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HERPETOFAUNAL MORTALITY DUE TO VEHICULAR TRAFFIC IN THE WESTERN GHATS, INDIA: A CASE STUDY

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Abstract: We monitored the mortality of herpetofauna on a fortnightly basis along National Highway 220, which cuts across the Western Ghats, India, during December 2006- November 2007. In all, 101 amphibians (3.5 amphibians/ 10km) belonging to six taxa and 78 reptiles (2.7 reptiles/ 10 km) of 23 taxa were found dead in 48 surveys. The mortality of amphibians during day and night was significantly different (Z= 3.12, n1= 24, n2= 24, P<0.01), whereas this was not so with respect to reptiles. The difference in the mortality of amphibians between seasons was not significant, but it was significant with respect to reptiles (Z= -1.188, n1= 24, n2= 24, p< 0.05). Overall, the road kills of amphibians were significantly correlated with that occurring in nearby forests (r = 0.67, n= 12, P< 0.01), but reptiles had no such relationship. The number of road kills of amphibians and reptiles on a monthly basis was not correlated with the intensity of vehicle plying on the road.

Keywords: Biodiversity hotspot, Asia, amphibians, reptiles, road kills.

Resumen: S. Bhupathy, G. Srinivas, N.S. Kumar, T. Karthik y A. Madhivanan. "Mortalidad de herpetofauna debido a tráfico vehicular en los Western Ghats, India: un caso de estudio". Monitoreamos la mortalidad de herpetofauna sobre una base bi-semanal a lo largo de la Autopista Nacional 220 que atraviesa los Western Ghats, India, durante diciembre 2006- noviembre 2007. En total, 101 anfibios (3.5 anfibios/ 10km) pertenecientes a seis taxones, y 78 reptiles (2.7 reptiles/ 10 km) de 23 taxones fueron encontrados muertos en 48 muestreos. La mortalidad de los anfibios durante el día y la noche fue significativamente diferente (Z= 3.12, n1= 24, n2= 24, P<0.01), mientras que esto no fue así con respecto a los reptiles (Z= -1.188, n1= 24, n2= 24, p< 0.05). En total, las muertes por arrollamiento en anfibios tuvo una correlación significativa con aquella que ocurre en bosques cercanos (r = 0.67, n= 12, P< 0.01), pero los reptiles no tuvieron tal relación. El número de anfibios y reptiles atropellados en la carretera sobre una base mensual no estuvo correlacionados con la intensidad de vehículos en la carretera.

Palabras clave: "Hotspot" de biodiversidad, Asia, anfibios, reptiles, muertes por arrollamiento.

INTRODUCTION

Globally, transportation of materials and people, especially by road, has become one of the major modes of travel. Roads fragment habitats; and with the growing networks, animals are increasingly forced to cross roads during their daily activities and hence are often killed by vehicles (Hourdequin 2000). Roads cause direct mortality of animals during construction and vehicular movement, changes in animal behaviour, alterations in the physical and chemical environment, spread of exotic species and land use pattern by humans (Trombulak and Frissell 2000 and Shepard 2008). Monitoring roads that cut across forests provides information on richness and relative abundance of species occurring in the area (Heyer *et al*. 1994). Based on regular road cruising, Klauber (1939) prepared an inventory of nocturnally active snakes.

Reports on the mortality of fauna due to vehicular traffic are available for various taxa; macro invertebrate soil fauna (Haskell 2000), herpetofauna (Rodsan and Lowe 1994, Fehrig *et al*. 1995, Gibbs and Shriver 2002, Andrews and Gibbons 2005, Glista *et al*. 2008, Elzanowski *et al*. 2009 and Langen *et al.* 2009), birds (Mumme *et al*. 2000) and mammals (Laurance *et al*. 2006). However, information in this regard is scanty in India (Gokula 1997, Vijayakumar *et al*. 2001, Sundar 2004, Das *et al*. 2007, Kannan 2007 and Rao and Girish 2007), and all these studies covered only one season or a few months. It is important to quantify the magnitude and the effect of vehicular traffic on faunal groups, which would help conserve them as various infrastructure projects, including roads, are planned to cater the growing needs of the country.

