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Research Article

Driver knowledge and attitudes on animal vehicle collisions in Northern Tanzania

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Abstract
Roads are a major cause of wildlife mortality by animal-vehicle-collisions (AVCs). We monitored the patterns and frequency of AVCs on two sections of a major highway in Northern Tanzania and compared these patterns to the knowledge and perceptions of drivers who frequently use the roads. While actual field survey showed that more birds were killed by AVCs, mammals were perceived by the drivers to be the most common AVC. Drivers were indifferent to whether AVCs were a major problem on the road, and 67% strongly felt that AVCs were mainly accidental, either due to high vehicle speed or poor visibility at night. There was a negative correlation between the likelihood of a species being hit by vehicles and its average body mass. Only 35% of drivers said they had attended an educational program related to the impact of roads on wildlife. This study highlights a need for collaborative efforts between the wildlife conservation and road departments to educate road users on the importance of driving responsibly and exercising due care for wildlife and human safety. This should be coupled with effective mitigation measures to reduce the extent of AVCs.

Key Words: Animal Vehicle Collisions (AVCs), Attitudes, Driver awareness, Mitigation, Roads

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Introduction

Animal Vehicle Collisions (AVCs) are collisions between a vehicle and an animal resulting in either death or injury of the animal. Globally, animal mortality from AVCs exceeds mortality from legal hunting and poaching [1]. For example, in the USA the annual number of ungulate vehicle crashes was estimated at 725,000 to 1,500,000 [2]. Beyond being a major concern for wildlife conservation, vehicle accidents involving animals pose a serious concern for human safety and cause severe economic losses [2]. AVC-related damages amount to billions of dollars in vehicular repairs and loss of human lives annually [3]. The costs of mitigation measures for wildlife protection would be lower than the costs of AVCs [4]. Sielecki *et al* [5] estimated that AVCs in the United States caused on average over $1US billion in damage to vehicles, 29,000 human injuries, and 200 human fatalities annually. Despite this evidence, AVCs are a "blindspot in public perception" that do not receive proper attention in the media [6]. Often, these ecological, safety and economic concerns are neglected because the transportation sector is viewed as key to overall economic development and growth in a region [7]. Indeed, there are few attempts to reconcile infrastructure development with wildlife conservation in the tropics [8, 9]. Although there are positive effects of roads, e.g., provision of edge habitat and movement corridors for some species, the negative effects of roads outnumber the positive effects by a factor of five [10].

The patterns of AVCs are determined by a variety of factors. Animal-related parameters that might affect the frequency and severity of AVCs are: animal density, ranging behavior [10-12], diet, and body size [13, 14]. The quality of habitat surrounding the road may affect the likelihood of AVCs [15]. Other important factors relate to the road type, vehicle speed, and traffic volume [16-19]. Recent studies suggest that drivers deliberately kill animals on roads. For example, drivers in Australia claimed to intentionally hit invasive Cane toads (*Bufo marinus)* [20], and drivers in Brazil intentionally kill snakes [21]. In the USA, drivers often consider vehicular crashes with deer as unavoidable [22]. In essence, AVCs constitute a biodiversity conflict between humans and wildlife. As attitudes presumably play a major role in determining conflict intensity [23, 24], their understanding is central to developing AVC mitigation strategies. In this study, we compared drivers' attitudes and awareness of AVCs with actual patterns of AVCs in a section of an East African savannah ecosystem.

