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RESEARCH ARTICLE

Effect of road kills on wildlife populations in Kalakad Mundanthurai Tiger Reserve, India

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Abstract

The effects of road traffic mortality on wild animal populations are in many cases hard to estimate and speculate, primarily due to the inaccuracy of the methods employed in studies. On Tiger reserve forest roadways totally, 1450 road kills belonging to 29 species was recorded during different seasonal road mortality in monsoon, winter, summer and pre-monsoon seasons on selected road sections in KMTR and have critically reviewed methods used for estimating the impact of road traffic on migrating animals. Species-specific parameter estimates of mortality, evaluated on ordinary and special day basis counts of road kills, road kills variables, seasonal variations of vehicle entry were positively correlated with the mean body mass of the species. The current status shows that high amount of road kill on forest routes have adverse impact on forest ecosystem that result from increased contact with humans and their behavior.

Introduction:-

Wildlife-vehicle collisions are destructive to motorists and wildlife populations. The influence of roads on wildlife comprises habitat fragmentation, alteration of movement patterns, and mortality from collisions with vehicles (Forman and Alexander, 1998; Trumbulak and Frissell, 2000, Forman et al., 2003). Roads might influence wildlife populations by dropping dispersal success, reducing gene flow between populations, and constitute a basis of mortality for some species (Maehr et al., 1991; Trombulak and Frissell, 2000). Many of the environmental collisions associated with roads might enlarge beyond the road surface and associated right-of-way (Forman and Deblinger, 2000). Drivers might maintain property damage or personal injury in the event of a wildlife-vehicle impact, mainly when involved in collisions with large ungulates (Conover et al., 1995; Romin and Bissonette, 1996, Malo et al., 2004).

Different taxonomic groups worldwide are affected by vehicle collisions, including birds (Erritzoe et al., 2003), reptiles (Bernardino and Dalrymple, 1992), amphibians (Fahrig et al., 1995), mammals (Oxley et al., 1974; Drews, 1995; Clarke et al., 1998), and invertebrates (Mackenzie et al., 2001). At the global level, collision with vehicles go beyonds hunting as the foremost direct human cause of terrestrial vertebrate mortality (Forman and Alexander, 1998). Road kill rates can exceed natural mortality (Ferreras et al., 1992), moving the density (Huijser and Bergers, 2000) and sex structure (Gibbs and Steen, 2005) of wild populations. Associated with fragmentation effects of roads, casualties can effect in population declines, inbreeding, and local extinctions (Row et al., 2007). Due to the known impacts of road kill on wildlife populations, events to mitigate faunal casualties are required. However, to improve the effectiveness of such measures, local evaluations of road kills may be significant before adoption of general recommendations for mitigation like crossing structures. The mortality of animals' collision with vehicle is well recognized (Groot and Hazebroek, 1996). 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; Hodson, 1966) birds and other animals collision with vehicle and trains are common (Chhangani, 2004). Owing to the wide development of road networks, millions of animals were killed annually (Bujoczek et al., 2011). Roads across the wildlife refuges are an intrusion and affect the wildlife and its habitats unfavorably.

In India, highways bisect many sheltered areas. It has been understand in recent years that highways cause severe impact to wildlife and their habitats (Gokula, 1997; Vijayakumar et al., 2001; Das et al., 2007). The negative impact of roads on wildlife has dramatically amplified with the increased networks of roads throughout the world (Vijayakumara et al., 2001). This impact on the natural environment has been questioned. Is there a selection of victims in the vehicles collisions? Further the road-kills of ecological balancing species influence a population by eliminating individuals in poor condition. Small but significant chances of small animals getting run over on forest routes are high, but such road kill often goes unrecorded as focus has been on the conservation of big animals. But they are also equally important to conserving, primarily millipedes, reptiles, amphibians, birds and small mammal species are frequent passing the road ways not only to cross the fragmented habitat, but they are also use roads as an open area to ambush prey, as well as use the road surface for thermal regulation (Bambaradeniya et al., 2001; Karunarathna, 2005). Herpetofaunal mortality due to vehicular traffic on roads and highways is considered a significant threat to species inhabiting forested areas adjoining roads (Das and de Silva, 2005; Karunarathna and Amarasinghe, 2011). Amphibians are probably the best indicators of environmental health of all vertebrates (Daniels, 2002). Increasing millipedes and amphibians dead was more vulnerable to highway mortalities due to comparatively slow movements while crossing the roads. But the effects get compounded due to increased mobility during rainy periods and mass reproductive migrations (Trombulak and Frissell, 2000). Nowadays, the greatest effect of road traffic is on the number of birds killed annually (Pons, 2000). The scale of this phenomenon is millions of individuals killed every year by car collisions (Erritzoe et al., 2003). Recent studies have examined road-system planning and creation of mitigation measures; nature conservation included as an objective with road safety, effectiveness, and the cost of human use (Forman et al., 2003). Road avoidance (van der Zande et al., 1980), barrier effects (Bhattacharya et al., 2003), impacts on aquatic ecosystems (Jones et al. 2000), and planning and evaluation of mitigation systems for wildlife (Yanes et al., 1995; Clevenger et al., 2002; Lesbarrères et al., 2004; Clevenger and Waltho, 2005) are now discussed more than in the past.