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As per the National Highway Authority of India, the country has the second largest road system in the world, which covers over 3.31 million kilometers including 26,697 km passing through wildlife habitats and forests (Rajvanshi *et al*. 2007). According to Rao and Girish (2007), in India, the total length of the road and number of motorized vehicles increased by about 10 fold (0.4 to 3.4 million kilometers and 0.3 to 3.0 million vehicles) during 1951- 2004. The Western Ghats, southwestern India, is one of the 34 Biodiversity Hotspots of the World (Mittermeier *et al*. 2005). Though the Western Ghats constitutes only 5% of the total land area of India, it harbors about 30% of India's biological species (Rodgers and Panwar 1988). A total of 130 species of amphibians and 165 reptiles have been reported from this hill range (Das and Dutta 2006 and Das 1996). Several National and State Highways connect the Indian state of Kerala and Tamil Nadu cutting across the Western Ghats. However, impact of these and other proposed road networks on wildlife is poorly understood. In the present paper, we report the mortality of herpetofauna along National Highway 220, which cuts across the Western Ghats.

METHODOLOGY

The present study was conducted along a stretch of six kilometers (Fig. 1) of the National Highway (NH 220; 9º.36'N, 77º.10'E and 9º.37'N, 77º.11'E) between December 2006 and November 2007. Mountainous forests surround this road, which connects the Indian states Kerala and Tamil Nadu. It also connects Kumuly, a tourist spot and Sabarimala, a pilgrimage centre that attract a large number of visitors annually.

This stretch of road was traversed fortnightly on foot once during morning (0600- 0800 hrs, Indian Standard Time) and evening (1600-1800 hrs) hours. All freshly killed animals found during 0600-0800 hrs were assumed to have been killed during the previous night and the others have been killed during the day. The dead animals were identified to species level, wherever possible, and removed from the road to avoid repeat count. Herpetofaunal abundance in the forests found 500m on either side of the road was assessed during dry (December -May) and wet (June - November) seasons using time constrained visual encounter survey (Heyer *et al*. 1994). The road under this study was divided into six equal segments and each of them was surveyed for 40 man hours totaling 240 hours of search per season. All possible microhabitats such as leaf litter, trees, tree holes, fallen logs, boulders, crevices and water bodies were examined to locate herpetofauna. Traffic intensity was monitored around the clock counting vehicles that pass through a particular point on a monthly basis.

A Mann-Whitney U-test was performed to test the difference between the mortality and abundance of herpetofauna in the environs between seasons, and mortality during the day and night. The Pearson correlation coefficient was used to find out the relation between number of road killed animals with vehicle intensity and number of road kills with the abundance of herpetofauna observed in the adjacent forests.

RESULTS

A total of 48 (24 morning and 24 evening) surveys were conducted along the six kilometer stretch of the road from December 2006 to November 2007. In all, 101 amphibians (3.5 amphibians/ 10km) belonging to six taxa and 78 reptiles (2.7 reptiles/ 10km) of 23 taxa were found dead during the fortnightly surveys. Among the six taxa of amphibians found dead, *Indirana* sp. contributed the most (47.52%) followed by *Duttaphrynus melanostictus* (41.58%). Higher number of amphibians was killed during wet season especially those belong to *Indirana* sp. (Table 1). Twenty three taxa of reptiles were found killed on the road during the sampling. The number of snake species found dead on the road was higher than that of the lizards (Table 2). However, many snake species were represented by singletons. Among reptile species that were killed, the snake *Macropisthodon plumbicolor* constituted the highest (15.38%) followed by the lizard *Calotes calotes* (11.54%).