Methods

Study area

This study was conducted within the Tarangire-Manyara-Ecosystem (TME). TME is a critical wildlife area in Tanzania [25] with three key protected areas: Lake Manyara National Park (648 km^2), Manyara Ranch (183 km^2) and Tarangire National Park (2,850 km^2). The climate varies from tropical semi-arid to semi-humid and receives an annual rainfall of 650 mm, occurring during two wet seasons from November-December and March-May [26, 27]. The habitat is savannah grassland [28], largely dominated by trees of the *Vachellia-Commiphora* genera. The area is rich in wildlife diversity, with around 350 bird, 290 reptile, and 40 amphibian species and over 35 large (> 5kg) mammal species [29,30]. The spatial temporal distribution of water, however, limits the presence of reptiles and amphibians, with higher numbers occurring during the rainy season. Due to the high wildlife diversity, photographic tourism is an important source of income in the area [25]. Crop farming is concentrated on low-lying floodplains on the Rift Valley floor [30] in the Mto wa Mbu area. Recently, there has been proliferation of peri-urban centers such as Mto wa Mbu and Makuyuni. We focused on two interlinked stretches of tarmacked road that traverse the area (Fig 1): A 40 km transect on the Makuyuni-Babati Road (A104) and a 35 km transect on the Karatu-Makuyuni Road (B144). Both roads are paved, are single-lane with variable speed limits from 30-100km, and have high vehicle traffic.

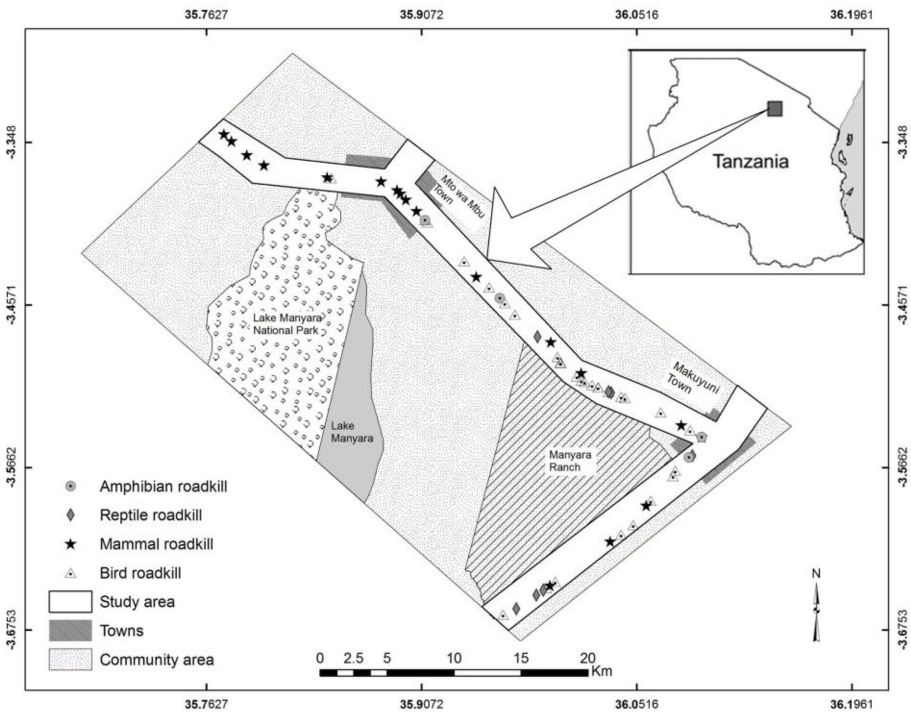

Fig. 1. Map showing the study area in the Tarangire-Manyara Ecosystem (TME), Tanzania. In total we studied a 75 km section of the Arusha Highway. We separated the roads into the 40 km section on the Makuyuni-Babati Road (A104) and the 35 km section on the Karatu-Makuyuni Road (B144). The map also shows the locations of roadkill in the different animal categories.

Data collection

We collected data on AVC incidences by driving daily along both roads from 07:30-09:30 for a total of 18 days (12 April- 22 April, 2013 and 17 April- 24 April, 2014). All AVCs detected along the road or on the road verges were identified to species level and photographed for verification, and a GPS (Garmin International, Inc.) location was taken. All carcasses were removed from the road to avoid double counting. Sixty questionnaire surveys were conducted among drivers at bus stops in Makuyuni and Mto wa Mbu towns to determine driver attitudes, knowledge, and level of awareness of AVCs. Public transport drivers were chosen because they frequently use the road and therefore were assumed to be more informed about animal-vehicle interactions on the road. Drivers were asked to rate the main causes (accidental, speed, darkness, bad weather, animal behavior, intentional, bad weather) of AVC on a scale (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree). Drivers were asked about their reactions (on a score 2 =strongly agree, 1= agree, 0 = disagree) on seeing a number of animals, including domestic dogs, frogs (*Rana spp.)*, tortoises/terrapins (e.g. *Stigmochelys pardalis* and *Pelomedusa subrufa*), birds, snakes (Serpentes), mongooses (e.g. *Ichneumia albicauda; Mungos mungo*), olive baboons (*Papio anubis*), common wildebeest (*Connochaetes taurinus*), plain's zebra (*Equus quagga*), and African elephants

