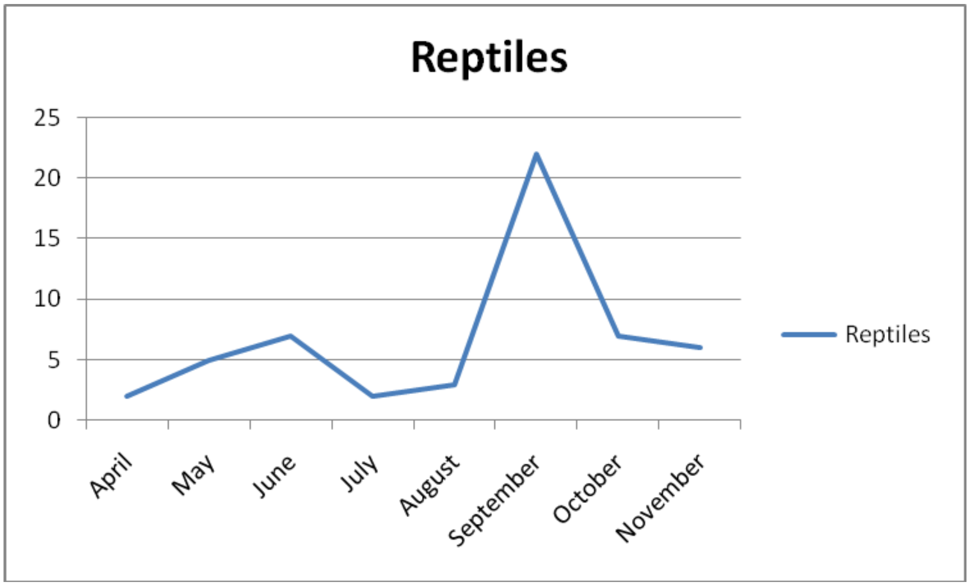


Fig. 18 Monthly distribution of reptile mortality on Mananthavady – Kutta Road

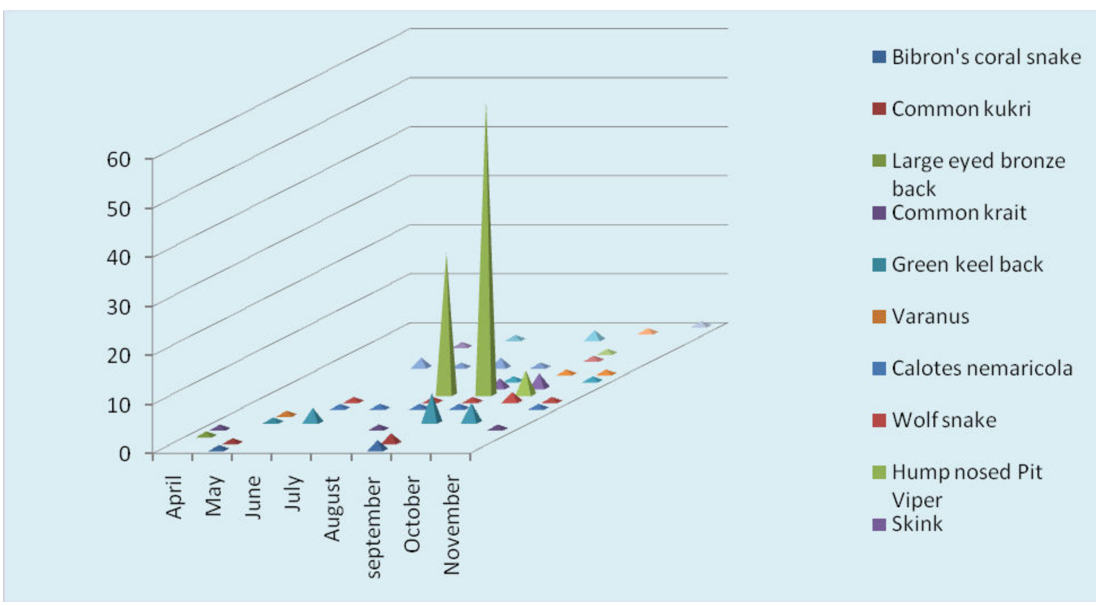


Fig. 19 Monthly distribution of mortality of different reptile species on Mananthavady – Kutta Road

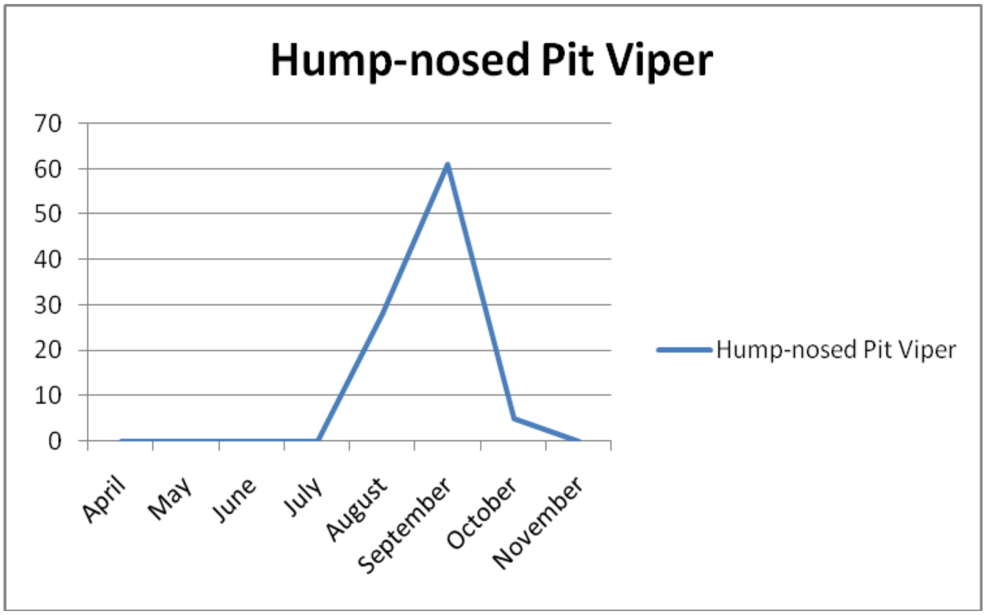


Fig. 20 Monthly distribution of Hump-nosed Pit Viper kills on Mananthavady – Kutta Road

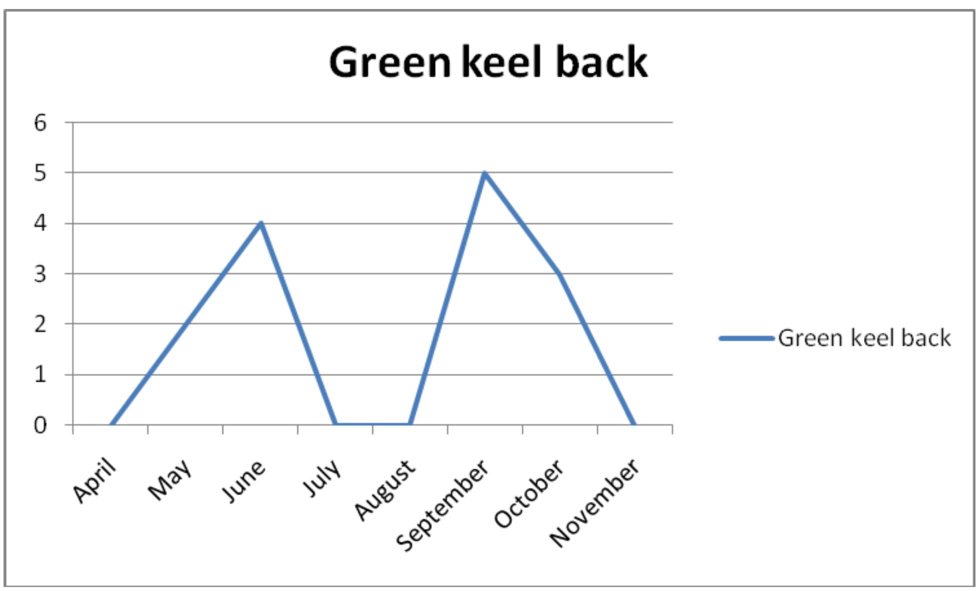


Fig. 21 Monthly distribution of Green Keel Back mortality on Mananthavady – Kutta Road

During the present study, only three road kills of birds were observed. Two of these were of spotted dove, *Spilopelia thinness* and one of Orange-headed Thrush, *Geokichla citrine.* The spotted dove kills were in October and November and the thrush in September (Fig. 22).