Traffic may be destructive to animal populations in two ways: directly, in the sense of in fact killing individuals and not directly, by fragmenting a population's habitat (Mader, 1984; Mader et al., 1990; Andrews, 1990; Reed et al., 1996). Fragmentation in revolve may lead to isolation of populations which again may result in a reduced population size and an increased stochastic risk of extinction (Bennett, 1990). Several studies have quantified road kills of many different taxa, e.g. toads (van Gelder, 1973; Cooke, 1995), birds, mammals, amphibians, and reptiles (Hansen, 1982; Fuellhaas et al., 1989), butterflies (Munguira and Thomas, 1992), snakes (Rosen and Lowe, 1994), mammals, birds and reptiles (Drews, 1995), deer and other ungulates (Romin and Bissonette, 1996). Kalakad Mundanthurai Tiger Reserve (KMTR), 895 km^2 (8^{o}25′–8^{o}53′ N and 77^{o}10′ –77^{o}35′ E) is located in the South Indian state of Tamil Nadu. It comprises a matrix of habitats ranging from thorny scrub to the wet evergreen forests thus supporting a high diversity of flora and fauna (Johnsingh, 2001). It has several forest routes, they are mostly used by the pilgrims and tourism activity although the other roads are used by the forest department, electricity board and private estate peoples. Increasing road kills engendered by the increasing vehicles are subjected to evaluate the mortality of species kill. In the present study was to compare the seasonal variations of mortality, ordinary (Low in vehicle presence) and special (High in vehicle presence) days vehicles movement and relevant road kill variables were studied in KMTR.

Material and Methods:-

Study area

Data were collected from pilgrims and tourism dominated forest route of Ambasamudram division ranges of Papanasam and Mundanthurai. Survey works were carried on four anthropogenic pressures dominated forest roads of the Tiger Reserve (08.71-08.64N and 77.36-77.31E). Elevation of the area is between 102 to 277m. The assessment roads were beginning from the (i) Papanasam check post to Sorimuthaiyanar(SM) Temple (10km), (ii) SM Temple main road to Karayar dam (4km), (iii) Mundanthurai range office to Servalar dam (5km) and (iv) Lower dam road to Agasthiar falls (1km). The survey was done in 20kms road, which comprised of both sides of dry deciduous and mixed deciduous forests. The temperature varies from 20 to 32˚C and the seasonal rainfall ranges from 16 to 583mm.

Road kill survey

Road kill data were sampled from October 2013 to September 2014. It has included of four climatic seasons like monsoon, winter, summer and pre-monsoon. The roads were systematically surveyed in morning 7am to 10am through personal observation (15 to 20km/h vehicle speed). Each forest routes were surveyed on 42 ordinary days (Wednesday) and 42 special days (Saturday). Trials were made on forest routes. The overall percentage of mortality rate was calculated in habitat, vehicle movement and season wise. Dead animals (counted) were removed from the road to avoid the repetition. The road kills were recorded according to vehicular movement and other variables influences of animal kill was identified. We have not preserved any animals during our survey.

Road kill variables and models

We have measured eight variables to be used as possible factors for road kill explanation. Vegetative cover, habitat, topography were estimated visually and elevation and visibility were measured by the GPS and range finder. Road width and side open area was measured by the measuring tape. A range finder (Olympus®1000, e-Trex vista H®) was used to measure distance to nearest vegetative cover and the inline and angular visibility measurements. Field visibility variables estimated the extent to which a motorist could see birds on the road right-of-way, or conversely how far away an oncoming vehicle could be seen from the side of the road. Spatial and elevation data were collected along each forest routes approximately every 2km. Elevation was obtained on-site from a GPS unit for the spatially accurate data locations, whereas elevation for the mile-marker points was extracted from the GPS-created track layer.

Statistical analysis

Differences between the seasons were determined by Tukey's multiple range test and ANOVA were used to detect the difference in ordinary day, special day, rainfall and vehicle entry among the routes. Difference between means was considered significant at ($P \leq 0.05$) (Snedecor and Cochran, 1989; SAS Institute, 2001).

Results:-

Road kills survey

On Tiger reserve forest roadways totally, 1450 road kills belonging to 29 species was recorded during monsoon, winter, summer and pre-monsoon season road kills survey (Table 1). Of the 1450 road kills, 49.96% , 28.07%, 6.76% and 18.21% were recorded at monsoon, winter, summer and pre-monsoon season, respectively and surveys of the four roads (1680km of 84trails) over twelve months. Among the 681 (46.96%) road kill in monsoon season both special and ordinary day, diplopoda's were the most affected accounting for 70.10% ($F_{1,8}$=19.16, p<0.000), followed by reptilia and insecta were 11.87% ($F_{1,8}$=11.26, p<0.000) and amphibia 6% ($F_{1,8}$=2.71, p<0.001) as well as mammalia 1.14% ($F_{1,8}$=1.69, p<0.001). There was high mortality in diplopoda during monsoon season due to the slow moving behavior and significant difference between the individuals. Despite the low number of aves was moved and least affected by the vehicular traffic and comprised 0.85% ($F_{1,8}$=1.18, p<0.001) of the total 29 species excluded gastropoda (Fig.1). There was no significant difference between movement rates of aves individuals moving in monsoon.