Of the 101 amphibians found dead, 89 (88.1%) were killed during night and the rest during day. In the case of reptiles, 50/78 mortalities occurred during night. Traffic intensity in 24 hour cycle was low during night (7147±595.58) compared to day (14630 ± 1219.17). The mortality of amphibians during day and night was significantly different ($Z= 3.12$, $n1= 24$, $n2= 24$, $P<0.01$), whereas this was not so with respect to reptiles.

TABLE 1. Mortality of amphibians during dry and wet seasons along the National Highway 220. Numbers within parentheses are relative abundances.
TABLA 1. *Mortalidad de anfibios durante las estaciones seca y lluviosa a lo largo de la Autopista Nacional 220. Números entre paréntesis son abundancias relativas.*

Amphibian Species	Dry season	Wet season	Total
Duttaphrynus melanostictus	22	20	42 (41.58)
Sylvirana temporalis	2	2	4 (3.96)
Indirana sp.	2	46	48 (47.52)
Polypedates pseudocruciger	1	0	1 (0.99)
Rhacophorus malabaricus	3	0	3 (2.97)
Sphaerotheca breviceps	0	3	3 (2.97)
Total	30	71	101

A higher proportion (70.3%, n= 101) of amphibians was killed during wet season compared to dry season. Of the six species of amphibians found dead during this study, *Sphaerotheca breviceps* was observed only during wet season and *Polypedates pseudocruciger* and *Rhacophorus malabaricus* were observed only during dry season (Table 1). Among the reptiles, a higher number (44/78) of them were killed during the dry season than during the wet season (Table 2). Of the 23 taxa found dead, 10 were observed in both the seasons, seven were restricted to the dry and six to the wet season. The difference in the mortality of amphibians between seasons was not significant, but it was significant with respect to reptiles ($Z= -1.188$, $n1= 24$, $n2= 24$, $p< 0.05$).

Among the 11 species of amphibians recorded in forests adjacent to the road, *Indirana* sp. (39.85%), *Fejervarya* sp. (29.12%) and *Duttaphrynus melanostictus* (12.64%) were common (Table 3). In both seasons, 261 amphibians (5.43/ 10 man hour effort) were observed using VES. Eight species of amphibians were common for both seasons, but number of amphibians observed varied greatly between season; 73 during dry and 188 in wet season (Table 3).

In all, 507 reptiles (10.56/ 10 man hour) belonging to 21 species were observed during both seasons in the nearby forests (Table 4). The visual encounter surveys revealed the dominance of three species (by number); *Cnemaspis mysoriensis* (40.24%), *Eutropis macularia* (27.81%) and *Psammophilus blanfordanus* (11.41%). Eleven of them were observed in both seasons; five each exclusive to dry and wet seasons.

Seasonal variations in the abundance of reptiles and amphibians observed in the forests were not significant. Overall, the road kills

TABLE 2. Seasonal variation in the mortality of reptiles along the National Highway 220. Numbers within parentheses are relative abundances.
TABLA 2. *Variación estacional en la mortalidad de reptiles a lo largo de la Autopista Nacional 220. Números entre paréntesis son abundancias relativas.*

Reptile Species	Dry season	Wet season	Total
Calotes versicolor	5	1	6 (7.7)
Calotes calotes	7	2	9 (11.5)
Psammophilus blanfordanus	0	1	1 (1.3)
Chamaeleo zeylanicus	1	1	2 (2.6)
Eutropis macularia	2	1	3 (3.9)
Varanus bengalensis	1	2	3 (3.9)
Ramphotyphlops braminus	3	3	6 (7.7)
Uropeltis sp.	0	4	4 (5.1)
Eryx conicus	1	0	1 (1.3)
Ahaetulla nasuta	1	0	1 (1.3)
Ahaetulla pulverulenta	1	0	1 (1.3)
Boiga beddomei	0	1	1 (1.3)
Coelognathus helena	6	0	6 (7.7)
Macropisthodon plumbicolor	7	5	12 (15.4)
Oligodon arnensis	0	2	2 (2.6)
Ptyas mucosa	1	0	1 (1.3)
Bungarus caeruleus	1	2	3 (3.9)
Calliophis nigrescens	0	1	1 (1.3)
Daboia russelii	0	5	5 (6.4)
Echis carinatus	1	1	2 (2.6)
Hypnale hypnale	3	2	5 (6.4)
Unidentified gecko	1	0	1 (1.3)
Unidentified snake	2	0	2 (2.6)
Total	44	34	78 (100.00)