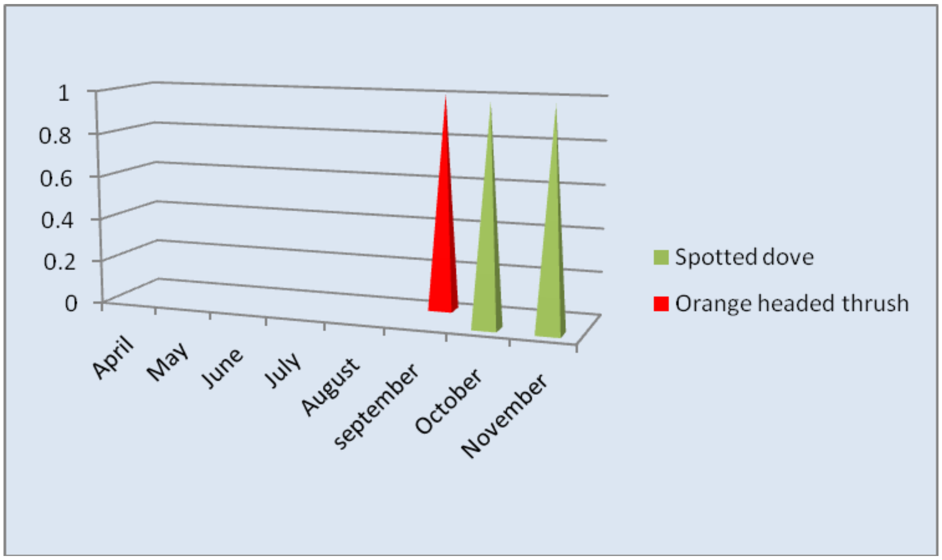


Fig. 22 Monthly distribution of mortality of various bird species on Mananthavady – Kutta Road

The monthly distribution indicates the highest mortality of mammals in September followed by October, August and June (Fig. 23).

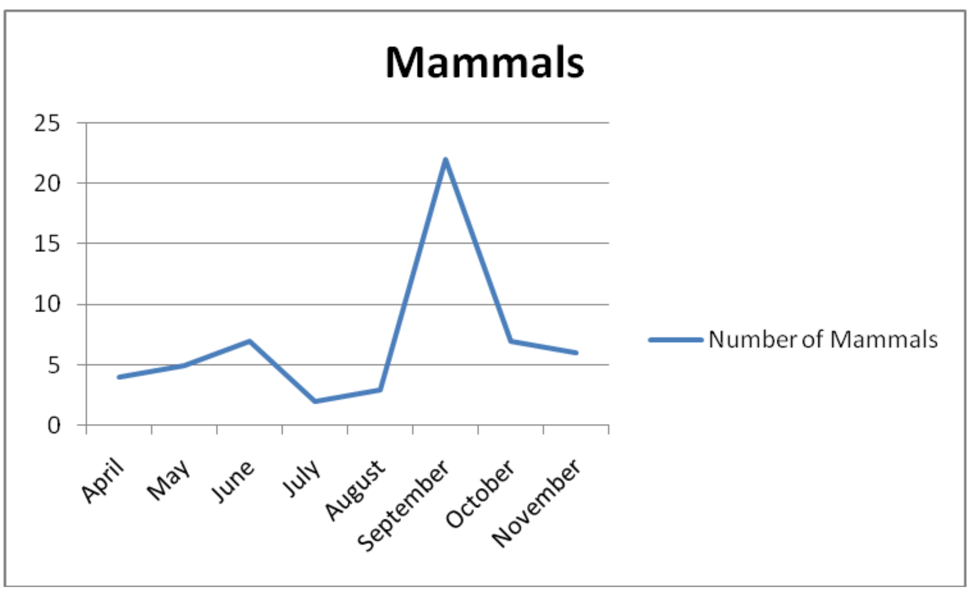


Fig. 23 Monthly distribution of mammalian mortality on Mananthavady – Kutta Road

Fifty seven individuals of mammals forming about 29% of the total were observed as road kills during the present study. These included nine identified species. There were 27 individuals of unidentified rats and 14 individuals of unidentified bats. Though rats formed the largest number of kills among the mammals, these could not be identified because of the state of the kill leaving no chance to go for identification to the species level. Only two could be identified out of the 14 bats. Other mammals included Bonnet Macaque, Hanuman langur, Porcupine, small Indian civet, common palm civet, grey Mongoose, black-naped hare, three striped Squirrel and Malabar Giant Squirrel.

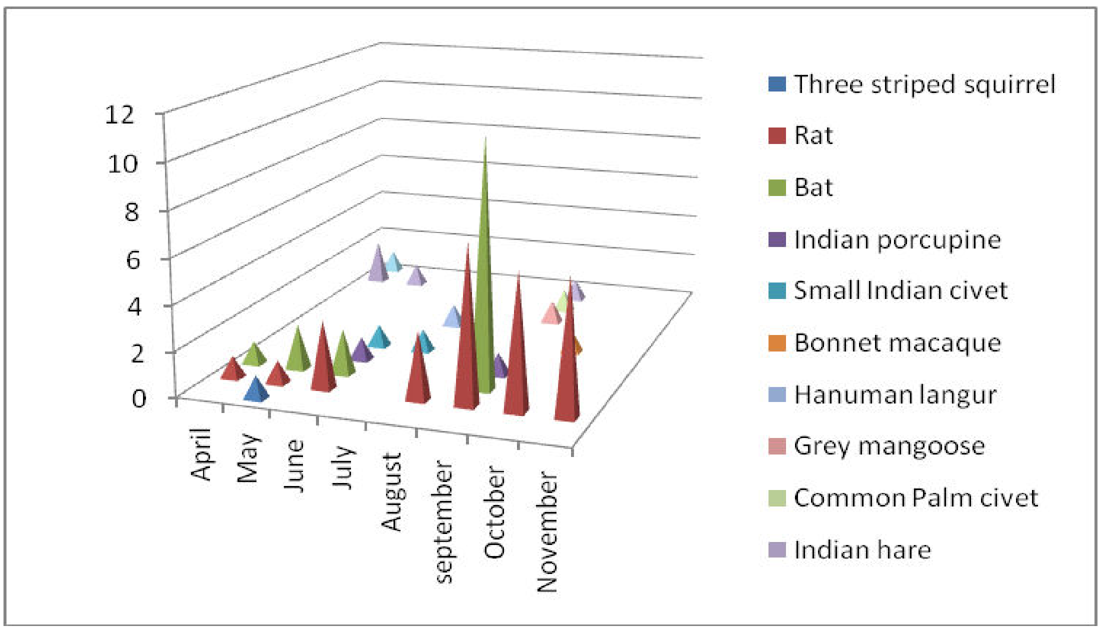


Fig. 24 Monthly distribution of mortality of various mammal species on Mananthavady – Kutta Road

Monthly distribution of mammalian species killed is given in Figure 24. Most of the bats killed were in September though there had been a few in April, May and June. The rat kills were observed almost all months except July. The largest number was in september followed by October.

CHAPTER VI

DISCUSSION

Modification of landscapes has adverse effect on the plant and animal diversity in the area. The linear infrastructural developments like roads and rail lines fragment the habitat thereby isolating some of the animal groups sometimes leading to extinction (Mader, 1984). It has also been reported to affect the seasonally or annually migrating species forcing them to take the risk of getting killed during the movement process (Smith and Dodd, 2003;Whitaker and Shine, 2000). There had been observations indicating that the nocturnal ones are not susceptible to mortality in places where the traffic is less at night (Enge and Wood, 2002). Conversely, it is also possible that the heavy traffic at night could lead to mortality of the nocturnal ones.

The slow moving animals like amphibians (Hels and Buchwald, 2001), turtle (Gibbs and Shriver, 2002) and snakes (Andrews, 2004) are probably the groups which will be most affected because of the roads. However, the snakes, which move comparatively faster could probably escape from the speeding vehicles.

