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Impact of Vehicular Traffic on Vertebrate Fauna in Horton Plains and Yala National Parks of Sri Lanka: Some Implications for Conservation and Management

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Impact of vehicular traffic on vertebrate fauna in Horton Plains and Yala national parks of Sri Lanka: some implications for conservation and management

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Abstract: Impacts of roadkills are extensively documented in developed nations. Only a handful of studies on road mortality has emerged from developing nations where tourism and rural development have led to an expansion of transportation networks. To fill such gaps, we conducted a survey to document roadkills in and around two tourism-heavy national parks of Sri Lanka and identified factors that contribute to road mortality. Based on a questionnaire, we interviewed 68 local villagers, 56 local and 59 foreign visitors, and 57 safari drivers to document their opportunistic observations on roadkills, their awareness about roadkills, and to understand potential causes of roadkills. We found 47 roadkilled vertebrate species at both parks; among these, 19 are threatened and 20 are endemic. Our research revealed that herpetofauna were killed the most. We concluded that increased visitation, high-speed driving, lack of awareness, and poor law enforcement as the likely causes of roadkills at both parks. As mitigatory actions, we proposed posting speed limits, increasing awareness of the tourists and safari drivers, limiting vehicle access to the parks, seasonal or night-time access restrictions, and strict enforcement of the speed limits inside national parks.

Keywords: Conservation, lowland forests, management, montane forests, over-visitation, roadkills, speed limits, tourism.

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Author Contribution: SK and MM conceived the concept, ideas, plan of work and did field work; SK and TS preparing the manuscript; SR supervised the project and did the final editing; TS prepared the map, figures and improved the manuscript; All authors equally contributed to the manuscript.

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INTRODUCTION

Roads impose multiple ecological impacts on local biodiversity including habitat fragmentation, altered microclimates with edge effects, nonpoint-source pollution, increased anthropogenic disturbances, high rates of pest infestations and non-native invasions, altered animal behavior, impeded dispersal and migration, and altered hydrology (Trombulak & Frissell 2001; Laurance et al. 2009). Being barriers against movements, roads can isolate populations, reduce metapopulation dynamics, lower genetic heterozygosity, and cause mortality due to vehicular collision (Forman & Alexander 1998). Such incidental mortality leads to reduced abundance and diversity of local wildlife (Gibbs & Shriver 2002; Laurance et al 2008). Continuous expansion of the land-based transport networks, their linear nature, and increasing traffic volume can amplify negative impacts of roadkills on population persistence (Carr & Fahrig 2001; Gibbs & Shriver 2002; Karunarathna et al. 2013).

Impacts of road mortality have been mostly studied in developed nations where both multi-lane highways and volume of motor traffic are growing rapidly (Taylor & Goldingay 2004). Twenty percent of the US landscapes are affected by public road systems, which include the total spatial coverage of roads, roadsides, and the "road-effect zone" which extends 100m beyond the roadside (Forman 2000). In New South Wales of Australia, one roadkill occurred per week for every 4-km stretch along a 100-km road circuit where victims were mostly endemic arboreal and ground-dwelling mammals (Taylor & Goldingay 2004). Road networks are expanding in the developing nations with a concurrent rise in the traffic flow (Vijayakumar et al. 2001; Das et al. 2007). Protected areas of the developing countries have extensive road networks, which facilitates tourism, especially safaris (Laurance et al. 2008; Karunarathna et al. 2013). These conditions could be highly pertinent to Sri Lanka, a biodiversity-rich Indian Oceanic tropical island where a number of protected areas attract both local and international tourists (Buultjens et al. 2005). The road development schemes of Sri Lanka have largely neglected the importance of landscape connectivity or mitigation of wildlife road mortality, which may aggravate negative impacts of roads on local and regional biodiversity.

There is a paucity of studies documenting roadkills in Sri Lanka (Karunarathna et al. 2013). Among the few existing research, many are biased towards herpetofauna (de Silva 1999; Maduwage et al 2003; Amarakoon et al. 2010; Karunarathna et al 2012). De Silva (1999) reported a brief account on road mortality of reptiles in Horton Plains National Park - a popular tourist destination in Sri Lanka. In addition, Karunarathna et al. (2012) highlighted the severity of roadkills of land monitors, in and around multiple national parks of Sri Lanka that entertain high volumes of tourists. These studies emphasized that roadkills in and around protected areas of Sri Lanka are of a critical conservation concern, especially national parks that entertain mass tourism. Given the potential impact of motor traffic on local wildlife, we investigated wildlife road mortality in two Sri Lankan national parks—Horton Plains National Park (HNP) and Yala National Park (YNP)—that experience high volume of tourists (Fig. 1). Our main objectives in this study were to (i) document species that suffer road mortality in and around the two national parks, and (ii) identify factors that contribute to roadkills.