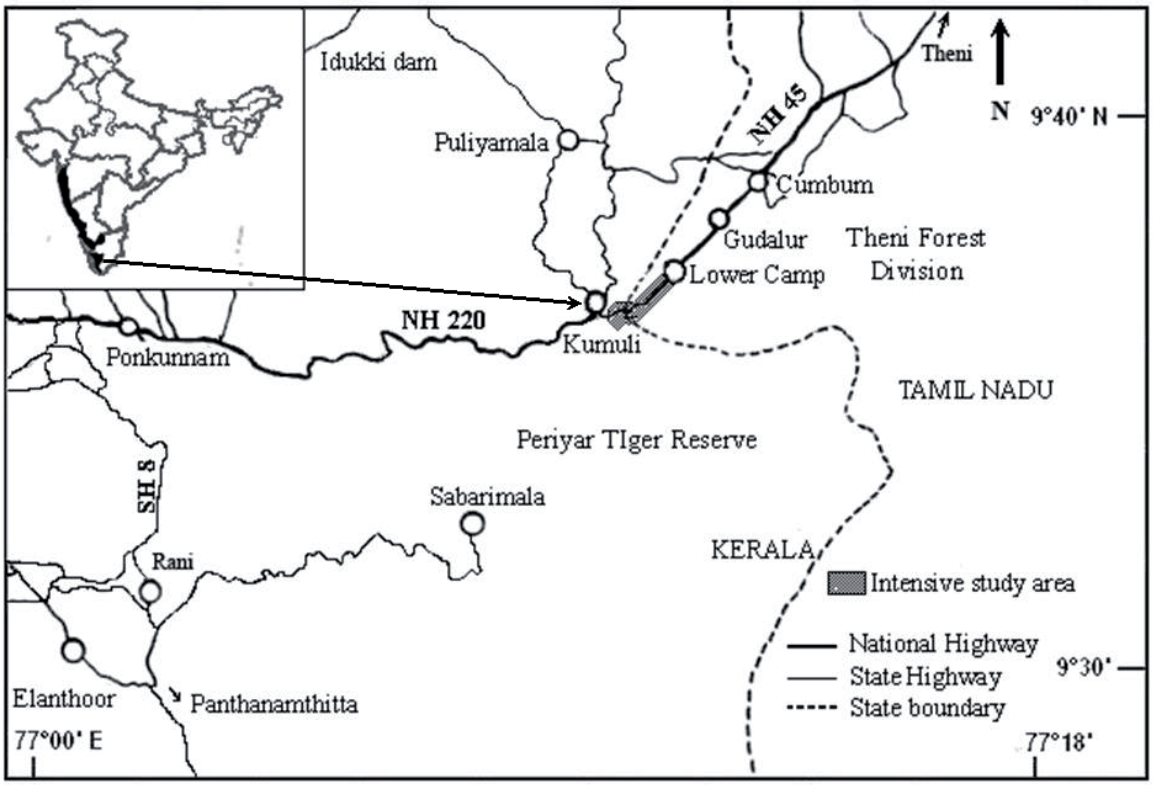

FIG. 1. Map showing the study area, National Highway 220, India.
Mapa que muestra el área de estudio, Autopista Nacional 220, India.

of amphibians had a significant correlation with those that occurred in nearby forests (r = 0.67, n= 12, P< 0.01). Reptiles had no such relation overall or seasonally. Amphibian kills were highly correlated with their abundance in the adjacent forests during wet season (r = 0.79, n= 12, P< 0.01), but it was not significant during dry season.