The Mananthavady – Kutta road passes through moist deciduous forests with water sources intermittently thereby increasing the possibility of crossing the road. During the present study of eight months duration, a total of 2426 kills were recorded within a stretch of about 13 km. Of these, majority were amphibians and reptiles (Table 1). Of the 42 species, 19 were reptiles, 13 were mammals and 8 amphibians. Among the reptiles, Hump-nosed Pit Viper was observed to be killed in large numbers. Hump-nosed Pit Viper is a Western Ghat endemic. *Varanus bengalensis* Among the amphibians, Bi-colored Frog, *Clinotarsus curtipes* is endemic to Western Ghats. Though caecilians could not be identified because of the bad shape of the observed kills, there is every possibility that a few of them could be endemic or endangered. Among the amphibian kills observed, *Clinotarsus curtipes, Duttaphrynus parietalis* and *Hylarana temporalis* and the reptile *Melanochelys trijuga* are near threatened as per the IUCN Red Data Book. *Varanus bengalensis* is in Part II of Schedule I of Indian Wildlife (Protection) Act. Though not directly observed, *Prionailurus bengalensis* (leopard cat) was reported at least once by the Forest Staff. This is under Schedule I of Indian Wildlife (Protection) Act.

The locations of amphibian kills are plotted in the Figure 25. Most of these locations are with moist deciduous forest and teak plantations. The kills were more near the locations with water sources like water holes. Monthly distribution of the recorded kills indicate a peak in the number of kills in September (Fig. 9) followed by August and October. This is mostly due to the amphibian mortality (Fig.11). The Common Indian Toad and the Bi-colored Frog were the most affected on the Mananthavady – Kutta Road. Bi-colored Frog top the list with the highest number of kills and is a near threatened one. The breeding season of Bi-colored Frog is reported to be from June to July and that of Common Indian Toad normally coincides with monsoon rains (Daniels, 2005). The time taken by the tadpoles of Common Indian Toad to metamorphose varies according to places and reported to vary from 45 to 90 days. The Bi-colored Frogs gather around small tanks during breeding season (Daniels, 2005) and are susceptible to road kills while migrating to breeding habitats (Stuart *et al.,* 2008). Juveniles of Common Indian Toad tend to stay in large groups, slow moving and hop after small insects. The Indian Bull

Frog, *Hoplobatrachus tigerinus,* a slow moving frog turns lemon yellow during breeding season, which coincides with rains. The baby frogs are brightly coloured with extensive patches of green on the head and sides (Daniels, 2005). Warty Frogs reportedly congregate around small rain water puddles on road sides. The road kills observed in the study area were both lemon yellow and the colour of the baby frogs. The breeding habit and the seasons explain the findings of the present study, where the amphibians are getting killed in large numbers especially during August – October. It was also expected to be killed during the first heavy rains in June and then July. It is possible that the kills were washed out in the gushing water during the heavy rains leaving no chance of seeing it even on the edge of the road. Earlier studies in India have not reported such a huge number of kills, especially in a short stretch of 13 km.

There were 19 species in 153 reptile kills recorded during the study. The peak was in September followed by August and October. The locations of reptile kills are represented in Figure 26. Hump - nosed pit viper, a Western Ghat species, with 94 individuals was the most affected. The monthly distribution of hump – nosed mortality shows that the kills were mostly in August and September. The Green Keel Back, the second largest in terms of number of kills, had the highest number of death in June, September and October. Hump-nosed Pit Viper is nocturnal and is found mostly in deciduous forests and plantations. They are rather slow moving with breeding season in March – September (Whitaker and Captain, 2008). It feeds on frogs in addition to reptile eggs, rodents etc. Green Keel Back, a crepuscular species' eggs hatch in August – October. The most preferred prey is the toad. The Travancore Wolf Snake is nocturnal and feeds on toads and frogs. Russell's Viper is also nocturnal, found in forest edges and feeding on rodents. The nocturnal behavior, the feeding habit and breeding seasons explain the large scale mortality of these two species. The Indian Black Turtle, (*Melanochelys trijuga*), near threatened species is the slowest among the reptiles observed to be killed on the road and explains the six kills recorded during the study. All the kills were near water sources. The three kills of the rarely sighted *Calliophis bibrioni* is interesting as record of its occurrence in the area.

There were only three kills of two bird species, which is comparatively negligible. Spotted dove is a granivorous and are commonly seen on the roads make it more susceptible to vehicle hit. Orange Headed Thrush is a ground dweller.

The locations of mammalian kills are plotted in Figure 27. Rat was the largest group observed to be killed. Unfortunately, except for a bandicoot, 26 kills could not be identified because of the smaller size and the stage of the carcass. Only two kills of painted bat could be identified out the 14 bat kills observed during the study period. Indian hare, which is normally seen running in criss - cross manner along the road is not much killed. There had also been instances of just signs of fresh blood and hair of this animal indicating the possibility of removing/taking away the dead one after getting hit. The small Indian civet, Porcupine, common palm civet and grey Mongoose kills indicate the vulnerability of nocturnal/crepuscular species. Malabar Giant Squirrel kill was at a location, where there was a problem of canopy connectivity indicating the need to maintain/restore canopy connectivity for facilitating easier movement of arboreal mammals. These could also be the reason for the mortality of primates though both the species hit by vehicle are not strictly arboreal. The Bonnet Macaque mortality also indicate the need to totally ban feeding of the animals by the visitors and also throwing away of food waste and food containers/packets.