Study Areas

Both HNP and YNP are managed by the Department of Wildlife Conservation under the jurisdiction of the Ministry of Environment and Natural Resources. Both national parks are home for unique assemblages of native biodiversity including charismatic megafauna, and possess picturesque landscapes that are characteristic of their respective geographies (DWC 2004).

YNP ($06^0$21'42.49"N & $81^0$28'45.13"E) is located in the lowland dry zone (annual average precipitation ~640mm, annual average temperature ~29.5^{0}C) of southeastern Sri Lanka and covers ~97,800ha (Buultjens et al 2005). YNP hosts a variety of ecosystems including moist monsoon forests, dry monsoon forests, semi-deciduous forests (Image 1a,b), scrub forests, thorn forests, and grasslands (de Silva & de Silva 2004). The Inland aquatic habitats of YNP are seasonal rivers, waterholes, tanks, and rock pools; these are seasonal water bodies and are heavily dependent on monsoons (IUCN & CEA 2006). YNP experiences a prolonged hot and dry climate from June to October; and receives rain mostly via northeast monsoons during November–January period (DWC 2004). Since the park is located in the coastal peneplain, saltwater habitats such as coastal marshes, mangrove–associated lagoons, seasonal rivers, and sandy beaches are also found there (IUCN & CEA 2006). The vertebrate fauna of YNP includes 45 species of mammals, 230 species of birds, 46 species of reptiles, 18 species of amphibians, and 25 species of fish (DWC 2004).

HNP ($06^0$48'35.55"N & $80^0$48'21.27"E) is located in the wet zone (annual average precipitation >2000mm,