Further, among the 407 (28.07%) road kills in winter season both special and ordinary day, the most abundant group of killed animals were diplopoda's accounting for 42.98% ($F_{1,8}$=48.73, p<0.001), followed reptilia, insecta, amphibia and gastropoda were 19.42% ($F_{1,8}$=14.26, p<0.000), 17.61% ($F_{1,8}$=1.98, p<0.001), 19.42% ($F_{1,8}$=13.20, p<0.000) and ($F_{1,8}$=5.88, p<0.001), respectively. There was significant difference between the individuals and greater mortality in diplopoda during winter due to the slow moving behaviour. Aves and mammalia was low number of moved and killed by vehicular traffic and comprised 0.59% ($F_{1,8}$=8.98, p<0.001) and 0.29% ($F_{1,8}$=5.71, p<0.001), respectively (Fig. 2). There was no significant difference between movement rates of aves and mammalia, those moving in winter.

In the summer season, among the 98 (6.76%) road kills both special and ordinary day, at first diplopoda's were the most affected accounting for 50.96% ($F_{1,8}$=11.05, p<0.000), followed amphibia, insecta and mammalia were 7.84% ($F_{1,8}$=1.70, p<0.001), 22.54% ($F_{1,8}$=2.68, p<0.001), and 8.82% ($F_{1,8}$=2.09, p<0.001), respectively. There was significant difference between the individuals and greater mortality in diplopoda during summer due to the slow moving behaviour. Aves and reptilia were least as well as equally affected by vehicular traffic and comprised 2.94%

($F_{1,8}$=8.33, p<0.001) of the total 17 species excluded gastropoda (Fig. 3). There was no significant difference between movement rates of aves and reptilia, those moving in summer.

Finally, belonging the 264 (18.21%) road kill in pre-monsoon season both special and ordinary day, the most abundant group of killed animals were diplopoda's accounting for 54.54% ($F_{1,8}$=17.0, p<0.000), followed by reptilia, insecta, amphibia and mammalia were 17.42% ($F_{1,8}$=6.68, p<0.000), 9.85% ($F_{1,8}$=5.98, p<0.001), 9.85% ($F_{1,8}$=1.45, p<0.001) and 8.34% ($F_{1,8}$=4.0, p<0.001), respectively. There was significant difference between the individuals and high mortality in diplopoda during pre-monsoon due to the dawdling moving behavior. It was shown moderately affected by the vehicular traffic than the diplopoda of the total 29 species excluded aves and gastropoda (Fig. 4). Road mortality is probably the most acknowledged effect of traffic on wildlife, as carcasses of dead are a common view along trafficked roads (Fig. 5).

Road kills variables and models

Road kills associated with some of the relevant influencing factors to determine the amounts of mortality in forest road kills. Such variables were measured in obtainable condition to predict the factors of road kill. We measured site-specific variables at sites from the spatially accurate data and mile-marker dataset between Oct 2013 and Sep 2014. Table 2. shows the results of the univariate comparison of each environmental variable contributing to the probability in each dataset. Both datasets had variables in each group that were significant in detecting differences between high and low kill zones within all the datasets. Within the spatially accurate dataset, Table 2. shows eight of the field-based variables (habitat class, topography, vegetation cover, elevation, visibility, alignment, road width and road side open area), while only two of the field variables (road width and topography) were significant from the mile-marker dataset.We addressed specific questions as to which landscape and road-vehicular factors contribute to this non-random distribution of collisions in the study area.

Seasonal variations of vehicle entry in specific days

Analysis of diversity parameters of road kills has shown a peak in vehicle entry and rainfall at special and ordinary day during October to December (2013) for monsoon, January to March (2014) for winter, April to June (2014) for summer, July to September (2014) for pre-monsoon in tiger reserve. Significant variations of vehicles were highly recorded in December and January except November and March comparatively low vehicular entry at special day and further variations were highly noticed in December and January except November and March at ordinary day (Fig. 6 a,b). Although we expected at rainfall season in November an increased mortality of organisms when compared to the month of February and May. Further in summer season special and ordinary days of vehicular entry was very high in May (Fig. 6c) due to the summer holidays and also in pre-monsoon season, the vehicle was extremely entered in July (Fig.6d), moderate entry in August and very low moving in September. The variations between the different seasons and vehicle entry have shown significant difference in both specific and ordinary days.

Relation between the rainfall, road kill and vehicle movement

The data's of the road kills have revealed that the vehicle movement and rainfall to determine the mortality rate. The results indicate that increased mortality of the road kills and low rainfall as well as moderate vehicle movement was recorded in July during pre-monsoon season (Fig.7). There was no significant differences were found between the three relations.