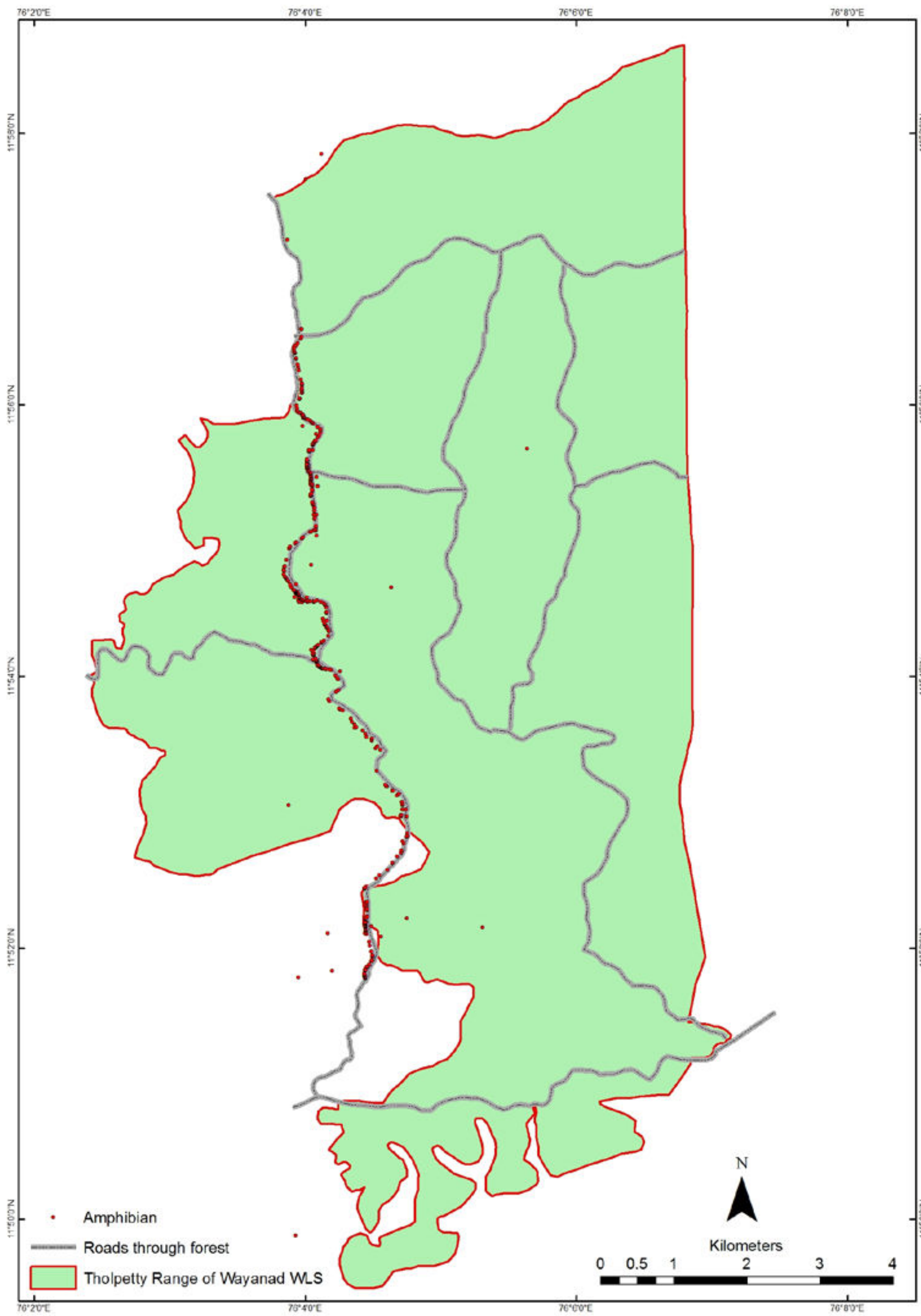


Fig. 25 Locations of amphibian kills on the Mananthavady – Kutta road

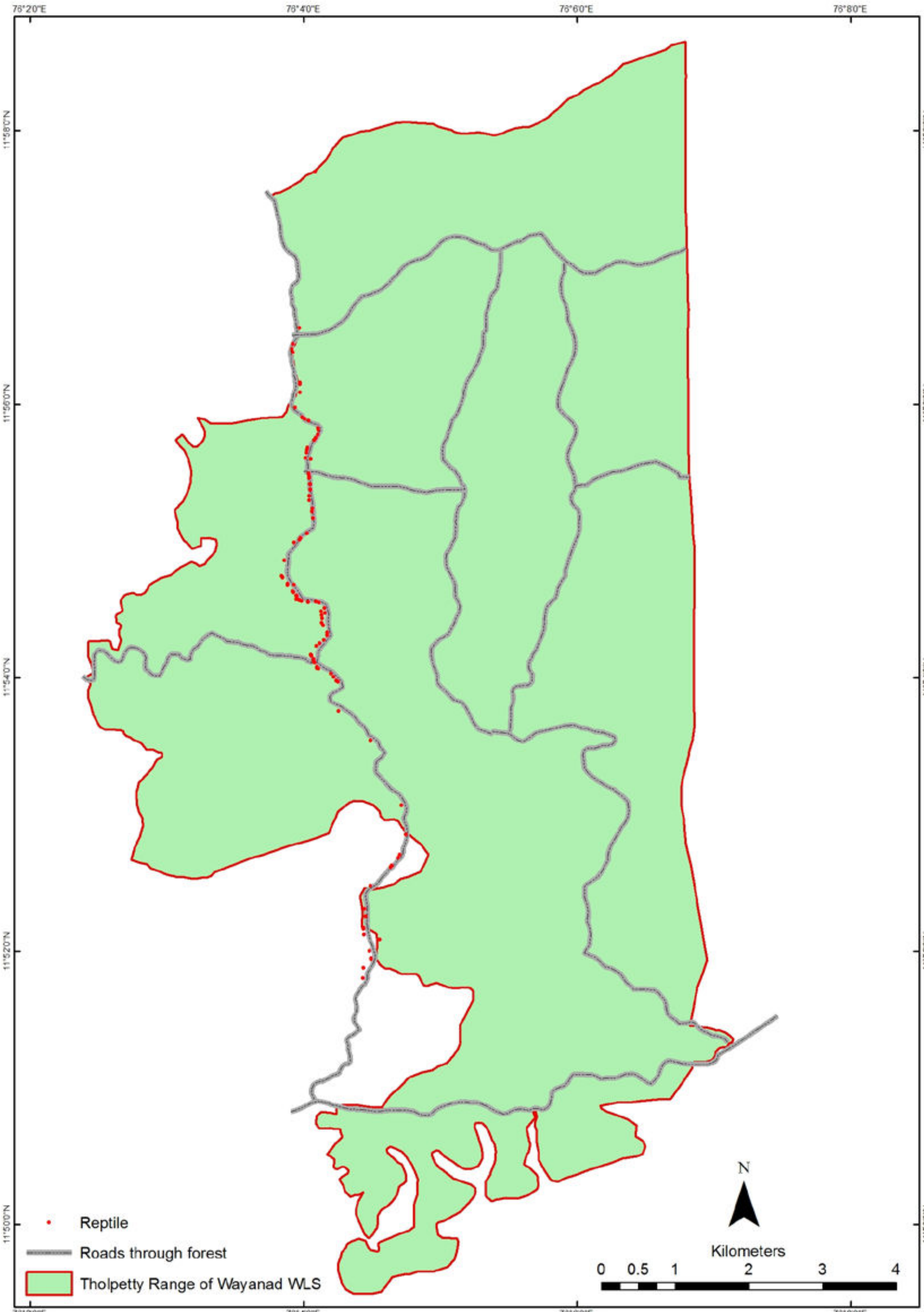


Fig. 26 Locations of reptile kills on the Mananthavady – Kutta road

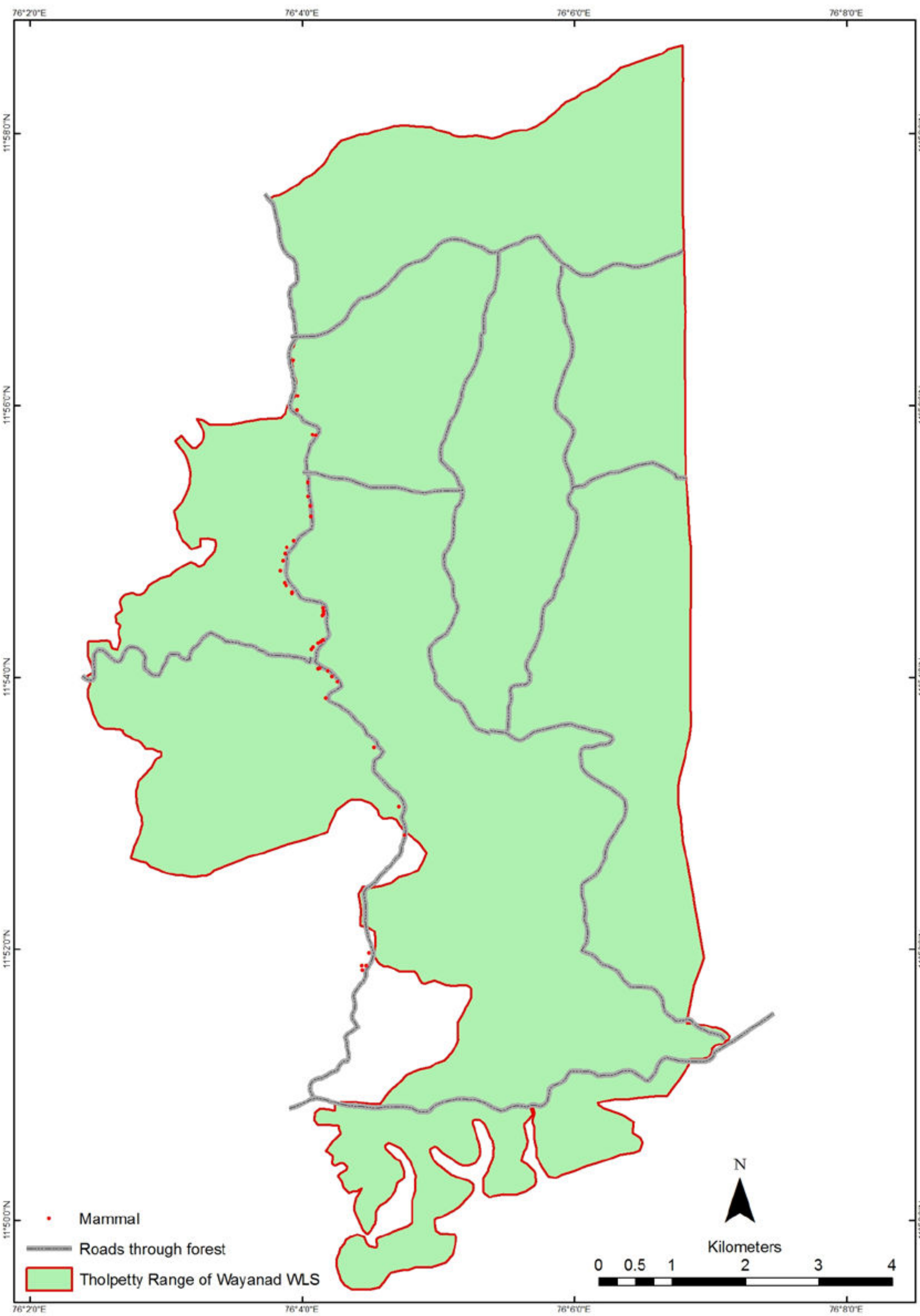


Fig. 27 Locations of mammalian kills on the Mananthavady – Kutta road

Details of number of vehicles during day time in September were collected during morning hours. The number of goods carriages running at night and recorded by the Forest Check Posts at Tholpetty was also collected for a comparison. When the average number of vehicles including bikes, car, bus and goods carriages was 63 during day time, the number of goods carriages varied from 28 to 64 during nights. There seems to be not much correlation between the volume of traffic and the mortality of animals. The available information indicates the possibility of nocturnal animals getting killed during night hours due to the less importance given to the smaller animals by the vehicle drivers. However, this aspect needs further studies and careful scrutiny with more data on volume of traffic for confirmation.