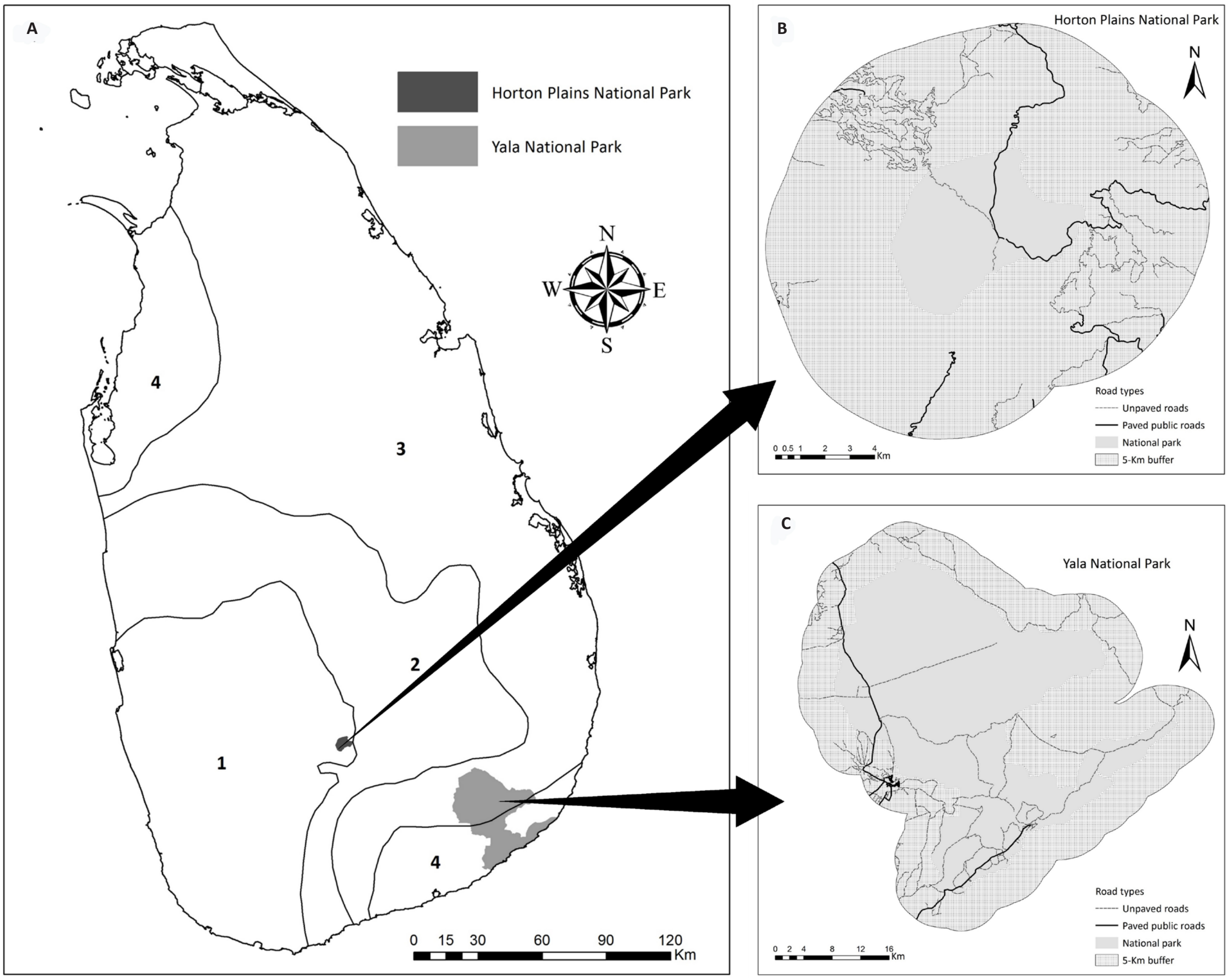

Figure 1. Study areas for the survey of roadkills: (A) the location of Horton Plains National Park (HNP) and Yala National Park (YNP) in Sri Lanka. Bioclimatic zones: 1 - wet zone, 2 - intermediate zone, 3 - dry zone, and 4 - arid zone in Sri Lanka. (B) Horton plains National Park and (C) Yala National Park with the associated road network. The 5-km-buffer is the 5-Km-wide area adjoining the park that was surveyed for roadkills.

annual average temperature ~20^{0}C) central highlands (2,100–2,300 m) of Sri Lanka and spans ~3,160ha (Pethiyagoda 2012). Moist evergreen upper montane forests and montane grasslands (Image 1e,f) comprise the dominant vegetation types (de Silva 2007). Diverse arrays of aquatic habitats are found throughout the park, including forested pools, low-order streams, and waterfalls (Gunawardana et al 1998). Southwestern monsoons bring heavy rain to the park for a major part of the year (May–October). The vertebrate fauna of the park includes 25 species of mammals, 90 species of birds, 10 species of reptiles, 15 species of amphibians and locally rare fish species; the point endemism within the park of the park is highly remarkable for both fauna and flora (DWC 2004; IUCN & CEA 2006).

MATERIALS AND METHODS

Documentation of species composition of roadkills

We recorded the presence of roadkills from 2009 to 2014 on motor-traffic accessible roads inside and immediately around (all roads located within a distance of 500m from the park boundary) both national parks. All surveyed roads were unpaved gravel roads with the exception of the public transportation roads; the latter were paved. None of the surveyed roads had any restrictions on vehicular access. In each year, we surveyed ~160km and ~50km stretches of roads at YNP and HNP, respectively. The same stretches were revisited in the following years. Our field survey team consisted three trained vertebrate field biologists. Our sampling efforts were even between both dry and wet

Image 1. (a) & (b) - Dryzone forest and wetland habitat on the roadside in YNP; (c) & (d) - vehicular presure and braking the regulations inside the YNP; (e) & (f) - Montane forest and wet grassland habitat on the roadside in HNP; (g) & (h) - vehicular presure and offroad parking in HNP. (© Ishan Seneviratne, Majintha Madawala & Sanjaya Atapattu).

seasons at both parks. On each sampling day, we recoded roadkills while walking (YNP: 2km; HNP: 10km) or riding on motor vehicles at an average speed of 25kmh^{-1} (YNP: 60km; HNP: 15km). Throughout the survey, both road surface and the road verges (50cm on either side of the road) were scanned for carcasses. All observations were made during the mornings (approximately 07:00–11:00 hr) and early evenings (approximately 14:00–17:00 hr) on a given day (average sunrise time: 06:10hr, sunset: 17:50hr). We used standard field guides and keys to identify roadkilled specimens. All specimens were photographed and identifications were verified through expert zoologists.

Identification of causes of road mortality

We interviewed local villagers (68), both Sri Lankan and foregn visitors (115), and vehicle drivers of safari tours (57) using a questionaire at both national parks. Safari tours are only limited to YNP. Through these in-person interviews, we asked the folowing questions to gather information on people's opportunistic observations on and attention to roadkills, their attitudes and perceptions about roadkills, driving speed, specific causes of roadkills as observed or speculated, and people's view on prevention of roadkills. We also inquired about the purpose of visit from all tourists. Questions and available responses (in parenthesis) in the questionaire included: what is your purpose of visit? (wildlife observations, recreation and relaxation, other); have you ever seen roadkills? (yes, no); do you like to see roadkills? (yes, no); what are the major sources of roadkills?; what do you feel about roadkills? (very sad, sad, indifferent); do you drive faster than 30km/h, the maximum speed limit allowed? (yes, no); and what are your suggestions on mitigating roadkills? We also obtained information on annual vehicle entry at both parks from the Department of Widllife Conservation for the 6-year duration of our study to calculate the trends in visitation rates. We ran a Wilcox sign-rank test to identify significant differences between the two parks for the total number of vehicles entered and the rate of increase in vehicle entry.

