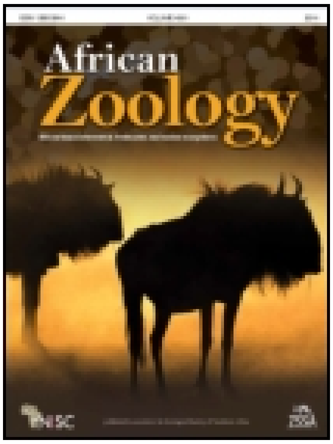

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Wildlife roadkill patterns on a major highway in northern Tanzania

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Despite expanding road networks, there is limited understanding of the effects of roads on wildlife in East Africa. We present a baseline survey and describe the patterns of roadkill in the Tarangire–Manyara ecosystem of Tanzania. A 75 km stretch of the Arusha Highway that passes adjacent to Manyara Ranch and Lake Manyara National Park was studied for 10 consecutive days in November 2013 (the rainy season). Wildlife species killed on the road, roadkill frequency and road characteristics were determined. A total of 101 roadkill were recorded (0.13 roadkill km^{-1}) comprising 37 species from all terrestrial vertebrate groups, of which two species, house cat (*Felis catus*) and domestic dog (*Canis lupus*), were domesticated species. Birds were the most frequently killed taxon (50%), followed by mammals (30%), reptiles (17%) and amphibians (3%). Excluding birds, roadkill primarily consisted of nocturnal species (65%) versus diurnal species (35%). Most roadkill (77.3%) were encountered on road stretches adjacent to protected areas of Manyara Ranch and Lake Manyara National Park compared with 22.7% on the road stretches adjacent to non-protected areas. These findings highlight that roads are a potential threat to wildlife in East Africa and serve as a baseline for future comparisons.

Keywords*:* mitigation measures, protected areas, road ecology, wildlife mortalities

Introduction

Roads can impact wildlife in two ways; indirectly, roads may create unstable meta-populations by fragmenting habitat patches and may result in animal movement restrictions leading to functional isolation of populations (Vos and Chardon 1998). More directly, roads can cause mortality of animals as a result of collisions with the vehicles that travel on them (Gunson et al. 2012; Kambourova-Ivanova et al. 2012). The distribution of roadkill is, however, heterogenous. Roadkill are more likely to occur along sections of the road that are surrounded by thick vegetative cover (van der Hoeven et al. 2009), as driver visibility is often impeded by denser roadside habitats (Caro et al. 2000; Ansara 2004; Eloff and van Niekerk 2005). In addition, recent research suggests that roadkill frequency increases with higher traffic speeds, particularly on paved roads (Drews 2008; Smith-Patten and Patten 2008; Collinson 2013), and high traffic volume often acts as a barrier for wildlife (Seiler 2003). Despite reduced traffic volume at night (van Langevelde and Jaarsma 2005), nocturnal and crepuscular species are more impacted by roads than diurnal species, possibly due to reduced driver visibility at night (Braunstein 1998).

Roads can alter animal behaviour, with many animals being attracted to roads (Santos et al. 2011). For example, snakes and other ectotherms habitually bask on asphalt; birds consume spilt grain from roadsides and some birds use roadside gravel to aid digestion (Noss 2002). Similarly, browsing herbivores are attracted to the dense vegetation of roadside edges (Noss 2002). This attraction often results in direct mortality and a cascading effect along the trophic hierarchy where scavenging animals seek out carcasses and are often killed themselves (Dean and Milton 2003; Antworth et al. 2005; Collinson 2013).

While the economic benefits of roads are appreciated (Gwilliam et al. 2008), the negative effects of roads for wildlife are rarely considered (van der Hoeven et al. 2009; Holdo et al. 2011) and few attempts are made to find workable solutions for these opposing objectives (Caro et al. 2014). Studies on the effects of roads on wildlife in Africa are limited (but see Newmark 1996; Laurance et al. 2006; Drews 2008; van der Hoeven et al. 2009; Mkanda and Chansa 2010; Bullock et al. 2011; Collinson 2013). To mitigate the effects of roads on wildlife, science-based evidence is imperative. This study is a preliminary investigation on the influence of a major road on wildlife in northern Tanzania, focusing on roadkill incidences in the Tarangire–Manyara ecosystem (TME). The study area is critical for wildlife conservation in Tanzania, and there is a need to balance conservation with development (Msoffe et al. 2011; Caro et al. 2014). The aim of the study was to determine the extent of wildlife mortalities through vehicle collisions and to establish relationships between roadkill occurrence and several biological and physical factors.