The habitat on the west side of the road is comparatively narrow with human habitations. Naturally, access to a wider landscape o the eastern side will require crossing of the road with the risk involved. This also emphasizes the need to have larger undisturbed landscape for long term conservation.

CHAPTER VII

CONCLUSION

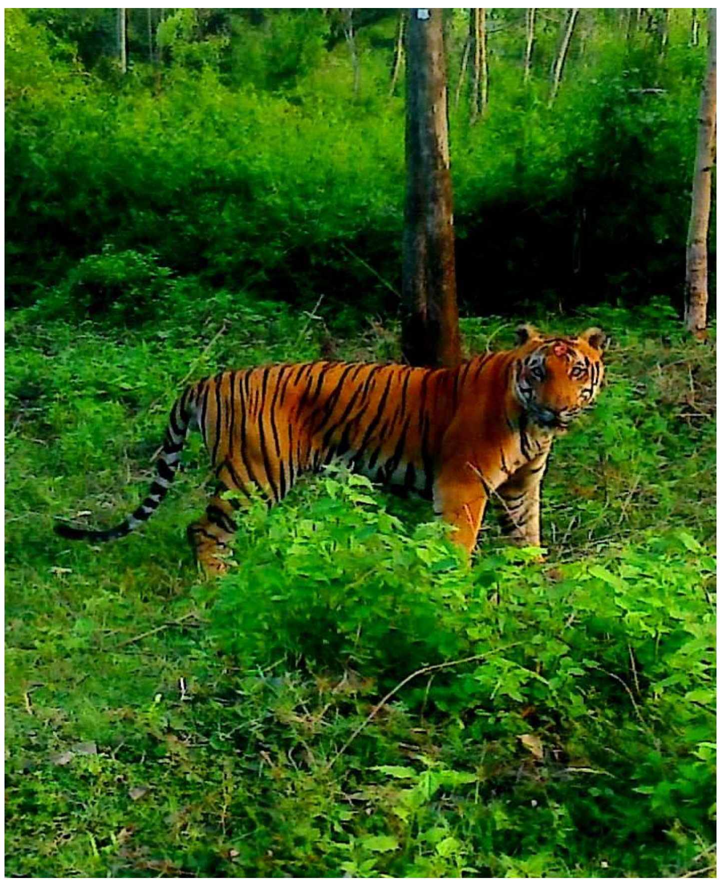
The study indicates the vulnerability of the smaller, nocturnal animals on the road. This is especially true of the amphibians and reptiles. The findings have management implications especially in the wake of the threatened status of some of the species. It is evident that the drivers do not give much importance to these groups may be because of the lack of sighting of these on the road. It will be good if a briefing is done for the information of the drivers. It is also suggested that speed breakers are established at vulnerable points like the turnings and areas with water holes. Canopy connectivity may have to be maintained or established through planting of appropriate species along the road sides, wherever it is required. Artificial canopy bridges may help till such permanent solutions are in place.

Photographic documents

Study area during April

Study area during July

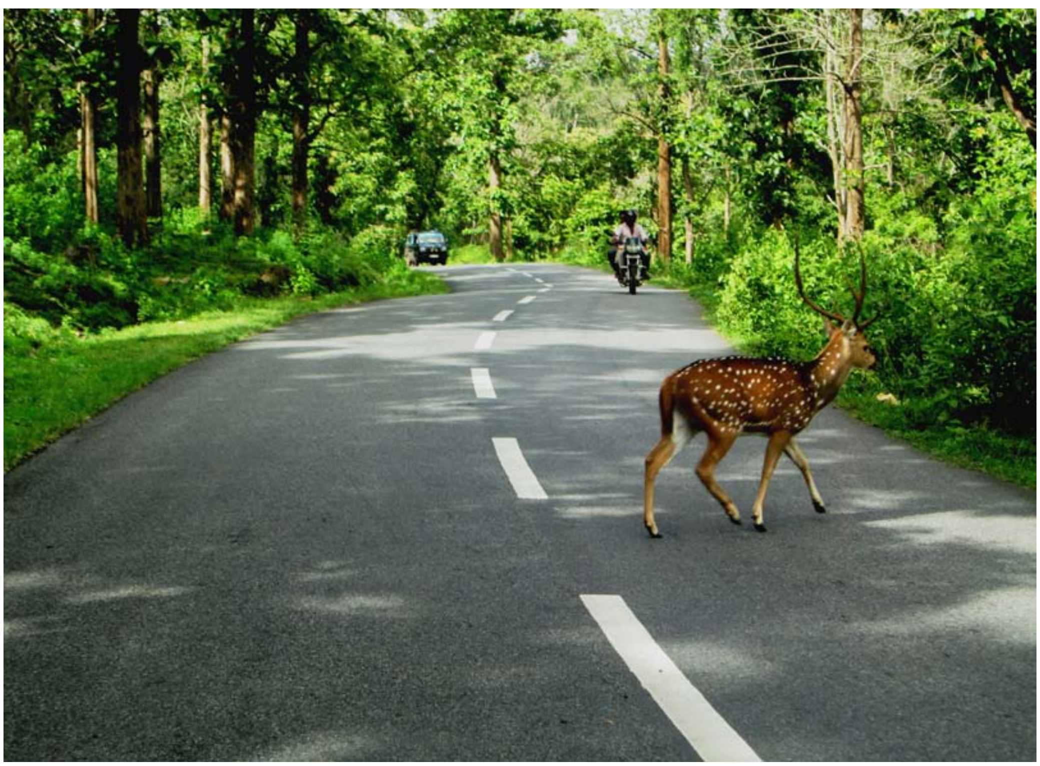

Study area during September


Tiger from the study area

Kutta- Mananthavady bus facing tusker


Elephant near the road

Wild dog crossing the road



Spotted deer crossing the road

Gaur on road at night


Data collection


Data collection


Data collection

Indian porcupine (*Hystrix indica)* kill

Indian hare *(Lepus nigricollis)* kill

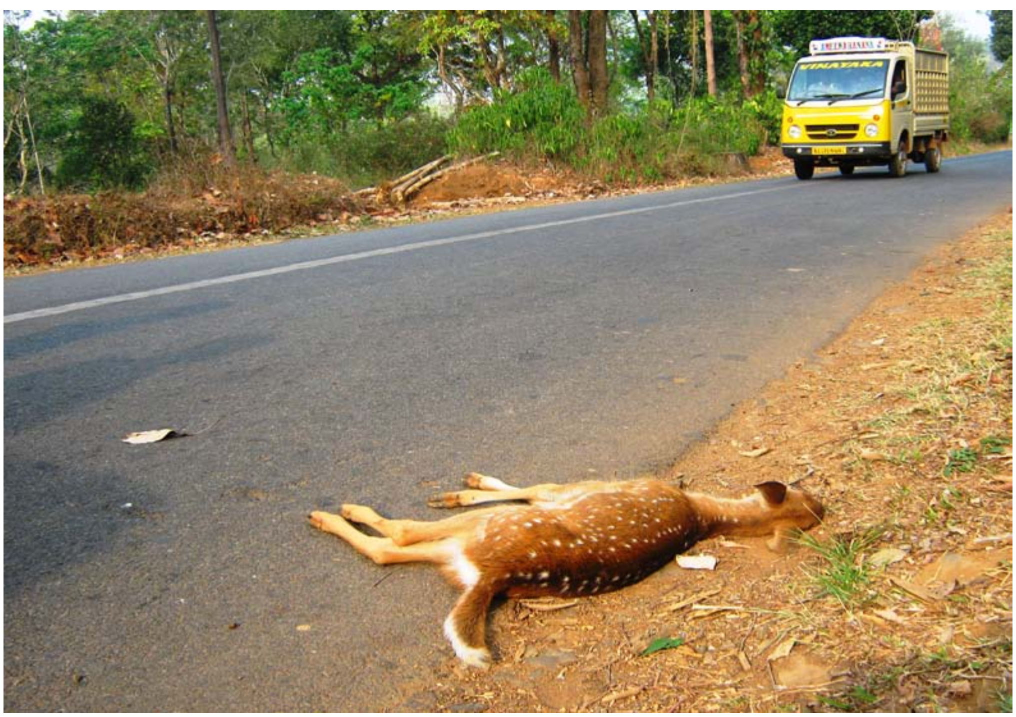
Common palm civet (*Paradoxurus hermaphroditus)* kill