RESULTS

Species composition of roadkills

Our roadkill survey comprised 47 vertebrate species (16 amphibians, 16 reptiles, 8 mammals, and 7 birds) in both national parks (Fig. 2a). Among these fatalities, 20 species (11 amphibians, 6 reptiles, 2 mammals and 1 bird) are endemic while 24 species (10 amphibians, 7 reptiles, 5 mammals and 2 birds) are listed threatened in Sri Lanka's National Red List of Threatened Species (Table 1). According to the IUCN Global Red List, 12 roadkilled species are considered threatened.

We noted remarkable differences in species composition of roadkills between the two national parks. We recorded a total of 26 vertebrate species (11 reptiles, 7 amphibians, 5 mammals and 3 birds) in YNP among which three species are endemic, and another two (1 reptile and 1 mammal) are threatened. At HNP, we documented 22 roadkilled vertebrate species (10 amphibians, 5 reptiles, 4 birds and 3 mammals). Among these fatalities, 17 species (9 amphibians, 5 reptiles, 2 mammals and 1 bird) are endemic; another 17 species (8 amphibians, 5 reptiles, 2 mammals and 2 birds) are threatened. The vertebrate species most vulnerable to road mortality differed between the two parks. Reptiles were the most prevalent roadkill (40% of all species) in YNP whereas amphibians (~46%) suffered the greatest road fatalities at HNP. More than one-third (~77%) of roadkills found in HNP are endemic whereas only a one-tenth (~12%) of YNP roadkills are endemic. A similar pattern was observed among Red Listed species that suffered road fatalities; only ~8% of the roadkilled species in YNP are listed threatened whereas the equivalent figure for HNP was ~77%. In YNP, more than one-fifth of roadkilled threatened species belonged to four vertebrate families—Bufonidae, Boidae, Testudinidae and Felidae—all but the last are herpetofauna. Among the roadkilled threatened species in HNP, nearly half (~45%) was accounted by three herpetofaunal families: Agamidae, Microhylidae, and Rhacophoridae.

Visitation rate

We noted marked distinctions between the two parks in terms of the average visitation rates, the total number of motor vehicles admitted, and rate of increase in visitations. In all metrics, YNP figures exceeded those of HNP by multiple folds. For the 6-year period, a total of 2,94,435 motor vehicles entered YNP with an average entry rate of ~49,072 vehicles per year (Fig. 2b). The visitation rate (based on vehicle entrance) increased consistently from year to year throughout our study for both parks; however, the rate of increment varied between consecutive years. The smallest increase (~2.9%) was observed in the 2012–2013 period while the greatest increase (~124.9%) was recorded from 2009–2010 periods. The visitation rate of YNP has more than doubled (~222.5%) from 2009 to 2014. Compared with YNP, the visitation rate was lower at HNP where only a total of 1,43,010 vehicles entered the park with an average rate of ~23,835 vehicles per year— approximately, half the number recorded at YNP (Table 2). The rate of increase in traffic throughout the study period was comparatively lower in HNP which had ~40% less vehicular entries per year than that of YNP. The smallest raise (~3.1%) in vehicular traffic was observed in 2012–2013 period while that of the greatest increment (~22.9%) was recorded in 2011–2012. The overall growth of visitations for HNP was ~83.4% for the six-year period. There was a significant difference between the two parks in the total number of vehicles

Table 1. Roadkills recorded from two national parks in 2009–2014 (E - endemic; LC - Least Concern; NT - Near Threatened; VU - Vulnerable; EN - Endangered; CR - Critically Endangered; HNP - Horton Plains National Park; YNP - Yala National Park); * indicates the percent species composition per each vertebrate class = (Number of roadkilled species of a certain vertebrate class in a given park ÷ total number of roadkilled species in all vertebrate classes) x 100; Red List criteria use according to MOE 2012.