The mean number of vehicles traveling on the road during this study was 1814.75/ 24 hours (day). Figure 2 provides data on the mean number of vehicles passing on a monthly basis, which showed that the intensity was higher during December (2908) and May (2482), but it was the lowest during September (1449). The mean herpetofaunal mortality was 7.55/ day (n=24). Herpetofaunal daily mortality was highest during November (31) and lowest in September (4). The mortality pattern of reptiles and amphibians differed; reptiles- maximum during January and February (5.5/ 24 hours) and minimum in September (1) and amphibians- the highest mortality during October (13.5) and the lowest during April, May, August and September (1/ 24 hours). The correlation between number of vehicles traveling on the road and mortality of both amphibians and reptiles was not significant.

DISCUSSION

A total of 23 taxa of reptiles have been observed during the fortnightly sampling covering all months of the year during this study. Mukherjee (2007) reported 33 species of reptiles in a study spanning for three years in Anaikatty Hills, Western Ghats and suggested road cruising as the best way to make an inventory/monitor reptiles compared to other methods such as visual encounter survey, quadrat and transect. Road kills may indicate herpetofaunal diversity of the area (Hels and Buchwald 2001). However, the mortality of animals may depend on season, traffic density and behaviour of species involved. The edge of the road may support a greater variety of food items for some reptiles. Spellerberg (2002) reported higher abundance of a few species of spiders and insect along the edges of the road. Presence of breeding habitat and open patches near the road may enhance the herpetofaunal mortality especially in amphibians and lizards (Andrews and Gibbons 2005).

In all, 3.5 amphibians/ 10km and 2.7 reptiles/ 10km were found dead during the present study. Mortality of herpetofauna reported from other parts of the Western Ghats are as follows: Anamalai (amphibians: 20/ 10km, reptiles: 4.3/ 10km; Vijayakumar et al. 2001; Study period: May-June 1998), Mudumalai (amphibians: 19/ 10km; reptiles: 8.3/ 10km; Boominathan 1999; December 1998- March 1999) and Anaikatti Hills (3.49 reptiles/ 10km; Mukherjee 2007; January 2003- December 2004). The present study augments the view of Sundar (2004) that amphibians are more susceptible to vehicular traffic. Amphibians constituted higher number of road kills compared to reptiles in the present study, which is similar to the earlier studies undertaken in the Western Ghats (see above).

A higher number of amphibians and reptiles were killed during night despite relatively low vehicular traffic density. This could be related to higher nocturnal activity of many species of herpetofauna. For instance, species such as *Bungarus caeruleus* were killed

only during night confirming their restricted activity during night (Whitaker and Captain 2004). Insects may be attracted to the light post and or head lamps of the vehicles plying on the road, which may in turn attract insectivorous species of herpetofauna. Dodd *et al*. (1989) hypothesized that reptiles and amphibians are attracted to road to elevate their body temperature on cool nights following the sunny days, because the road surface remain warmer than the surroundings. Species that move frequently, especially snakes, are at the highest risk of mortality (Bonnet *et al*. 1999 and Roe *et al.* 2006) as their movement in relatively smoother surface may be difficult. Even though only fewer species of lizards were killed on the road compared to snakes, their number was higher. Higher number of openings in the canopy near the road might have enhanced the activity of lizards near roads.

A higher number (72%) of amphibians was recorded during wet season, which could be due to the increased activity associated with breeding such as aggregation nearby puddles and dispersal of froglets. The present result augments the findings of Hels and Buchwald (2001) and Mazerolle (2004). However, mortality of reptiles was high during dry season, which may be due to their enhanced activity during this season as most of the reptiles in tropics begin reproductive activity prior to rain. However, a few taxa such as uropeltid snakes (Rajendran 1985, Kumara *et al*. 2000 and Vijayakumar *et al*. 2001) may differ from this general pattern. As in the present study, a higher proportion of road kills has been contributed by *Indirana* sp. and *Duttaphrynus melanostictus* (Vijayakumar *et al*. 2001 and Sundar 2004).