Small Indian civet *(Viverricula indica)* kill

Three striped squirrel (*Funambulus palmarum)* kill

Common langur *(Semnopithecus entellus*) kill

Spotted Deer (*Axis axis*) kill recorded by forest officials



Spotted Deer (*Axis axis*) kill recorded by forest officials

Leopard cat (*Prionailurus bengalensis)* kill recorded by forest officials

Painted bat *(Kerivoula picta)* kill


Bat kill


Rat kill

Common Indian monitor *(Varanus bengalensis)* kill

Hump-nosed pit viper *(Hypnale hypnale)* kill

Green Keel back (*Macropisthodon plumbicolor)* kill

Russell's viper *(Daboia russelii)* kill


Calotes sp. kill


Bibron's snake *(Calliophis bibroni)* kill

Indian black turtle *(Melanochelys trijuga)* kill

Spotted dove *(Spilopelia chinensis)* kill

Orange headed thrush *(Zoothera citrine)* kill

Common Indian toad *(Duttaphrynus melanostictus)* kill

Indian bull frog *(Hopolobatrachus tigrinus)* kill

Indian bull frog kill (in lemon yellow color)

Bi- colored frog *(Clinotarsus curtipes)* kill

Bronzed frog *(Hylarana temporalis)* kill

Caecilian kill

Indirect evidence of road kills


Indirect evidence of road kills


Indirect evidence of road kill

REFERENCES

Agoramoorthy, G. (1987). Reproductive behaviour in Hanuman Langur, *Presbytis entellus*. Ph. D Thesis. University of Jodhpur, Jodhpur.

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: A review. *Australian Zoologist* **26**, 130-141.

Andrews, K. M. 2004. Interspecific comparisons of behavioral responses of southeastern snakes to roads. M.S. Thesis. University of Georgia. Athens, GA.

Angold, P.G. 1997. The impact of a road upon adjacent heathland vegetation: Effects on plant species composition. *Journal of Applied Ecology* **34**, 409-417.

Aresco, M. J. 2003. Highway mortality of turtles and other herpetofauna at lake Jackson, Florida, USA, and the efficacy of a temporary fence/culvert system to reduce roadkills. Pp. 433-449 *In*: Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K. P. McDermott, Raleigh, NC: Center for Transportation, and the Environment, North Carolina State University, 2003.

Ashley E. P., J. T. Robinson 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. *Canadian Field Naturalist*, 110: 403-412.

Auerbach, N.A., Walker, M.D. and Walker, D.A. 1997. Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. *Ecological Applications* **7**, 218-235.

Babisch, W., Ising, H., Gallacher, J.J., Sweetnam, P.M. and Elwood, P.C. 1999. Traffic noise and cardiovascular risk: The caerphilly and speedwell studies, third phase-10-year follow up. *Archives of Environmental Health* **54**, 210-216.

Baldwin, E. A., M. N. Marchand, and J. A. Litvaitis. 2004. Terrestrial habitat use by nesting painted turtles in landscapes with different levels of fragmentation. *Northeastern Naturalis*t 11: 41-48.

Bauske, B. and Goetz, D. 1993. Effects on de-icing salts on heavy metal mobility. *Acta Hydrochimica Et Hydrobiologica* **21**, 38-42.

Bennett, A.F. 1991. Roads, roadsides and wildlife conservation: a review. In: Saunders, D.A. andHobbs, R.J., (Eds.) *Nature conservation 2: The role of corridors*, pp. 99-118. Chipping Norton: Surrey Beatty & Sons.

Bernard, J.-M., Lansiart, M., Kempf, C. and Tille, M., (Eds.) 1987. Actes du colloques "Route et fauna sauvage". Strasbourg, Conseil de l'Europe, 5-7 Juin 1985. Ministère de l'Equipement, du Longement, de l'Aménagement du Territoire et des Transports, et Ministère délégué chargé de l'Environnement, Colmar, France. 403 pp.

Bernardino, Jr., F. S. and G. H. Dalrymple. 1992. Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park, USA. *Biological Conservation* 61: 71-75.

Bhaskaran, N. and Boominathan, D. 2010. Road kills of animals by highway traffic in the tropical forest of Mudumalai Tiger Reserve, South India. Journal of Threatened Taxa 2(3):753-759.

Blaustein, A.R. and Wake, D.B. 1990. Declining amphibian populations: global phenomenon? *TREE* **5**, 203-204.

Blomqvist, G. 1998. Impact of de-icing salt on roadside vegetation - a literature review. VTI rapport 427A, pp.1-36. Linköping, Sweden: Swedish National Road and Transport Research Institute. URL: http://www.vti.se.

Boarman, W. I. and M. Sazaki. 1996. Highway Mortality in Desert Tortoises and Small Vertebrates: Success of Barrier Fences and Culverts. Pp. 169-173. *In* G.L. Evink, P.Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida Department of Transportation, Tallahassee, Florida. FL - ER -58 – 96.

Bonnet, X., G. Naulleau and R. Shine. 1999. The dangers of leaving home: Dispersal and mortality in snakes. *Biological Conservation* 89: 39-50.

Canters, K., Piepers, A. and Hendriks-Heersma, A. 1997. Habitat fragmentation, infrastructure and the role of ecological engineering. – Proceedings of the international conference on Habitat fragmentation and infrastructure in Maastricht & DenHague 1995. Delft, The Netherlands:Ministry of Transport, Public Works and Water Management, Road and Hydraulic Engineering division.

Clevenger A. P. 1998-9. Highways and wildlife-An online bibliography. URL: http://www.cmiae.org /biblio. html (last visit: October 2000).

Chhangani, A. K. 2004. Frequency of avian road-kills in Kumbhalgarh Wildlife Sanctuary, Rajasthan, India. Short notes, *Forktail 20.*

Chhangani, A. K. 2004. Killing of Hanuman Langur in road accidents in Kumbhalgarh Wildlife Sanctuary, Rajasthan, India. *Primate Report* 69.

Coffin, A.W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography 15: 396-406.

Cooke, A. S. 1989. Mortality of toads (*Bufo bufo*) on roads near a Cambridgeshire breeding site. *British Herpetological Society Bulletin* 26: 29-30.

Daniel Smith. 2005. Wildlife impact study. *Summary of Final Report, BC354-74*

Das, Abhijith, Firoz Ahmed, M. Bibhuti, P. Lahkar and Pranjit Sharma 2007. A preliminary report of reptilian mortality on road due to vehicular movements near Kaziranga National park, Assam. *Zoos' print Journal 22(7): 2742-2744.*

deMaynadier, P. G. and M. L. Hunter, Jr. 2000. Road effects on amphibian movements in a forested landscape. *Natural Areas Journal* 20: 56-65.

Dodd C. K., Jr., K. M. Enge, and J. N. Stuart. 1989. Reptiles on highways in north-central Alabama, USA. *Journal of Herpetology* 23: 197-200.

Ellenberg, H., Müller, K. and Stottele, T. 1981. *Strassen-Ökologie:Auswirkungen von Autobahnen und Strassen auf Ökosysteme deutscher Landschaften.* Bonn: Deutsche Strassenliga.

Enge, K. M. and K. N. Wood. 2002. A pedestrian road survey of an upland snake community in Florida. *Southeastern Naturalist* 1: 365-380.

Ernst, W.O. 1998. Invasion, dispersal and ecology of the South African neophyte Senecio inaequidens in The Netherlands: from wool alien to railway and road alien. *Acta Botanica Neerlandica* **47**, 131-151.

Evink, G.L., Garrett, P. and Zeigler, D., (Eds.) 1999. Proceedings of the third International Conference on Wildlife and Transportation. FL - ER-73 -99. Florida Department of Transportation, Tallahassee, Florida. 330 pages.

Evink, G.L., Garrett, P., Zeigler, D. and Berry, J., (Eds.) 1996. Highways and movement of wildlife: Improving habitat conditions and wildlife passageways across highway corridors. Proceedings of the Florida Department of Transportation / Federal Highway Administration transportationrelated wildlife mortality seminar. Orlando April 30 – May 2, 1996, Florida Department of Transportation, FHWA-PD-96- 041, Tallahassee, Florida 336.