Taxa	% Sp. comp.*		Species	Roadkilled site	IUCN status	Endemicity
	HNP	YNP				
Amphibians - 16	48	24	*Duttaphrynus atukoralei*	YNP	NT	E
			Duttaphrynus melanostictus	Both	LC	-
			Fejervarya greenii	HNP	EN	E
			Hoplobatrachus crassus	YNP	LC	-
			Hylarana gracilis	YNP	LC	E
			Hylarana temporalis	HNP	NT	E
			Microhyla ornata	YNP	LC	-
			Microhyla zeylanica	HNP	CR	E
			Polypedates maculatus	HNP	LC	-
			Pseudophilautus alto	HNP	EN	E
			Pseudophilautus femoralis	HNP	CR	E
			Pseudophilautus schmarda	HNP	CR	E
			Pseudophilautus silus	HNP	EN	E
			Ramanella palmata	HNP	CR	E
			Taruga eques	HNP	EN	E
			Uperodon systoma	YNP	LC	-
Reptiles - 16	22	44	*Amphiesma stolatum*	YNP	LC	-
			Aspidura trachyprocta	HNP	EN	E
			Calotes versicolor	YNP	LC	-
			Calotes nigrilabris	HNP	EN	E
			Ceratophora stoddartii	HNP	EN	E
			Cophotis ceylanica	HNP	EN	E
			Dendrelaphis tristis	YNP	LC	-
			Eutropis carinata	YNP	LC	-
			Geochelone elegans	YNP	NT	-
			Gongylophis conica	YNP	VU	-
			Hemidactylus leschenaultii	YNP	LC	-
			Lankascincus taprobanensis	HNP	EN	E
			Melanochelys trijuga	YNP	LC	-
			Oligodon taeniolata	YNP	LC	-
			Oligodon sublineatus	YNP	LC	E
			Varanus bengalensis	YNP	LC	-
Birds - 7	17	12	*Caprimulgus atripennis*	YNP	LC	-
			Clamator coromandus	HNP	LC	-
			Gallus lafayetii	HNP	LC	E
			Saxicola caprata	HNP	EN	-
			Saxicoloides fulicatus	YNP	LC	-
			Pycnonotus cafer	YNP	LC	-
			Turdus merula	HNP	EN	-
Mammals - 8	13	20	*Felis chaus*	YNP	NT	-
			Funambulus palmarum	YNP	LC	-
			Lepus nigricollis	YNP	LC	-
			Muntiacus muntjak	HNP	NT	-
			Panthera pardus	YNP	EN	-
			Sus scrofa	YNP	LC	-
			Srilankamys ohiensis	HNP	EN	E
			Suncus montanus	HNP	EN	E

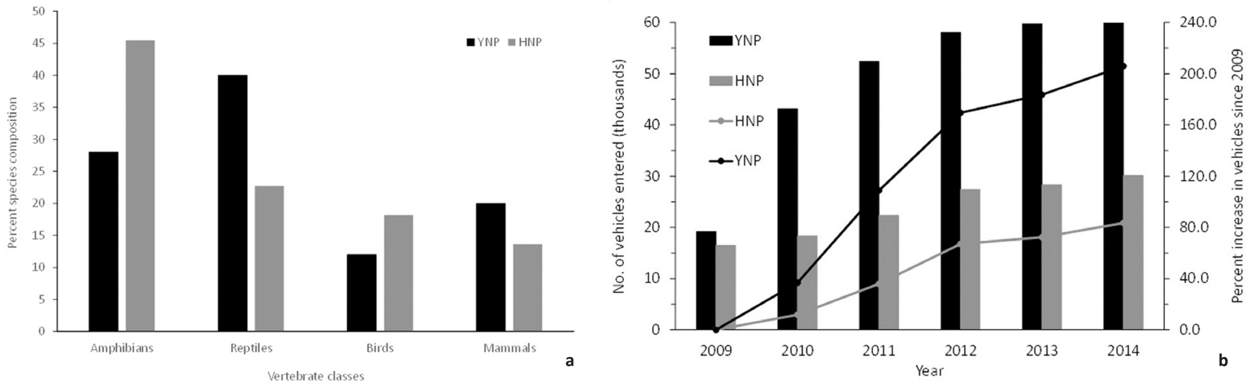

Figure 2. (a) Percent species composition of road mortality in both YNP (Yala National Park, black) and HNP (Horton Plains National Park, grey). Species composition = (Number of roadkilled species per each vertebrate class at each national park ÷ total number of roadkilled species of all classes found at each national park) × 100%; (b) Entrance of tourist vehicles into the Yala National Park (YNP) and Horton Plains National Park (HNP) from 2009 to 2014. The bars indicate total number of vehicles entered each park in each year. The lines indicate the percent increase in number of vehicles in each year at each park as a fraction of number of vehicles entered in 2009. Percent increase in vehicles since 2009 = (Number of vehicles entered each park each year ÷ Number of vehicles entered each park in 2009) × 100%.

Table 2. Trends in entry of tourist vehicles into Horton Plains National Park (HNP) and Yala National Park (YNP) from 2009 to 2014 (abbreviations: NVE - Number of vehicles entered; DAV - Daily average number of vehicles entered; NVP - Number of vehicles as a percentage of total; IVS - Increment in number of vehicles between successive years; PBS - Percent increase between successive years).