Discussion:-

One approach is to found the mortality of road-crossing migrants (henceforth referred to as the road-crossing mortality) and establish the fraction of an entire population that crosses the road. The road-crossing mortality has been recorded either by continuous counting of all individuals on a road, both dead and alive (van Gelder, 1973), or by a combination of continuous counting and road fencing (Kuhn, 1987; Gibbs and Shriver, 2005). Populations of slow moving animals and those which frequently cross roads suffer in particular from the negative effects of increased mortality due to vehicle collisions (Coffin, 2007). The slow moving behavior of arthropods with slow movement with their leaded to the mortality while cross the road. Because their movement was very slow when compared with vehicle speed. Therefore among soil arthropods and millipedes primary destructors of plant debris and play a crucial role in soil formation procedure was failure. Hundred numbers of millipedes is equal to one tiger in the role of forest ecosystems.

In most cases, only a fraction of the population crosses the surveyed section of the road, and thus the road-crossing mortality (i.e., mortality calculated for this fraction only) is higher than the road mortality of the entire population, which can be estimated by complex modeling as engaged by Gibbs and Shriver et al. (2005). A straightforward elucidation for the species differences in amphibian road mortality between rural and suburban landscapes is that it reflects differences in relative species abundance, which is what is assumed in British monitoring studies of amphibian decline (Cooke and Sparks, 2004). In a full agreement with this explanation, differences in the colonization rates of pools by three most common amphibian species in the Netherlands are related to their great quantity. It follows that monitoring amphibian road mortality may prove to be the most effective method of detecting overall population trends in addition to determining the impact of vehicular traffic. There was greater mortality in amphibians and reptiles during rainy season than summer due to the slow moving behavior of those species (Baskaran and Boominathan, 2010; Selvan, 2012). Most of the amphibians were unidentified due to the vehicle ran over the animals and the data was shown higher mortality during rainy season (Vijayakumar 2001 and Selvan, 2012). Moreover, millipedes are serving as an indicators of environmental conditions and improve the structure content of organic matter and nutrient elements of soil progress also destructed by the road kill. The rainfall also influenced with the road kill species. In case of reptiles, has shown the highest mortality due to their use of road substrate for their thermo regulation (Vijayakumar, 2001; Das et al., 2007). The fact that birds were getting killed more in rainy season than the summer due to the herpetofaunal movement on the road during rainy season (Selvan, 2012).

A key aim of the study was to use the road kill survey data to access whether particular attributes of the road or surrounding landscape had an influence on the frequency with which species were killed on roads. Such information could be useful for road management designed to minimize road kills (Taylor and Goldingay, 2004). The road kill encounter rate was highest in forest with 55 kills/km, followed by the agriculture with 38.33 kills/km and water body being least with 26.66 kills/km (Seshadri et al., 2009). The few of the variables were significant predictors of road kills for seven species like insecta, diplopoda, amphibia, mammalia, aves, reptilia and gastropoda. Arthropods had the high mortality followed by the insecta, diplopoda, amphibia, mammalia, aves, reptilia and gastropoda. The master piece of road kills varied according to vegetation, habitat, topography and visibility. Among the field-based variables, only two were identified in the mile-marker dataset as being significant in detecting differences between UVC high and low kill zones. The same variables were also identified among the six significant variables in the spatially accurate dataset. Two of the variables from the distance to landscape features and GIS-generated buffer variables were significant from the spatially accurate dataset, whereas the mile-marker dataset had none.

Univariate tests are often used as a preliminary step to identify variables (or combinations of them) that are most likely good predictors of responses to include in an a priori logistic regression analysis (Hosmer and Lemeshow, 1989). The results of the univariate tests of significance provide an interesting comparison of how well each dataset is able to describe the relationship between predictor variables and the location of UVCs. Seshadri et al. (2011) was observed mammals like Wild pig *(Sus scrofa)*, Leopard *(Panthera paradus)*, Deers, Civets and Bears cross the road when the separation time between vehicles is ca. 2 min. We have shown the eight variables used in the initial univariate test to identify variables that differed significantly between high and low UVC kill zones, roughly half of the spatially accurate variables compared to only 3 (ca.10%) of the mile-marker variables were statistically significant. Arthropods, reptiles and amphibians mortality were high in mixed deciduous and teak dominated places. Other reviewed study, found that ungulates use road and riparian corridors as movement pathways, increasing their risk of collisions with vehicles (Gunson et al., 2009).

Moreover, birds and mammals getting killed in dense area due to their poor visibility, which was covered by the shrubs and bushes closer to the vehicles movement dominated forest places. Arthropods had the highest mortality since they came to across the road for their leaf dwelling. And insects was observed that the owlet and nightjars often come to road; also, high flying birds crossing the road unfortunately getting killed by vehicles. Among mammals macaque was found to be high in tourist zone due to the begging behavior and the mammals kill were high in summer and it might be in search of food and water.