(*Loxodonta africana).* Pictures of these species were shown to them to ensure they recognized/knew the species. The questions were administered in Kiswahili, the official language in Tanzania. The questions were designed to gather information on the driver's experience of wildlife on the road, the driver's view of causes of AVCs, if people would collect the AVCs or not, and the driver's awareness of AVC mitigation measures.

The School for Field Studies Committee on Human Subjects reviewed and approved the questionnaire and survey protocol. The interview protocol was reviewed and approved to meet the conditions for the U.S. federal code on human subject's protections in research (IRB: TZ-02-13-14). All the interviewees were briefed on the study and voluntarily answered the research questions.

Data analysis

Data were analyzed using SPSS [32]. Descriptive statistics were used to analyze the respondent's demographics. A Chi Square goodness of fit test was used to test for variations in respondent's primary income, whether AVCs occurred during the day or night, whether the driver thought that AVCs were a major problem or not on the roads, whether the driver showed respect to wildlife on the road or not, and whether the driver had attended educational awareness programs on impacts on roads or not. Chi-square contingency test was used to test the relationship between the demographic variables (education level) and whether or not the driver had participated in an educational/awareness program(s). Spearman's rank correlation test was used to determine if the number of years one had been driving and their age was correlated to whether they had participated in road impact educational programs or not. Spearman's rank correlation test was also used to determine the relationship between species' body mass and their AVC risk (based on whether drivers said they would hit them or not). Spearman's rank correlation test was applied in these cases due to the small data sample and the fact that only a few select species were tested.

Results

Driver demographics

Of the 60 drivers interviewed, 98% were male. Their age ranged from 22 to 58 ($\bar{x}$ = 35.53 ± 0.99 SE). Only one driver had no formal education, 36% had completed primary education, 34% had completed secondary education, and the remaining 31% had completed tertiary studies. The primary income of the drivers varied significantly (χ^2 = 14.254, df = 1, p = <0.001), with 77% stating that being a driver was their main source of income. The number of years driving ranged from 1-38 years ($\bar{x}$ = 10.74 ± 1.05 SE), driving an average of ($\bar{x}$ = 8.43 ± 0.53 SE) hours per day. Most of the drivers were of local Tanzanian tribes, except two expatriates of European descent.

Observed and perceived roadkill pattern

There were 161 AVCs detected, consisting of 60 species (Appendix 1). The most abundant taxonomic group was birds (49%), followed by mammals (23%), reptiles (18%), and amphibians (9). By contrast, responses from the questionnaire surveys showed that drivers believed mammals to be the most impacted by AVCs (74%), followed by reptiles (12%), birds (8%), and amphibians (7%) (Fig 2). As the study was only done in the wet season, changes may be expected at other times of the year, but in the wet season species abundance was assumed to be highest in order to overcome this limitation. There was an inverse relationship between whether a driver reported he would hit a species and its body mass (kg) (rho = -6.28, p = 0.003), with drivers saying that they would often hit small-bodied animals encountered on the roads. However, there was no significant relation between the proportion of actual species AVCs and their body mass.