Year	HNP					YNP				
	NVE	DAV	NVP	IVS	PBS	NVE	DAV	NVP	IVS	PBS
2009	16427	45.0	11.5	-	-	19194	52.6	6.5	-	-
2010	18374	50.3	12.8	1947	11.9	43175	118.3	14.7	23981	124.9
2011	22333	61.2	15.6	3959	21.5	52362	143.5	17.8	9187	21.3
2012	27443	75.2	19.2	5110	22.9	58048	159.0	19.7	5686	10.9
2013	28306	77.6	19.8	863	3.1	59754	163.7	20.3	1706	2.9
2014	30127	82.5	21.1	1821	6.4	61902	169.6	21.0	2148	3.6
Total	143010					294435				

entered in each year (w=4, p<0.05); the rate of increase in vehicle entry did not differ significantly between the two parks (w=15.4, p>0.05).

Questionnaire survey

Our questionnaire survey revealed that all respondents, in general, are distressed by seeing roadkills and aware of the problem. Over 80% of the local inhabitants interviewed at both national parks said that they have seen roadkills. In contrast, >50% of both local and foreign visitors as well as safari jeep drivers had not seen any roadkills in any of the national parks with the exception of foreign visitors at HNP where 68% of visitors claimed to have seen roadkills (Table 3). All the interviewees claimed that they would rather not see any roadkills. In addition, ~90% of all tourists and jeep drivers were pitiful towards roadkills. Among local inhabitants of HNP, only 10% were indifferent towards roadkills whereas <40% of local villagers of YNP were unmoved. The majority (>65%) of local inhabitants and local tourists ruled high-speed driving as the most detrimental source of road mortality. Foreign tourists at both national parks as well as the safari drivers (≥50%) considered carelessness as the main cause of road mortality. All respondents at both national parks ranked carelessness or high-speed driving as the top two causes of roadkills. The majority (>70%) of all visitors at both parks did not consider fast–driving as a necessity except local visitors to HNP where >60% wanted to drive beyond speed limits. Similarly, the majority (~55%) of safari derivers deemed fast–driving as a necessity. In general, at least 50% of all respondents at both parks agreed on reduced vehicular speed via enforced speed limits, speed bumps, and monitoring to mitigate roadkills.

Table 3. The questionnaire survey results based on in–person interviews with the local inhabitants, tourists (local visitors and foreign visitors) and safari jeep drivers. Yala National Park (YNP) and the Horton Plains National Park (HNP) in 2014; * Safari tours are only avaiable at YNP.

	YNP				HNP		
Questions	**Local villagers**	**Local visitors**	**Foreign visitors**	**Safari jeep***	**Local villagers**	**Local visitor**	**Foreign visitors**
What is your purpose of visit?							
To see wildlife	N/A	12	27	N/A	N/A	9	11
Just a fun or a rest and relax	N/A	15	8	N/A	N/A	14	7
Other	N/A	5	2	N/A	N/A	1	4
Have ever seen any roadkills?							
Yes	35	8	13	9	21	11	15
No	7	24	24	48	5	13	7
Do you want or like to see roadkills?							
Yes	0	0	0	0	0	0	0
No	17	5	2	32	14	8	5
Never	25	27	35	25	12	16	17
What is the major cause of roadkills?							
Speeding	32	22	12	9	17	16	5
Use of cell phones	0	4	3	17	0	0	0
Careless driving	10	6	17	24	9	5	11
Poor knowledge about wildlife	0	0	5	7	0	3	6
What are your perceptions about roadkills?							
Very sad	21	7	29	23	16	3	16
Sad	5	23	8	28	7	17	8
None	16	2	0	6	3	4	0
Do you need to drive faster than 30km/h							
Yes	N/A	9	2	31	N/A	15	5
No	N/A	23	35	26	N/A	9	17
What are your suggestions regarding mitigation of roadkills?							
Speed limitation	36	17	14	37	11	5	10
Road barriers	6	5	9	7	15	7	2
Monitoring	0	2	3	2	0	0	5
Limitation of vehicles and visitors	0	8	11	11	0	12	5
Total number of respondents	42 people	32 people	37 people	57 people	26 people	24 people	22 people

DISCUSSION

Species susceptibility to roadkills

Our study revealed that herpetofauna are the most susceptible to road fatality among the vertebrate group in Sri Lanka, at least within the two bioclimatic zones our study sites represented, the lowland dry zone and upper montane wet zone. Our observations are in agreement with a few other studies conducted in tropical, subtropical, and temperate zones (Fahrig et al. 1995; Forman & Alexander 1998; Trombulak & Frissell 2001). Taxa with high vagility (inherent power of movements, including both the distance and frequency of movements for dispersion, or migration) are mostly susceptible to roadkills (Carr & Fahrig 2001; Laurance et al. 2009). Besides, taxa with larger home ranges, including large mammals, top carnivores, and chelonians are also considered vulnerable to roadkills (Gibbs & Shriver 2002; Laurance et al. 2009).