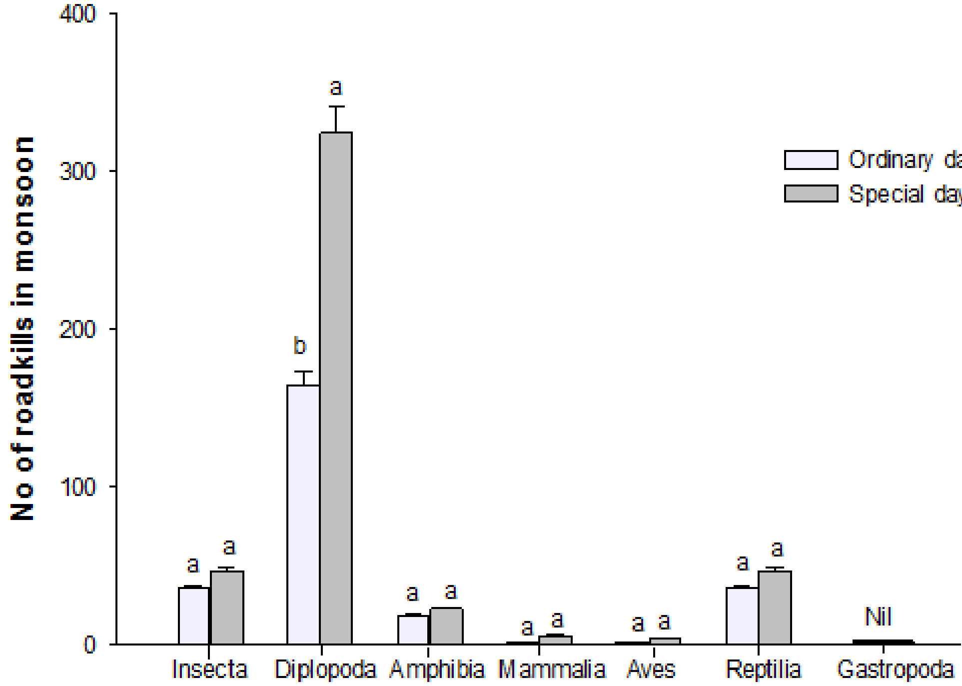

Fig.1. Number of road kills in monsoon season. Mean (±SEM) followed by the same letter in each animal in bars indicate no significant difference (P<0.05) in a Tukey's test.

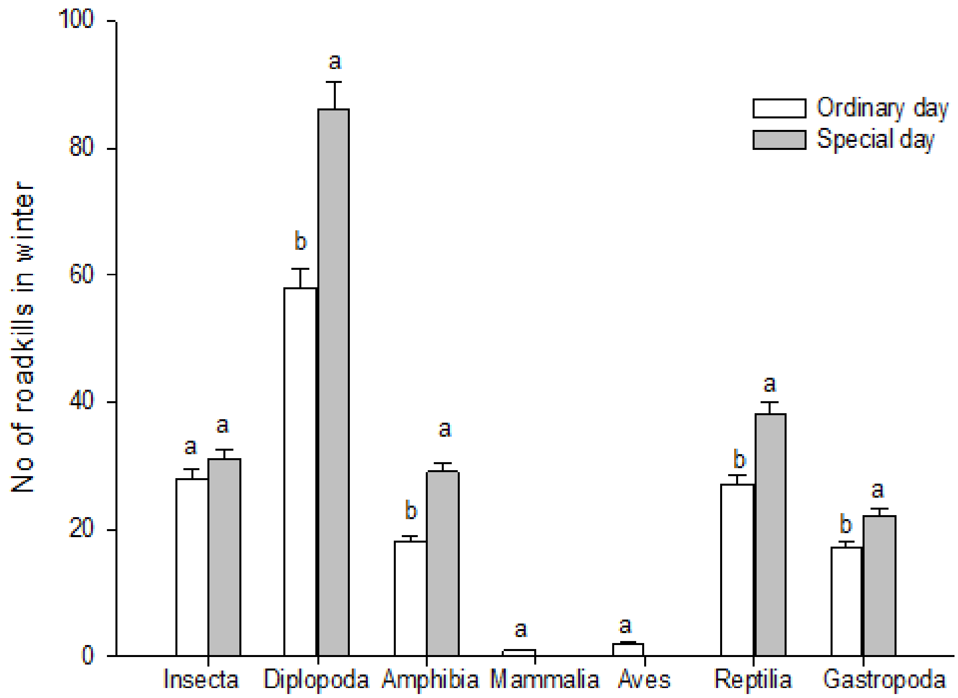

Fig.2. Number of road kills in winter season. Mean (±SEM) followed by the same letter in each animal in bars indicate no significant difference (P<0.05) in a Tukey's test.