The present study found no relation between number of reptiles found dead on the road and those found in adjacent forests. However, the number of amphibian kills had significant relationship to that found in the nearby forests (collectively and during the wet season). This shows the influence of climate on the activity of amphibians. Six taxa of amphibians were found killed on the road by vehicles; among them *Indirana* sp. contributed the most (47.52%) followed by *Duttaphrynus melanostictus* (41.58%). However, forests found adjacent to the road had 11 species, and *Indirana* sp. (39.85%) *Fejervarya* sp. (29.12%) and *Duttaphrynus melanostictus* (12.64%) contributed the highest proportion of these. The discrepancy in the abundance of these species in the forests and road kill records (Table 1 and 3) could be due to variation in their activity, behaviour and spatial use. For instance, *Fejervarya* spp. are largely aquatic and their activity may be restricted around water bodies, and hence they were not found in the road kills. Similar to amphibians, several reptile species observed in the forests were not found in road kills and *vice-versa*.

Various views are available on the relationship between traffic volume and mortality of herpetofauna. Smith and Dodd (2003) found no relationship between traffic volume and monthly road kill rate, which is similar to the findings of the present study. However, positive relationship between traffic volume and mortality of herpetofauna has also been reported (Amphibians: Fehrig *et al*. 1995, Hels and Buchwald, 2001 and Mazerolle 2004; Reptiles: Szerlag and McRobert 2006).

Roads are essential for transportation of materials and people. However, in India, the impact of roads on wildlife is poorly understood, barring a few fragmentary data on select taxa. The impact of road network may be server on wildlife, especially on herpetofauna, which are relatively slow moving. Including the present study, the rate of reptile mortality ranged from 0.27/ day (this study) to 0.83/ day in Mudumalai (Boominathan 1999) in the Western Ghats (see above), and a moderate road kill rate of 0.55/ day would result in the mortality of 14700 reptiles/day in about 26697 km of National Highways that

TABLE 3. Abundance of amphibians in the forests adjacent to the National Highway 220 during dry and wet seasons as recorded by Visual Encounter Survey. Number within parentheses are relative abundances.

TABLA 3. *Abundancia de reptiles en los bosques adyacentes a la Autopista Nacional 220 durante las estaciones seca y lluviosa, según registros con el método de encuentros visuales. Números entre parentesis son abundancias relativas.*

Amphibian Species	Dry season	Wet season	Total
Duttaphrynus melanostictus	12	21	33 (12.64)
Euphlyctis cyanophlyctis	7	1	8 (3.07)
Fejervarya sp.	15	61	76 (29.12)
Sphaerotheca breviceps	--	5	5 (1.92)
Silvirana temporalis	19	5	24 (9.20)
Clinotarsus curtipes	--	1	1 (0.38)
Indirana sp.	12	92	104 (39.85)
Nyctibatrachus beddomii	5	--	5 (1.92)
Nyctibatrachus aliciae	2	--	2 (0.77)
Philautus sp.	--	2	2 (0.77)
Polypedates pseudocruciger	1	--	1 (0.38)
Total	73	188	261 (100.00)

TABLE 4. Abundance of reptiles in the forests adjacent to the National Highway 220 during dry and wet seasons, as recorded by Visual Encounter Survey. Number within parentheses are relative abundances.