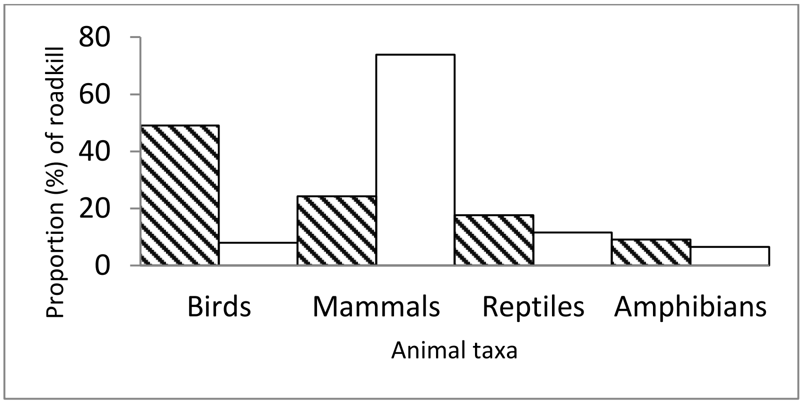

Fig 2. The proportion of observed and driver reported animal vehicle collisions separated by taxonomic.

Driver views on the causes of AVCs

Of the 60 drivers, 81% said AVCs were more likely to occur at night, and 12% stated that AVCs occurred during the day. The remaining 7% stated that AVCs occurred both at night and during the day (χ^2 = 57.789, df = 2, p = <0.001). Drivers were indifferent to whether AVCs were a major problem or not (χ^2 = 0.276, df = 1, p = 0.599). Accidental killing and high vehicle speeds were viewed as the main cause of AVCs, followed by darkness, slow movement, bad weather, and animal behavior. Intentional hitting by drivers and bad roads were rated lowest as potential causes of AVCs (Fig 3).

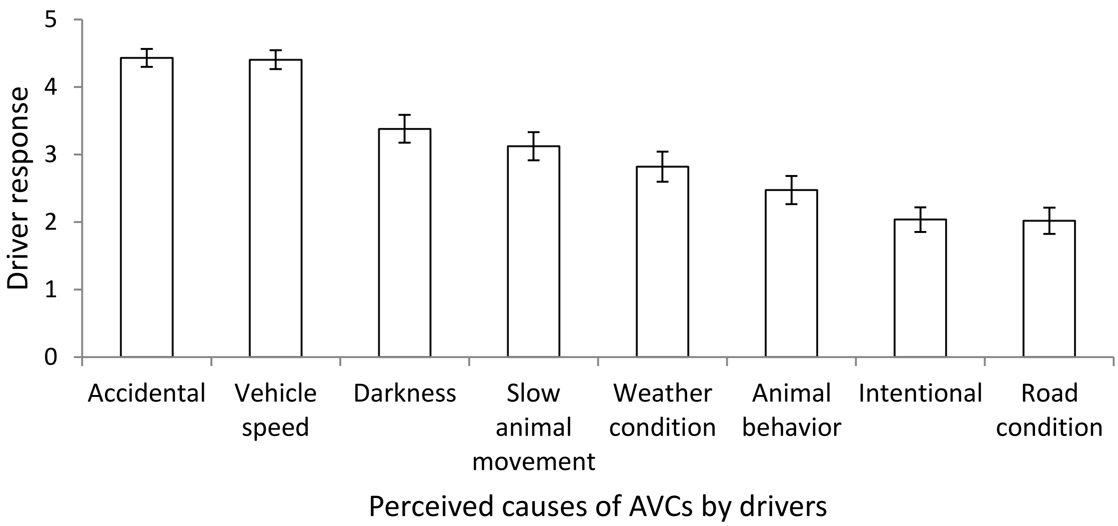

Fig. 3. Response rating of (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree) driver views on the causes of AVCs (±SE).

Drivers reported that they did everything possible to avoid hitting an elephant. Domestic dogs (*Canis lupus familiaris*), were reportedly most likely to be hit by vehicles, followed by frogs, birds and snakes (Fig 4). When asked how they would react (swerve, stop, or slowdown) to avoid an AVC, most drivers said they would swerve in case of snakes, tortoises/terrapins, and frogs. Drivers said that they were least likely to swerve in case of birds and would instead hit them. Drivers frequently reported they would stop for common wildebeest, elephant, and plains zebra, but were least likely to stop for birds, frogs and dogs.