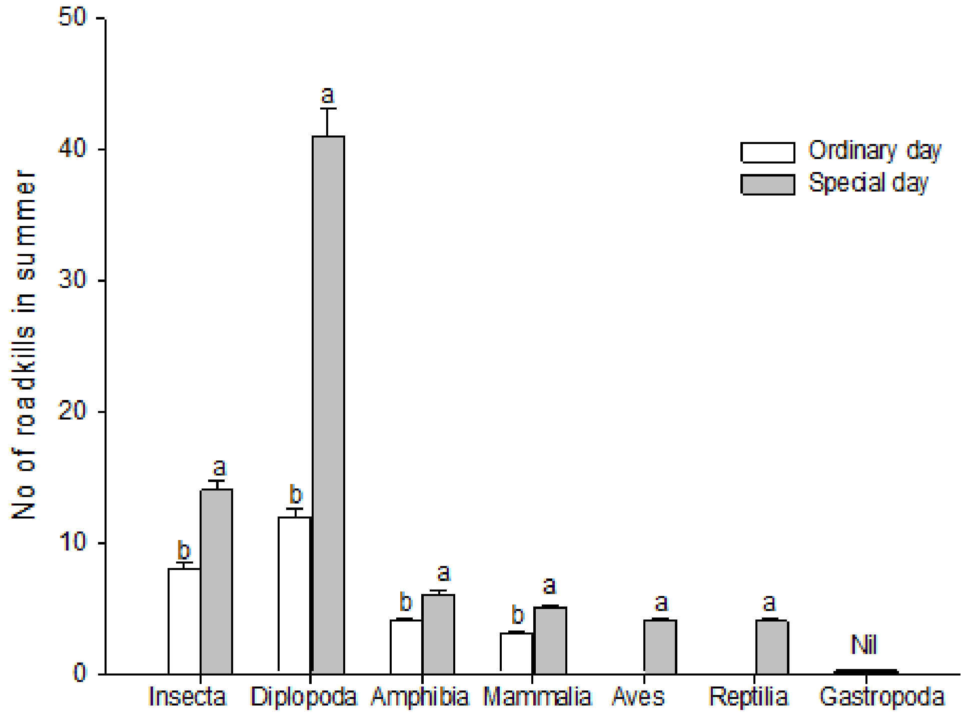

Fig.3. Number of road kills in summer season. Mean (±SEM) followed by the same letter in each animal in bars indicate no significant difference ($P<0.05$) in a Tukey's test.

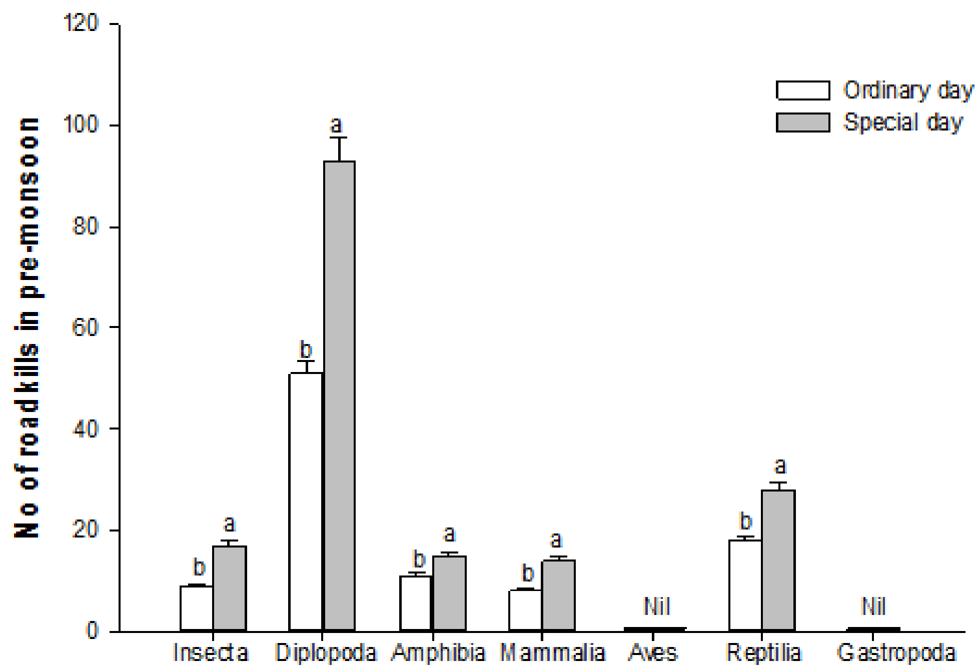

Fig.4. Number of road kills in post-monsoon season. Mean (±SEM) followed by the same letter in each animal in bars indicate no significant difference ($P<0.05$) in a Tukey's test.