Among amphibian roadkills in our study, 12 of 17 species are aquatic breeders. Among amphibians, pond-breeding species have the highest probability of road mortalities given their seasonal mass migrations and post-natal dispersal among multiple aquatic habitats (Hels & Buchwald 2001; Karunarathna et al. 2008). Sri Lanka's anurans are largely arboreal and undergo direct development (Bahir et al. 2005) hence considered relatively independent of standing water, which supposedly negate the necessity for movements among multiple aquatic habitats. Yet, we recorded four direct-developing amphibian species in our roadkill survey, which indicated that even arboreal species may disperse across the landscapes and can suffer road mortality. More than 90% of roadkilled herpetofauna in our study were ground-dwelling species with a slow-moving habit; such natural histories predispose them to road mortality (Laurance et al. 2009). During our survey, we noted that more amphibians crossed the roads during the rainy season in both national parks suggesting that rain triggered increased amphibian activities, such as foraging and mating. Increased activities of amphibians coinciding with rainfall have been reported in other parts of Sri Lanka (Weerawardhena et al. 2004). Roadside ditches created by tire ruts may function as ecological traps for many pond–breeding anurans (DiMauro & Hunter 2002).

The differential species composition of roadkills we noted between the two national parks can be attributed to differences in regional species pools and sampling effects (Zobel et al. 1998). The moist, wet climate of HNP favors amphibians that are dependent on high humidity and ample water availability whereas the dry, arid climate of YNP is much suitable for reptiles. Therefore, the most abundant taxa in each park appeared to suffer the most from roadkills. Although only recorded in a handful of instances, roadkills of Leopards and Jungle Cats at YNP were noteworthy (Image 2). One of the roadkilled Leopards was pregnant with three cubs. These carnivores tend to have large home ranges and actively roam and defend large territories (Spellerberg 1998); such requirements may predispose these large cats to road fatalities while crossing access roads. The population sizes of these carnivores are small and declining in Sri Lanka owing to habitat destruction, fragmentation, and vengeful killing (Miththapala 2006). For instance, in the block I of YNP, the population size of Leopards is estimated to be ~25 (Kittle & Watson 2005). Therefore, even the demise of a few individuals of a small and declining population can have deleterious effects through inbreeding depression, reduced genetic heterozygosity, and genetic drift (Ellstrand & Elam 1993).

Driving forces of roadkills

YNP is among the most visited tourist destinations in Sri Lanka, and the park attracts both local and foreign tourists for wildlife watching and scenic beauty (Buultjens et al. 2005). In 2014, approximately 245,120 people visited the park, and these numbers have kept rising during the past decades. In addition to access roads, two more major public roads bisect YNP; the traffic in these roads increases substantially during the Buddhist pilgrimage season (personal observations). The Department of Wildlife Conservation has imposed a maximum speed limit of 30km h^{-1}. Yet, we found faded speed limit posts inside the park or on public roads that bisect the park. There were no strict enforcements of traffic laws inside or around the parks, leading to rampant over speeding (>80km h^{-1}). Further, our interview survey also revealed prevalence of high-speed driving.

Tourism accounts for a greater proportion of national income of Sri Lanka; international tourism in particular is considered the fourth largest source of foreign exchange (Weerasinghe et al. 2003). Travel and tourism made a total contribution of US$ six billion to the gross domestic production of Sri Lanka in 2013 (9.4% of the gross domestic production), while generating many employment opportunities (WTTC 2014). The current status of tourism in both parks is not sustainably managed and has led to many other environmental concerns such as solid waste and garbage disposal, noise pollution, air pollution, deteriorating water quality and scenic beauty, changes in wildlife behavior that accompany fitness costs, erosion and others means of pollution from vehicles and roads, overcrowding, and wildlife harassment (Weerasinghe et al. 2003; Buultjens et al. 2005). We contend that lack of awareness among tour operators, absence of strict law enforcement, and poor communication between parks authorities and tour operators are the most detrimental factors that have contributed to roadkills in these national parks (Buultjens et al. 2005). Incidence of road mortality has substantially increased in many parts of the world following increased mass tourism and high traffic volume (Green & Higginbottom 2000; Seshadri & Ganesh 2011).