TABLA 4. *Abundancia de reptiles en los bosques adyacentes a la Autopista Nacional 220 durante las estaciones seca y lluviosa, según registros con el método de encuentros visuales. Números entre parentesis son abundancias relativas.*

Reptile Species	Dry season	Wet season	Total
Cnemaspis mysoriensis	124	80	204 (40.24)
Geckoella collegalensis	1	2	3 (0.59)
Hemidactylus frenatus	13	6	19 (3.75)
Hemidactylus maculatus	0	2	2 (0.39)
Draco dussumieri	15	0	15 (2.96)
Calotes versicolor	5	1	6 (1.18)
Calotes calotes	20	5	25 (4.93)
Calotes rouxii	2	0	2 (0.39)
Psammophilus blanfordanus	47	11	58 (11.44)
Chamaeleo zeylanicus	0	1	1 (0.20)
Lygosoma punctata	2	0	2 (0.39)
Eutropis carinata	2	9	11 (2.17)
Eutropis macularia	96	45	141 (27.81)
Varanus bengalensis	5	2	7 (1.38)
Ramphotyphlops braminus	1	2	3 (0.59)
Boiga beddomei	0	1	1 (0.20)
Dendrelaphis tristis	1	0	1 (0.20)
Coelognathus helena	1	0	1 (0.20)
Oligodon arnensis	0	1	1 (0.20)
Ptyas mucosa	1	1	2 (0.39)
Hypnale hypnale	0	2	2 (0.39)
Total	336	171	507 (100.00)

pass through the forest and wildlife habitats. The mortality of wildlife due to vehicular traffic may be influenced by various factors such as status of the forest, wildlife density, behaviour of the species, climatic conditions and traffic density.

Measures such as dwarf barriers (30 cm) on either side of the road, pipe culverts and bridges in appropriate areas such as stream crossings, as well as speed controls (breakers), would help to reduce the mortality of animals, especially the herpetofauna. Installation of signage regarding wild animal movements and regulation of speed of the vehicles and traffic regulations would also help to minimize mortality (Spellerberg 2002). Studies to identify important sectors of roads (Langen *et al*. 2009), especially those cut across forests may be useful for proposing measures to reduce their impacts on biota. A data base of mortality of wildlife in various categories of existing roads in India including the State Highways and further studies on designs to minimize the impact of roads on wildlife would provide further insights with respect to wildlife conservation and infrastructure development.

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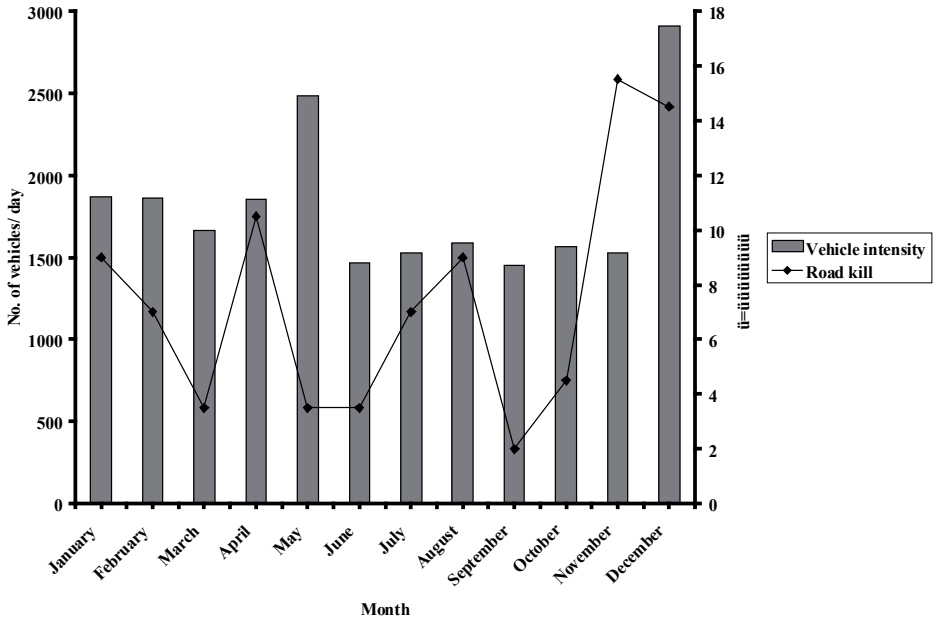

FIG. 2. Herpetofaunal mortality and Vehicle intensity in a stretch of National Highway 220, India.
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