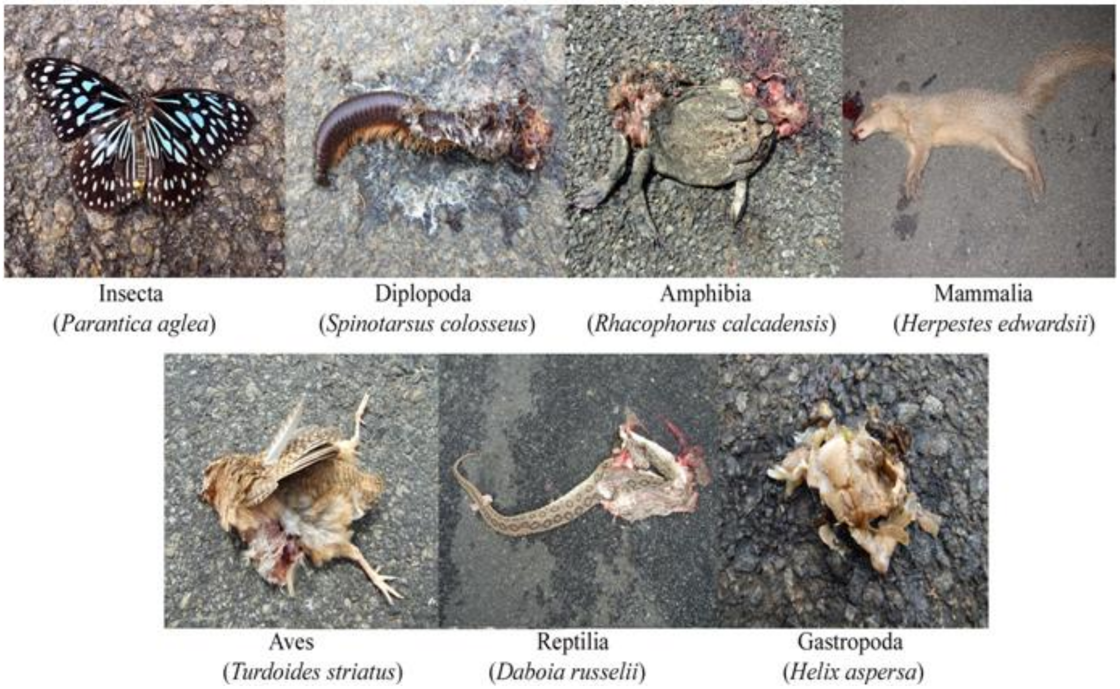

Fig.5. Wildlife casualties in KMTR.

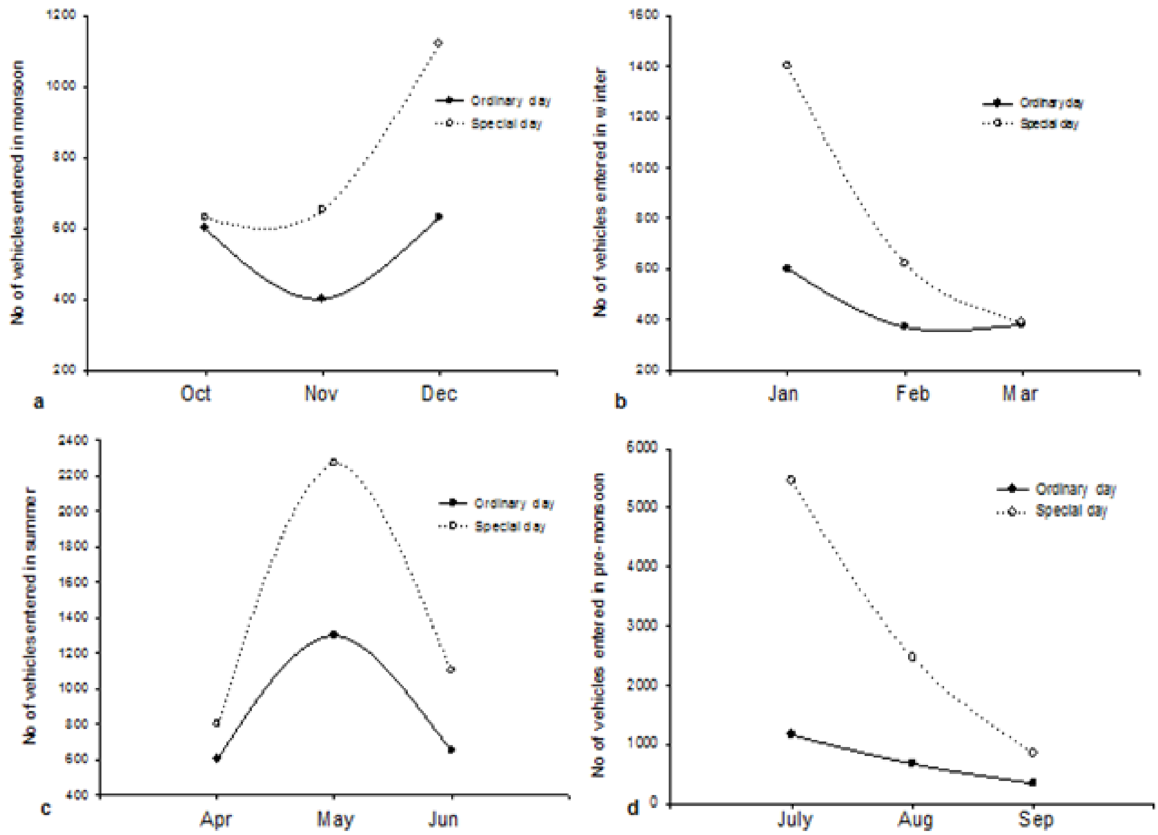

Fig.6. Seasonal variations of vehicle entry in special and ordinary days

a) Number of vehicles entered in monsoon b) Number of vehicles entered in winter c) Number of vehicles entered in summer d) Number of vehicles entered in post-monsoon.