Methods

Study area

The study was conducted on a 75 km section of the Arusha Highway in the TME, northern Tanzania. Two single-lane paved roads, a 40 km transect on the Makuyuni–Babati Road (A104) and a 35 km stretch on the Karatu–Makuyuni Road (B144), classified as ‘A’ (international road) and ‘B’ (national road), respectively (Figure 1), were selected. The roads were selected due to their location; the Karatu–Makuyuni Road is situated along Lake Manyara National Park (648 km²) and Manyara Ranch (183 km²), whereas the Makuyuni–Babati Road runs adjacent to Manyara Ranch. Both roads pass through sections comprising crop and livestock farming and human settlements, and have vehicle speed limits between 30 and 100 km h^{-1}. The area is semi-arid, with an annual average rainfall of 600 mm. There are two rainy seasons (Msoffe et al. 2011): the long rains (March–May) and the short rains (October–December) (Kioko et al. 2013). Rainfall varies greatly between 375 and 1 250 mm y^{-1} (Cohen et al. 1993). Two permanent and several seasonal rivers cross the study road. In addition, there are seasonal water pools and dams adjacent to the road that are utilised by livestock and wildlife.

The overall habitat is savanna, largely dominated by *Vachellia–Commiphora* grassland (Pratt and Gwynne 1977). The area has high species diversity, e.g. c. 350 species of birds (Prins and Loth 1988), c. 35 large (>5 kg) mammal species (Msuha et al. 2012; Kiffner et al. 2014) and a range of reptiles and amphibians (Branch 2005). The spatial and temporal distribution of water limits the presence of reptiles and amphibians, with higher activity patterns during the wet than the dry season.

Roadkill assessment

Roadkill data were collected daily over a 10-day period (11–22 April 2013) along the 75 km route during the wet season, as a baseline for long-term roadkill monitoring. Subsequent studies will be undertaken to cover both wet and dry seasons to allow seasonal comparisons. The third author, assisted by a driver, collected data for all the surveys, commencing at 06:30 and finishing at 09:30. Roadkill data were collected within thirty, 2 km transects of the total 75 km road length.

Sampling was done on 2 km transects separated by a length of 250 m. Roadkill locations, both on the road and on the road verge (total road width of 10 m), were recorded using a GPS (Garmin eTrex). In addition, habitat cover (closed or open), habitat type (grassland or bushland), and protection status of each 2 km road segment were recorded. Once recorded, roadkill were removed to avoid recounts. We categorised activity patterns of species as either diurnal or nocturnal based on Kingdon (1997) and Branch (2005).