Evink, G.L., Garrett, P., Zeigler, D. and Berry, J., (Eds.) 1998. Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, FLER- 69-98, Tallahassee, Florida 263 pp.

Fahrig, L., J. H. Pedlar S. E. Pope P. D. Taylor and J. F. Wegner. 1995. Effect of Road Traffic on Amphibian Density. *Biological Conservation* 73: 177-182.

Ferris, C.R. 1979. Effects of Interstate 95 on breeding birds in northern Maine. *J. Wildl. Manage.* 43: 421-427.

Fitch, H. S. 1949. Road counts of snakes in western Louisiana. *Herpetologica* 5:87-90.

Forman, R.T.T. 1995. *Land mosaics: The ecology of landscapes and regions*. Cambridge: Cambridge University Press.

Forman, R.T.T., Alexander, L.E., 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics, 207–232.

Fowle, S. C. 1996. Effects of roadkill mortality on the western painted turtle (*Chrysemys picta belli*) in the Mission Valley, Western Montana. 205-223 *in*

G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida Department of Transportation, Tallahassee, Florida. FL - ER - 58 – 96.

Gibbs, J. P. and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16: 1647-1652.

Gjessing, E., Lygren, E., Berglind, L., Gullbranden, T. and Skanne, R. 1984. Effect of highway runoff on lake water quality. *Science of the Total Environment* **33**, 247-257.

Glitzner, I., Beyerlein, P., Brugger, C., Egermann, F., Paill, W., Schlögel, B.and Tataruch, F. 1999. *Anlage- und betriebsbedingte Auswirkungen von Strassen auf die Tierwelt - Literaturstudie*. Graz, Austria: MA 22 Naturschutz und Landschaftspflege, Beiträge zum Umweltschutz, Heft 60/99.

Gopinathan, V. 1990. The First Management Plan for Wayanad Wildlife Sanctuary (1990-1991 to 1999-2000). Kerala Forest Department, Thiruvananthapuram.

Hansen, K. and Jensen, J. 1972. The vegetation on roadsides in Denmark. *Dansk Bot.Ark.* **28**, 1-61.

Harris, L.D. and Gallagher, P.B. 1989 New initiatives for wildlife conservation. The need for movement corridors. In: Anonymous *In defense of wildlife: Preserving communities and corridors*, pp. 11-34. Washington.

Haxton, T. 2000. Road mortality of snapping turtles, *Chelydra serpentina*, in central Ontario during their nesting period. *Canadian Field Naturalist* 114: 106-110.

Hels, T. and E. Buchwald. 2001. The effect of road kills on amphibian populations. *Biological Conservation* 99: 331-340.

Heine, G. 1987. Einfach mess - und rechenmethode zur ermittlung der ueberlebenschance wanderender amphibien beim ueberqueren von strassen. Naturschutz und Landschaftspflege in Baden - Wurttemberg. 41: 473-479.

Hodson, N. L. 1966. A survey of road mortality in mammals (and including data for the grass snake and common frog). *Journal of Zoology* 148: 576-579.

Holdgate, M. W. 1989. Preface. *In*: T. E. S. Langton (Ed.), Amphibians and Roads. Proceedings of the Toad Tunnel Conference, Rendsburg, Federal Republic of Germany, 7-8 January 1989. ACO Polymer Products Ltd., Shefford, U.K. 3 pp.

Holzang, O., Sieber, U., Heynen, D., von Lerber, F., Keller, V. and Pfister, H.P. 2000. *Wildtiere und Verkehr - eine kommentierte Bibliographie*. Sempach, Switzerland: Schweizerische Vogelwarte.

Hoskin Conrad, J. and Goosem Miriam, W. (2010). Road Impacts on Abundance, Call Traits, and Body Size of Rainforest Frogs in Northeast Australia.

Illner, H. 1992. Effect of roads with heavy traffic on Grey partridge (Perdix.perdix) density. *Gibier Faune Sauvage* **9**, 467-480.

Jalkotzky,M.G., Ross,P.I. and Nasserden,M.D. 1997. *The effects of linear development on wildlife: a review of selected scientific literature*. Prepared by the Arc Wildlife Services Ltd. 2201 - 34 St. S. W., Calgary, Alberta T3E 2W2, Canada (unpublished report, accessible from the author).

Job, R.S. 1996. The influence of subjective reactions to noise on health effects of the noise. *Environment International* **22**, 93-104.

Jochimsen, Denim M., Charles Peterson, R., Kimberly Andrews, M. and Whitfield Gibbons, J. 2004. A Literature Review of the Effects of Roads on Amphibians and Reptiles and the Measures used to Minimize Those Effects. Idaho Fish and Game Department USDA Forest Service: 11-4.

Klauber, L. M. 1939. Studies of reptile life in the arid southwest, Part 1. Night collecting on the desert with ecological statistics. *Bulletin of the Zoological Society of San Diego* 14: 2-64.

Kline, N. C. and D. E. Swann. 1998. Quantifying Wildlife Road Mortality in Saguaro National Park. Pp. 23-31 *In*: G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

Kuhn, J. 1987. Strassentod der erdkroete (*Bufo bufo L.*): verlustquoten und verhehsaufkommen, verhalten auf der strasse. Naturschutz und Landschaftspflege in Baden - Wurttemberg 41: 175-186.

Kuitunen, M., Rossi, E. and Stenroos, A. 1998. Do highways influence density of land birds? *Environmental Management* **22**, 297-302.

Langton, Thomas E. S. 1989. Toad Tunnel Conference: Amphibians and Roads Proceedings of the Toad Tunnel Conference, Rendsburg, Federal Republic of Germany, 7-8 January 1989. Shefford, Bedfordshire, England. 202 pp.

Laursen, K. 1981. Birds on roadside verges and the effect of mowing on frequency and distribution. *Biol.Conserv.* 20, 59-68.

Lehtinen, R. M. S. M. Galatowitsch and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands* 19: 1-12.

Litvaitis J. A., J. P. Tash 2008. An approach toward understanding Wildlife-vehicle collisions.*Environmental Management.,* 42: 688-697.

Mader, H.J., 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29, 81–96.

Mader, H.J. 1987. Direckte und indireckte einflüsse des Strassennetzesauf die freilebende tierwelt und auf die Populationsdynamik. In: Bernard, J.-M., Lansiart, M., Kempf, C. and Tille, M., (Eds.) *Actes du colloques "Route et fauna sauvage". Strasbourg, 1985*, pp. 19-29. Colmar, France.: Ministère de l'Equipement, du Longement, de l'Aménagement du Territoire et des Transports. *Andreas Seiler: Ecological effects of roads* 36(40).

Mader, H.J., Krause, A. and Brandes, D. 1983. *Zur Tier und Pflanzenwelt an Verkehrswegen. Sonderheft 4 der Dokumentation für Umweltschutz und Landschaftspflege.* Bonn-Bad Godesberg, Germany: Bundesforschungsanstalt für Naturschutz und Landschaftsökologie.

Mazerolle, M. J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. *Herpetologica* 60: 45-53.

McClure, H. E. 1951. An analysis of animal victims on Nebraska’s highways. *Journal of Wildlife Management* 15: 410-420.

Menon, V., Tiwari, Sandeep Kumar, Easa, P.S. and Sukumar, R. 2005. Right of Passage: Elephant Corridors of India. Conservation Reference series No. 3, Wildlife Trust of India, New Delhi.

Meunier, F.D., Verheyden, C. and Jouventin, P. 1999 Bird communities of highway verges: Influence of adjacent habitat and roadside management. *Acta Oecologica-International Journal Of Ecology* **20**, 1-13.

Mohnot, S. M. 1974. Ecology and behaviour of the common Indian langur, *Presbytis entellus*. PhD Thesis. University of Jodhpur, Jodhpur.

Neill, W. T. 1950. Reptiles and amphibians in urban areas of Georgia. *Herpetologica* 6: 113-116.

Nevena Kambourova-Ivanova, Yordan Koshev, Georgi Popgeorgiev, Dimitar Ragyov, Milena Pavlova, Ivelin Mollov, Nedko Nedialkov 2012. Effect of traffic on mortality of amphibians, reptiles, birds and mammals on two types of roads between Pazardzhik and Plovdiv region (Bulgaria) preliminary results. *Acta zool. bulg.,* 64 (1), 57-67.