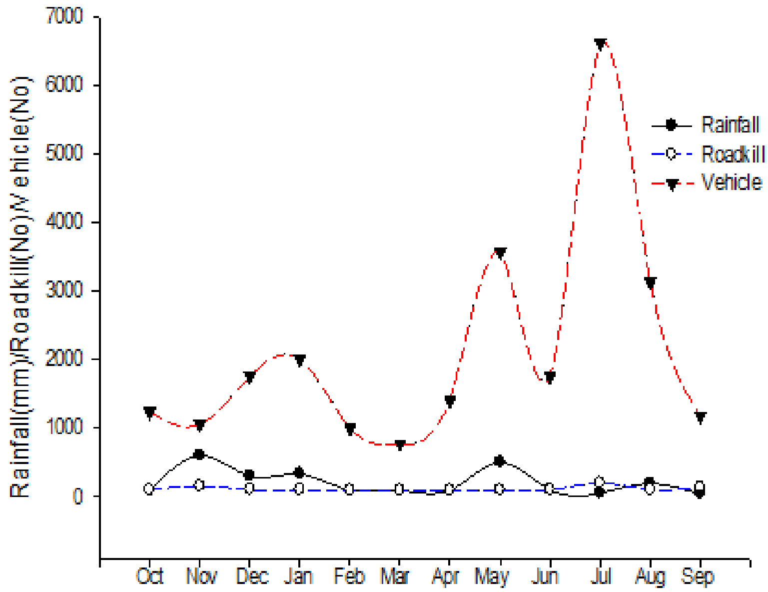

Fig.7. Seasonal variations and differences in Rainfall/ Road kill/ vehicle entry.

S.No	Common name	Species name	Number of road kills recorded
I	**Amphibians**		
1	Common Indian Toad	*Duttaphrynus melanostictus*	67
2	Southern Burrowing Frog	*Sphaerotheca rolandae*	35
3	Bi-coloured Frog	*Clinotarsus curtipes*	24
II	**Reptiles**		
1	Common Green vine Snake	*Ahaetuna nasuta*	9
2	Hump Nose pit Viper	*Hypnale hypnale*	5
3	Elliot's shied tail	*Uropeltis ellioti*	4
4	Russell's viper	*Daboia russelii*	1
5	Sand boa	*Eryx johnii*	2
6	Indian Rat snake	*Ptyas mucosa*	5
7	Monitor Lizard	*Varanus bengalensis*	3
8	Common Skink	*Mabuya carinata*	27
9	Green forest Lizard	*Calotes calotes*	48
10	Common garden Lizard	*Calotes versicolor*	72
11	Indian Black Turtle	*Melanochelys trijuga*	17
III	**Birds**		
1	Asian Koel	*Eudynamys scolopacea*	3
2	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	1
3	Common Tailor Bird	*Orthotomus sutorius*	3
4	Jungle Babbler	*Turdoides striatus*	5
IV	**Mammals**		
1	Three Striped Palm Squirrel	*Fanambulus palmarum*	14
2	Mouse	*Mus musculus*	18
3	Malabar Spiny Dormouse	*Platacanthomys lasiurus*	5
4	Jungle cat	*Felis chaus*	1
5	Indian gray mongoose	*Herpestes edwardsii*	3
V	**Insects**		
1	Common Crow	*Euploea core*	61
2	Common Lime	*Papilio demoleus*	37
3	Common Jezebel	*Dalias eucharis*	19
4	Baronet	*Eutbalia nais*	22
5	Blue Mormon	*Papilio polymnestor*	15
6	Mottled emigrant	*Catopsilia pyranthe*	23
7	Odonata (Dragon fly)	*Ortetrum cancellatum*	8
8	Grass hoper	*Melanoplus femurrubrum*	5
VI	**Arthropods**		

1	Millipedes	*Spinotarsus colosseus*	773
2	Pill Bug	*Arthrosphaera magna*	96
VII	**Mollusca**		
1	Snail	*Helix aspersa*	19
		Total	**1450**

Table.1. List of road kills recorded at Kalakad Mundanthurai Tiger Reserve (a total 1040km covered in 84 trails) between October 2013 and July 2014

S.No	Variables	Obtainable
1	Vegetation cover	0.1 - 0.4
2	Habitat	Deciduas and Mixed deciduas
3	Topography	Undulatary
4	Elevation	102 – 277m (MSL)
5	Visibility	0.5- 3m
6	Alignment	Straight and Curved
7	Road width	3.87m
8	Road side open area	0.5 -1m

Table.2. List of obtainable road kill variables

Conclusion:-

The present study shows that high amount of road kill on forest routes have adverse impact on forest ecosystem. The indirect effects of roads include changes or impacts that result from increased contact with humans and their activities. The residing people vehicles are also quite threaten and disturbed to the habitat and ecosystem. The growing number of pilgrims and tourists to the Sorimuthaiyanar temple and Karayar dam, which was situated inside the core area of the tiger reserve was resulted in lot of turbulence to the KMTR. Due to the heavy vehicular movement, lot of wild animals especially insecta, diplopoda, amphibia, mammalia, aves, reptilia and gastropoda were killed. Sometimes due to the disturbance of the wild animals are driven away from that area for quite some time. Creating awareness to drivers and local residing people about lower vertebrate's importance in forest ecosystem may be reducing road kill collisions in future.

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