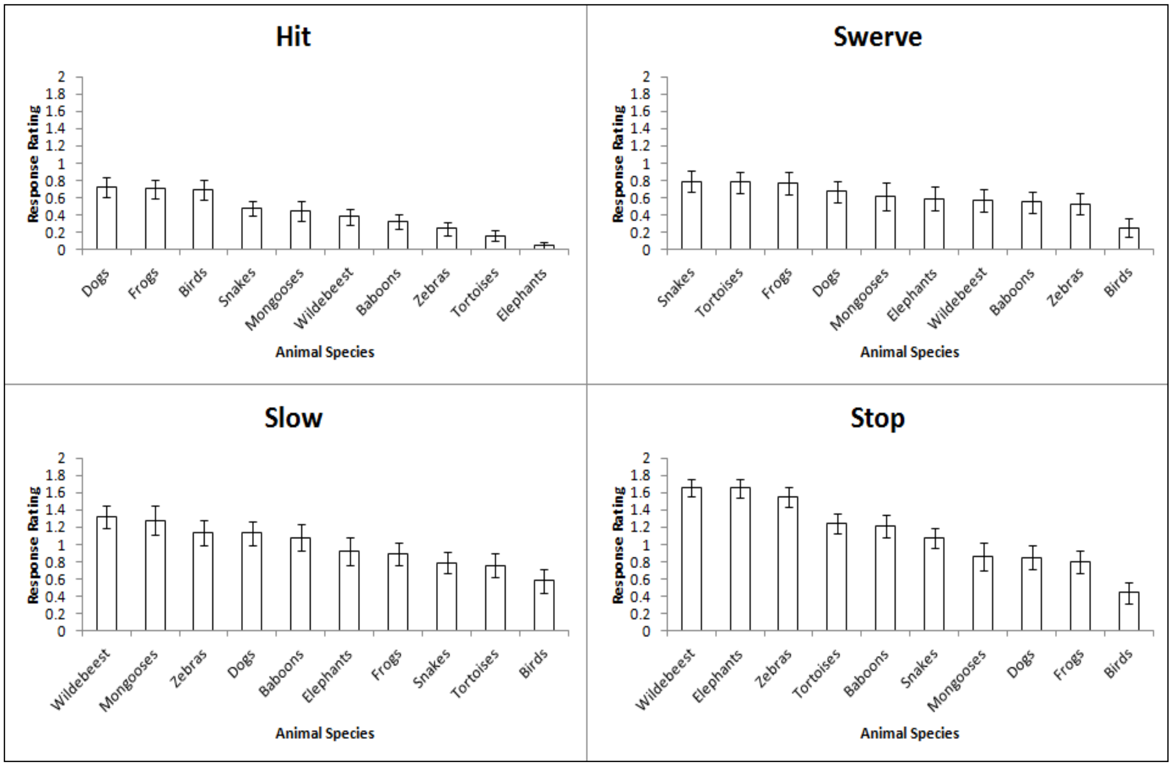

Fig. 4. Average scores (±SE), for four different reaction options (hit, swerve, slow down, stop) when different wildlife species were seen on the road by drivers, based on a score (2 =strongly agree, 1= agree, 0 = disagree). Scores were averaged over 60 responses of drivers for each species.

Most drivers (80%) felt that other drivers respected the wildlife crossing the road ($\chi^2 = 46.727$, p = <0.001); this was positively correlated to the extent to which they felt AVCs were a major problem on the road (rho = 0.351, p = 0.009, n = 60), their views on whether AVCs were seen to result from wildlife behavior on the roads (rho = 0.277, p = 0.041, n = 60), and the extent to which weather condition was seen to cause AVCs (rho = 0.406, p = 0.003, n = 60). The extent to which drivers said they would respect wildlife using the roads was negatively correlated to the extent to which drivers felt they intentionally caused AVCs (rho = -0.414, p = 0.002, n = 60).

Driver awareness and views on AVCs mitigation

The majority of drivers (65.5%) stated that they had not attended an educational/awareness program on the impacts of roads on wildlife ($\chi^2 = 5.255$, df = 1, p = 0.022). Whether or not they participated in an educational/awareness program on the impacts of roads on wildlife was dependent on the drivers' level of education ($\chi^2 = 6.73$, p = 0.03) but was not related to number of years they had been driving (rho =

0.025, p = 0.85, n = 60) or their age (rho = 0.147, p = 0.289, n = 60). Drivers suggested education on general safe driving practices (37%), use of road signs (22%), policy and regulation (20%), speed limits (14%), driver courtesy (5%), and improved road conditions (1%) as possible mitigation strategies.