Palis, J. G. 1994. *Rana utricularia* (Southern leopard frog) road mortality. *Herpetological Review* 25: 119.

Pierre-LePense, A.-M. and Carsignol, J., (Eds.) 1999. Actes des troisièmes rencontres "Route et fauna sauvage". Ministère de l'Equipement, des Transports et du Longement et Ministère de l'Aménagement du Territoire et de l'Environnement, Paris, France 460 pp.

Pragatheesh, A. 2011. Effect of human feeding on the road mortality of Rhesus Macaques on National Highway - 7 routed along Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa* 3(4): 1656–1662.

Prillevitz, F.C. 1997. Fragmentation, not forever. In: Canters,K., Piepers,A. and Hendriks-Heersma,A., (Eds.) *Proceedings of the international conference on*

Habitat fragmentation and infrastructure in Maastricht & DenHague 1995, Delft, The Netherlands: Ministry of Transport, Public Works and Water Management, Road and Hydraulic Engineering division.

Rajpurohit, L. S. 1987. Male social organization in Hanuman Langur (*Presbytis entellus*). PhD Thesis. University of Jodhpur, Jodhpur.

Räty, M. 1979. Effect of highway traffic on tetraonid densities. *Ornis Fenn.* **56**, 169-170.

Reck, H. and Kaule, G. 1993. *Strassen und Lebensräume: Ermittlung und Beurteilung strassenbedingter Auswirkungen auf Pflanzen, Tiere und ihre Lebensräume.* Bonn-Bad Godesberg, Germany. Bundesministerium für Verkehr, Abteilung Strassenbau.

Reh, W. and A. Seitz. 1990. The influence of land use on the genetic structure of populations of the common frog *Rana temporaria*. *Biological Conservation* 54: 239-249.

Reijnen, R. and Foppen, R. 1994. The effects of car traffic on breeding bird populations in woodland. 1. Evidence of reduced habitat quality for willow warblers (*Phylloscopus trochilus*) breeding close to a highway. *J. Appl. Ecol.* **31**, 85-94.

Reijnen, M., Veenbaas, G. and Foppen, R. 1995. *Predicting the effects of motorway traffic on breeding bird populations*. Delft, The Netherlands.: Road and Hydraulic Engineering Division and DLO-Institute for Forestry and Nature Research, P-DWW-95-736.

Reijnen, R., Foppen, R., Terbraak, C.J. and Thiessen, J. 1995. The effects of car traffic on breeding bird populations in woodland. 3. Reduction of density in relation to the proximity of main roads. *J.Appl.Ecol.* **32**, 187-202.

Rodda, G. H. 1990. Highway madness revisited: roadkilled *Iguana iguana* in the Llanos of Venezuela. *Journal of Herpetology* 24: 209-211.

Rodts, J., Holsbeek, L. and Muyldermons, S. 1998. Dieren onder onze wielen. - Koninklijk Belgisch Verbond voor de Bescherming van de Vogels.

Rosen, P. C. and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona*.* *Biological Conservation* 68: 143-148.

Rutherford, P. L. and P. T. Gregory. 2003. Habitat use and movement patterns of northern alligator lizards (*Elgaria coerulea*) and Western skinks (*Eumeces skiltonianus*) in southeastern British Columbia. *Journal of Herpetology* 37: 98-106.

Sanjay Gubbi. Poornesha, H. C. and Madhusudan, M. D. 2012. Impact of vehicular traffic on the use of highway edges by large mammals in a South Indian wildlife reserve. *Current Science,* 102 (7): 1047-1051.

Seiler, A. 2001. Ecological effects of roads – A review. Introductory Research Essay No. 9, Department of Conservation Biology, SLU

Scanlon, P.F. 1991. Effects of highway pollutants upon terrestrial ecosystems. In: Hamilton, R.S. and Harrison, R.M., (Eds.) *Highway pollution. Studies in environmental sciences*, pp. 281-338.Amsterdam: Elsevier.

Schmidley, D.J. and Wilkins, K.T. 1977. *Composition of small mammal populations on highway right-of-way in east Texas.* Texas State Department of Highways ana Public Transportation, Research Report 197-1F.

Selvan, K. M. Sridharan, N. and Sajan John. 2011. Roadkill animals on National highways of Karnataka, India. *Journal of Ecology and the Environment Vol. 4(14), pp. 362-364.*

Semlitsch, R. D. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64: 615-631.

Shine, R., M. Lemaster, M. Wall, T. Langkilde, and R. Mason. 2004. Why did the snake cross the road? Effects of roads on movement and location of mates by garter snakes (*Thamnophis sirtalis parietalis*). Online report. www.ecologyandsociety.org. vol. 9, iss. 1, article 9.

Sjölund, A., Eriksson, O., Persson, T. and Hammarqvist, J. 1999. *Vägkantsfloran*. Borlänge, Sweden: Swedish National Road Administration, Publ. 1999:40.

Smith B. 1990. Nature conservation and transport. *Landscape Design*, 51: 3.

Smith L. L., C. K. Dodd 2003. Wildlife mortality on U.S. Highway 441 across Paynes Prairie, Alachua County, Florida. *Florida Scientists*, 66 (2): 128-140.

Southwick, C. H., M.F. Sidiqi, M.Y. Farooqui & B.C. Pal (1976). Effects of artificial feeding on aggressive behaviour of rhesus monkeys in India. *Animal Behavior* 24(1): 11–15.

Spellerberg, I.F. 1998. Ecological effect of road and traffic: a literature review. Glob. Ecol. Biogeogr. lett. 7:311-313

Stansfeld, S.A., Sharp, D.S., Gallacher, J. and Babisch, W. 1993.Road traffic noise, noise sensitivity and psychological disorder. *Psychological Medicine* **23**, 977-985.

Stuart, S., Hoffmann, M., Chanson, J., Cox, N., Berridge, R., Ramani, P., and Young, B. (eds) 2008. *Threatened Amphibians of the World.* Lynx Edicions, IUCN, and Conservation International, Barcelona, Spain; Gland, Switzerland; and Arlington, Virginia, USA.

Sullivan, B. K. 1981. Distribution and relative abundance of snakes along a transect in California. *Journal of Herpetology* 15: 247-248.

Trombulak S. C., C. A. Frissell 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, 14 (1): 18-30.

Turtle, S. L. 2000. Embryonic survivorship of the spotted salamander (*Ambystoma maculatum*) in roadside wand woodland vernal pools in southeastern New Hampshire. *Journal of Herpetology* 34: 60-67.

Tyser, R.W. and Worley, C.A. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National-park, Montana (USA). *Conservation Biology* **6**, 253-262.

Usher, M.B. 1988. Biological invasions of nature reserves. *Biol.Conserv.* 44, 119-135.

Uthaman PK. 1993. Birds of Wayanad Wildlife sanctuary - a survey report. Report submitted to the Kerala State Forest Department

Van den Tempel, R. 1993. Vogelslachtoffers in het wegverkeer (in Dutch with English summary).- Vogelbescherming Nederland, Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat.

Van der Zande, W.J. ter Keurs & W.J. Van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat- evidence of a long-distance effect. *Biol. Conserv.*18: 299-321.

Van der Sluijs, J. and Van Bohemen, H.D. 1991. Green elements of civil engineering works and their (potential) ecological importance. In: Van Bohemen, H.D., Buizer, D.A.G. and Littel, D., (Eds.) *Nature engineering and Civil Engineering Works*, pp. 21-32. Wageningen, The Netherlands: PUDOC.

Van der Zande, A.N., ter Keurs, W.J. and Van der Weijden, W.J. 1980. The impact of roads on the densities of four bird spesies in an open field habitat - evidence of a long-distance effect. *Biol.Conserv.* **18**, 299- 321.

Van Gelder, J. J. L. 1973. A quantitative approach to the mortality resulting from traffic in a population of (*Bufo bufo*). *Oecologia* 13: 93-95.

Veen, J. 1973. De verstoring van weidevogelpopulaties. *Stedeb.en Volkshuisv.* **53**, 16-26. *Andreas Seiler: Ecological effects of roads* 40(40).

Vestjens, W. J. M. 1973. Wildlife mortality on a road in New South Wales. *Emu* **73**, 107-112.

Way, J. M. 1977. Roadside verges and conservation in Britain: a review. *Biol.Conserv.* **12**, 65-74.

Whitaker, R. and Captain, Ashok. 2008. Snakes of India – The Field Guide. Draco Books, Chennai, India.