Our questionnaire-based interviews revealed that the local villagers have seen more roadkills than the tourists, and hence we can infer that the local communities are at least aware of the problem. Nearly 60% of all tourists have not seen any roadkill at either of the national parks. Since local inhabitants spend more time in the region than tourists, the latter may not encounter many roadkilled wildlife; therefore may be less aware of the situation. Safari drivers appeared to be surprisingly unaware of the issue. Both tourists and safari drivers are important stakeholders of tourism, and therefore making them aware of roadkills as a critical conservation concern is paramount. None of the

Image 2. Roadkilled photos in the study areas in both National Parks: (a) Endangered - Sri Lankan Leopord *Panthera pardus*; (b) Common Squirrel *Funambulus palmarum*; (c) Land Monitor *Varanus bengalensis*; (d) Bronze-backed Snake *Dendrelaphis tristis* in YNP; (e) Endangered - Black-cheek Lizard *Calotes nigrilabris*; (f) Endangered - Eurasian Blackbird Turdus merula; (g) Endangered - Sri Lankan Pigmy Lizard *Cophotis ceylanica*; (h) Endangered - Common Rough-side *Aspidura trachyprocta* in HNP. (© Spencer Manuelpillai, Tharaka Kusuminda, Majintha Madawala, Dushantha Kandambi & Tharaka Priyadarshana).

respondents seemed to take any pleasure in seeing or committing roadkills and over 80% claimed that they would be emotionally distressed by seeing roadkills. This indicated that roadkills were a deterrent for the tourists and emphasized the necessity to take mitigatory actions. In stark contrast to our findings, recent studies done in North America and Australia indicated that, drivers intentionally ran over amphibians and reptiles or intend to do so (Ashley et al. 2007; Beckmann & Shine 2012).

Recommendations to mitigate roadkills

The Fauna and Flora Protection (Amendment) Act provides the Department of Wildlife Conservation with authorization to implement and enforce regulations to set lower speed limits and to prosecute violators (PDSRSL 2009). We strongly recommend that the government authorities immediately enforce posted speed limits in and around the parks and employ law enforcement officers to monitor violations. Creating speed-limit bumpers will force the safari drivers and commuters to slow down. Increasing the awareness among the safari drivers, tour business owners, and the tourists is of great importance. These stakeholders should be made aware of speed limits, impacts of roadkills on local wildlife, and importance of following regulations to ensure the sustainability of the tourism industry. The maximum number of vehicles permitted into the parks needs to be controlled. We strongly advise against construction of new access roads or public roads across either of the parks as such actions will exacerbate the problem.

We also suggest that public roads with high wildlife occupancy be closed for traffic during the nights since most wildlife activities peak nocturnally. Seasonal closure of certain roads, especially during the rainy season may mitigate amphibian road mortality. In addition, identification of roadkill hotspots (areas where wildlife are mostly susceptible to vehicular collision) is crucial. In 2013, both national parks earned 30 million Sri Lankan Rupees (US$ 240,000) through tourism. We urge that the conservation authorities invest some of this revenue into tourist awareness and law enforcement. A transition from mass tourism (where a large number of tourists are entertained with little opportunity for education and awareness) to ecotourism (where a fewer number of tourists are entertained with a greater opportunity of education, awareness, and recreation) is a much-needed endeavor for both parks (Weerasinghe et al 2003).

Many developing nations such as Costa Rica have successfully reformed their regulations in state protected areas with the introduction of ecotourism-driven approaches (Stem et al. 2003). Since ecotourism charges a higher bill per head, transition from mass tourism to ecotourism is financially beneficial for both the government and private-sector service providers as well as the local inhabitants. A conceptual change in the tourism industry may most likely warrant many other benefits to the environment (Weerasinghe et al 2003; Buultjens et al. 2005). Although building up green bridges, wildlife overpasses, and underpasses can establish unimpeded connectivity, such endeavors are costly. Further, such major constructions may accentuate disturbances and temporarily increase incidental mortality. Therefore, such major changes in the road network should be proceeded with caution. Construction of culverts or underground tunnels with minimal disturbances or use of low-cost underpasses that can be retrofitted into the existing access roads, however, can be a potential solution if carried out based on feasibility studies and environmental impact assessments, based on sound science and principles of ecology (Dodd et al. 2004).

Future directions for research

We acknowledge that our study design may have a few shortcomings. Removal of roadkilled carcasses by scavengers and postmortem destruction and displacement of the carcasses by traffic may have compromised our observations (Santos et al. 2011; Beckmann & Shine 2015). To account for these biases, surveys needs to be conducted in higher frequencies, particularly focusing on times of peak animal movements, highest traffic density, and peak feeding time of scavengers. Use of multiple survey methods (walking vs motor vehicles) may have biased our observations towards larger, conspicuous roadkills. Impacts on seasonality of rain and droughts as well as differential road mortality between days and nights need to be investigated.

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