Fig. 5. Elephant crossing Karatu-Makuyuni road into Lake Manyara National Park. Photo credit: John Kioko.

Discussion

While actual field survey showed that more birds than mammals were killed through AVCs, mammals were perceived by the drivers to be the most common AVC. Drivers were indifferent to whether AVCs were a major problem on the road, and 67% strongly felt that AVCs were mainly accidental, either due to high vehicle speed or poor visibility at night.

Observed and perceived AVC pattern

Surprisingly, compared to the actual AVC observations, drivers felt that the frequency of AVCs associated with birds was low. Generally birds are small (<0.5 kg), less likely to damage a vehicle, and therefore underrated by drivers. Because birds disappear quickly from the road due to rapid decomposition, the crushing caused by the vehicular traffic, and consumption by opportunistic scavengers, drivers do not realize the real mortality of this faunal group [33]. Mammals were perceived by drivers as the most frequent AVC (74%), although the observed frequency of mammal roadkill was only 23% of all AVCs. This view might be due to the fact that large animals (>10 kg), are more easily detected; furthermore, hitting them is more likely to cause damage to vehicles and can result in injury to the vehicle occupants [34]. The low proportion of mammal roadkill may be because of the mammal carcasses may have been removed by the residents for use as food. In Tanzania, bush meat represents a significant portion of local diets in the rural areas [35]; similarly, in North America for instance, collection and consumption of AVC is common [36]. The low proportion of reptile and amphibian AVCs reported by drivers (12% and 7% respectively) may be due to their low numbers because of the semi-arid climatic conditions [11] and a highly variable rainfall pattern [37]. In addition, amphibians may remain on the road for a shorter period of time than most mammal AVCs as they are likely to be quickly removed by scavengers or disintegrate through repeated hitting by vehicles [38].

Driver views on the causes of AVCs

The relationship between animal body mass and the likelihood of an AVC (as stated by the drivers) suggests that drivers intentionally hit species that are likely to cause less damage to vehicles. Drivers said that they were most likely to hit dogs, frogs, and birds. Dogs were said to be a “nuisance” for they are too common on roads. However, some drivers said they avoided hitting dogs as this was considered “bad luck.” Drivers further stated that frogs were hit more frequently during the wet season. Frogs are small and would not cause any harm to their vehicle. Drivers only occasionally stopped, slowed, or swerved to avoid hitting them. Drivers are less likely to swerve or stop suddenly on the road when they encounter a small animal that is unlikely to damage the vehicle [39]. Drivers noted that birds collided with their cars as they flew across the road. Drivers said they made little effort to swerve, stop, or slow for the birds to pass and would most likely hit them.

Drivers said they were least likely to hit African elephants, plains zebra, and Leopard tortoise. These species are generally more visible from a greater distance than the smaller species, which may have caused the drivers to actively prevent collisions. Moreover, collisions with elephant, wildebeest and zebra are likely to result in damage to both vehicle and passengers [34, 40]. In Southern Michigan, similar views were expressed regarding white-tailed deer (*Odocoileus virginianus*) [23]. In our study, some drivers believed that hitting slick shells of tortoises and terrapins could cause the car to skid, whilst others said that they liked tortoises, especially leopard tortoises. Some drivers would remove live tortoises from the road, either for the animals’ safety, to take home, or possibly to sell. Illegal trade in tortoise is reported to be well-established in the area [41].

The road in the study area crosses an important wildlife corridor, particularly for dispersal and migration of the common wildebeest [42] and African elephant [43]. Wildebeest travel in large herds, often crossing barriers such as roads [43], forcing drivers to stop and let them pass. Elephants often attract attention and many drivers said they would stop for them so the vehicle occupants could observe the elephants.

Most drivers viewed AVCs to be accidental and unavoidable. Similarly, in southern Michigan, USA, drivers felt that most deer collisions were random events and beyond their control [23]. The negative correlation between driver perception of whether they respected animals on roads and whether they intentionally hit animals, suggests that encouraging ‘respect’ may create a sense of care and consideration for wildlife.

Drivers considered high speed to be the second most important factor causing AVCs. Generally, speed and traffic volume are a major cause of AVCs [46], with high traffic volume often repelling animals from crossing roads [47]. Most drivers (81%) reported that AVC incidences occurred at night, with glare from headlights causing animals to freeze and subsequently get hit. However, considering that much of the diurnal AVCs consisted of small birds, it is likely that drivers did not pay much attention to them as an AVC, as they are not seen to be a threat.

Drivers reported that the potential for an animal to be killed on the road was related to animal behavior. Mongooses and dogs were considered to move more quickly than other species in response to vehicles, while amphibians and snakes were reported to be slow-moving, making them more susceptible to a collision with vehicles [48]. Snakes have different behavioral responses when faced with moving vehicles on the road; some species will freeze while others increase travel speed [49]. Weather conditions were considered relatively unimportant factors contributing to AVCs. This contradicts findings that AVCs increased with increased ambient temperature and precipitation in Indiana, USA [50]. While our study was done only in the wet seasons, it is likely that the rate of AVCs is lower in the dry season as there are fewer reptiles and amphibians. Lastly, poor road conditions (potholes) were seen to cause few AVCs, possibly because drivers usually drive slowly on these road sections.

Implications for conservation

We found a stark discrepancy between driver awareness of which species are most frequently impacted by AVCs and the actual composition of AVCs. Drivers' perception of different species is relevant to how they react to certain species on the roads. Furthermore, most drivers were indifferent to whether AVCs were considered problematic. Instilling consideration, care and empathy for all wildlife should form a focus of AVC mitigation forums. To that end, directed education can promote safe driving habits on the roads [23]. Education campaigns can be successful if they include specific information, e.g. are timed to coincide with peaks in animal migration [51]. This can be tailored to include specific information on the conservation status of species most at risk from AVCs, and the importance of specific areas of interest, such as migratory routes for wildlife.

Road signs were the second most important mitigation measure proposed. These are commonly used worldwide to alert drivers of animal-crossing areas [52]. However, signs have limited success when used in isolation and should be used alongside other mitigation strategies [53]. Because road signs are often ignored as drivers become used to seeing them [51], flexible sign posting during peak migration times may increase driver attention [54]. For example, signs could be an effective mitigation strategy on some of the road sections which are critical movement points for animals such as African elephants (Fig 5). In those areas, mandatory speed limits can be enforced. In addition, speed bumps have been effective in reducing human mortalities on roads [55], and could be constructed at critical wildlife crossings to slow traffic and allow wildlife safe passages. We suggest a need to increase both law enforcement and public education as complementary means to reduce AVCs in TME. In order to gauge the effectiveness of such environmental education and awareness campaigns, a wildlife roadkill monitoring program is needed in the medium and long-term both during and after the campaigns.

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Appendix 1. Cumulative **roadkill/km/day**, recorded for each taxon group on the Arusha Highway (12th April – 22nd April 2013, 17th April – 18th April 2014, 20th April – 24th April 2014).

Animal taxon Group	Common Name	Scientific Name	no of roadkill	roadkill/km/day
Birds	African Firefinch	*Langonosticta ubricate hildebrandti*	1	0.001
	Black Kite	*Milvus migrans parasitus*	1	0.002
	Black-headed Weaver	*Ploceus cucullatus*	1	0.002
	Blue-naped Mousebird	*Urocolius macrourus pulcher*	2	0.002
	Canary	*Serinus spp.*	1	0.002
	Cardinal Quelea	*Quelea cardinalis rhodesiae*	1	0.002
	Chestnut Sparrow	*Passer eminibey*	1	0.001
	Chestnut Weaver	*Ploceus rubriceps rubiginosus*	11	0.012
	Common Bulbul	*Pycnonotus barbatus*	2	0.002
	Common Fiscal	*Lanius collaris humeralis*	1	0.001
	Common Quail	*Coturnix coturnix erlangeri*	2	0.002
	Crimson-rumped Waxbill	*Estrilda rhodopyga centralis*	1	0.002
	Dusky nightjar	*Caprimulgus fraenatus*	1	0.002
	Grey-backed Camaroptera	*Camaroptera brachyura*	3	0.002
	Harlequin quail	*Corturnix delegorguei delegorguei*	2	0.002
	House sparrow	*Passer domesticus indicus*	1	0.001
	Lesser Striped Swallow	*Hirundo abyssinica unitatis*	1	0.001
	Lilac-breasted Roller	*Coracias caudata*	1	0.001
	Long-tailed Fiscal	*Lanius cabanisi*	1	0.001
	Northern Masked Weaver	*Ploceus taeniopterus taeniopterus*	2	0.002
	Rattling Cisticola	*Cisticola chiniana*	1	0.001
	Red-backed Shrike	*Lanius collurio*	2	0.002
	Red-billed Quelea	*Quelea quelea aethiopica*	5	0.004
	Red-cheeked cordon bleu	*Uraeginthus bengalus bengalus*	1	0.002
	Ring-necked Dove	*Streptopelia capicola somalica*	1	0.001
	Shining Sunbird	*Nectarinia habessinica turkanae*	1	0.002
	Slender-tailed Nightjar	*Caprimulgus clarus apatelius*	3	0.005
	Southern Red Bishop	*Euplectes orix nigrifrons*	2	0.003
	Speckled Mousebird	*Colius striatus kikuyuensis*	2	0.002
	Speckle-fronted Weaver	*Sporopipes frontalis emini*	1	0.002
	Dove	Streptopelia species	2	0.002
	Tawny-flanked prinia	*Prinia subflava melanorhyncha*	1	0.002
	Weaver species	*Ploceus spp.*	1	0.002

	White-browed robin-chat	*Cossypha heuglini heuglini*	1	0.002
	Yellow-crowned Bishop	*Euplectes afer ladoensis*	2	0.002
	Yellow-fronted Canary	*Serinus mozambicus*	2	0.002
	Unknown (too damaged to identify)		15	0.018
	Total Avian Species		**80 (50%)**	**0.094**
Mammal	African hedgehog	*Atelerix albiventris*	25	0.022
	African sheath-tailed bat	*Coleura afra*	1	0.001
	Black-backed jackal	*Canis mesomelas*	1	0.001
	Cape hare	*Lepus capensis*	2	0.002
	Common genet	*Genetta genetta*	2	0.002
	Common mouse	*Mus minutoides*	1	0.002
	Domestic dog	*Canis lupus familiaris*	2	0.003
	Domestic cat	*Felis catus*	2	0.003
	Fruit bat species	*Megachiroptera spp.*	1	0.002
	Olive baboon	*Papio anubis*	1	0.001
	Spotted hyena	*Crocuta crocuta*	1	0.001
	White-tailed mongoose	*Ichneumia albicauda*	1	0.002
	Total Mammalian Species		**37 (23%)**	**0.042**
Reptiles	Black Mamba	*Dendroaspis polylepis*	5	0.008
	Central African rock python	*Python sebae*	2	0.002
	Common egg-eater	*Dasypeltis scabra*	1	0.002
	Flap-necked chameleon	*Chamaeleo dilepis*	5	0.006
	Great plated lizard	*Gerrhosaurus major*	1	0.002
	Helmeted terrapin	*Pelomedusa subrufa*	8	0.006
	Pan hinged terrapin	*Pelusios subniger*	2	0.003
	Southern African rock python	*Python natalensis*	2	0.002
	Spotted blind snake	*Typhlops punctatus*	2	0.002
	Variable burrowing asp	*Atractaspis irregularis*	1	0.002
	Total reptilian species		**29 (18%)**	**0.034**
Amphibians	**Guttural toad**	*Bufo gutturalis*	**13**	**0.019**
	Garman's toad	*Bufo garmani*	2	0.003
	Total amphibians		**15 (9%)**	**0.023**
All Taxon	**Total roadkill**		**165**	**0.129**