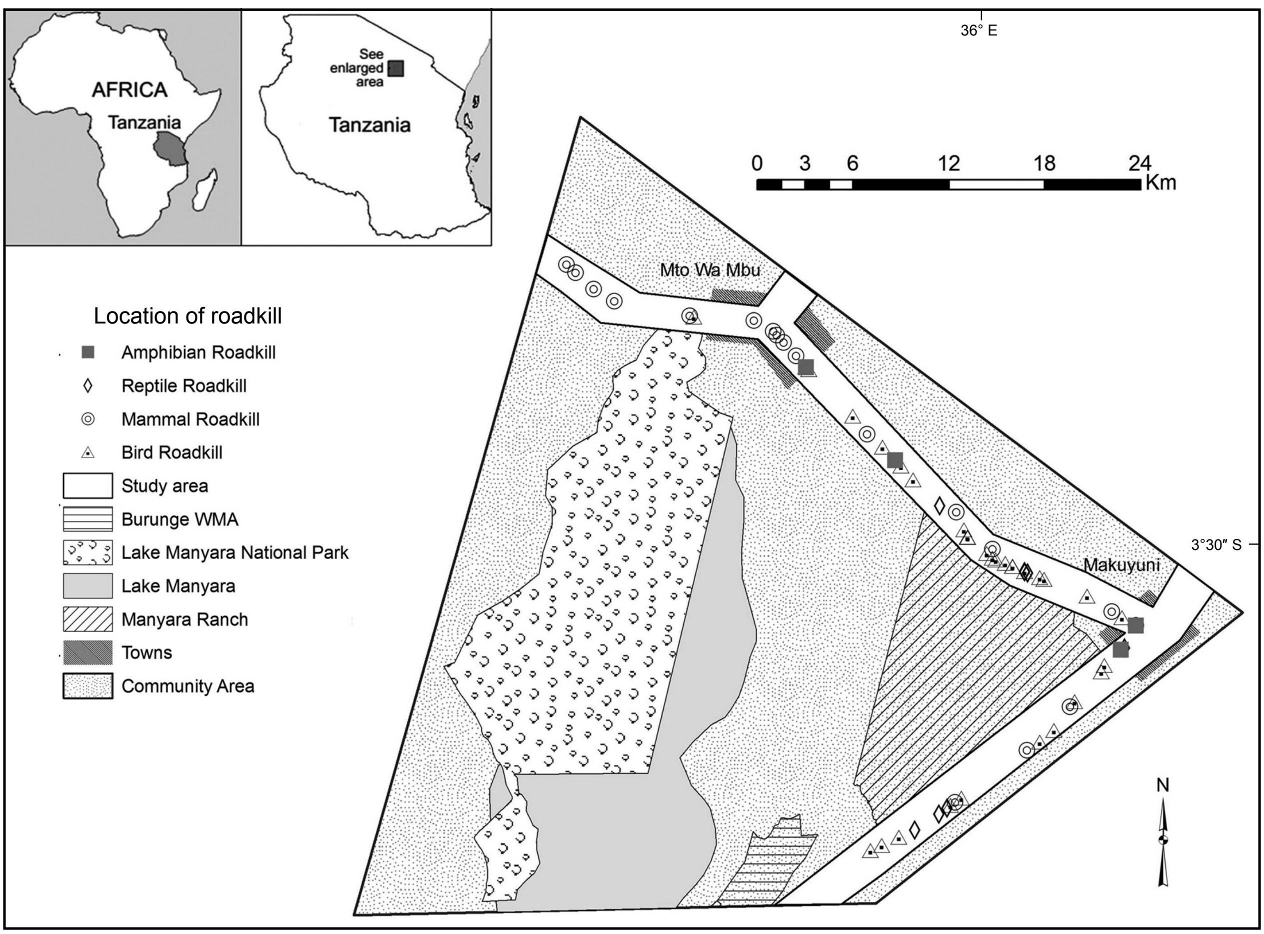

Figure 1: Location of roadkill recorded on the Arusha Highway (Makuyuni–Babati Road [A104] and Karatu–Makuyuni Road [B144]) in the TME, Tanzania

Data analysis

A chi-square goodness-of-fit test was used to compare the frequency of diurnal species with the frequency of nocturnal species killed. Whether roadkill were equally distributed in protected versus unprotected areas was also assessed using a chi-square goodness-of-fit test. The effect of habitat type on occurrence of roadkill was determined using Jacobs' index (Jacobs 1974). The statistical analysis was undertaken using SPSS 10 (SPSS 1999).

Results

Species composition of roadkill

A total of 750 km were driven and we recorded a total of 101 roadkill events (0.13 roadkill km^{-1}). Three percent of the roadkill were domestic animals (two house cats *Felis catus*, and one domestic dog *Canis lupus familiaris*), whilst 97% were wild animals. Of the four vertebrate taxa, bird roadkill constituted the highest proportion (0.065 roadkill km^{-1}), followed by mammals (0.043 roadkill km^{-1}), reptiles (0.023 roadkill km^{-1}) and amphibians (0.004 roadkill km^{-1}) (Table 1).

Of the 22 recorded bird species, Chestnut Weaver (*Ploceus rubiginosus rubiginosus*; 17%), Red-billed Quelea (*Quelea quelea aethiopica*; 12%) and Grey-backed Camaroptera (*Camaroptera brachyuran*; 7%) were the most abundant roadkill species. The African hedgehog (*Atelerix albiventris*) was the most commonly encountered mammal (69%). There were five species of reptiles killed on the roads: helmeted terrapin (*Pelomedusa subrufa*; n = 8), flap-necked chameleon (*Chamaeleo dilepis*; n = 3), Southern African rock python (*Python natalensis*; n = 2), Central African rock python (*Python sebae*; n = 2) and spotted blind snake (*Typhlops punctatus*; n = 2).

Table 1: Roadkill recorded on the Arusha Highway in April 2013

Taxon group	Common name	Scientific name	Number of roadkill detected	Cumulative roadkill km^{-1}
Birds	African Firefinch	*Lagonosticta rubricata hildebrandti*	1	0.001
	Blue-naped Mousebird	*Urocolius macrourus pulcher*	1	0.001
	Chestnut Sparrow	*Passer eminibey*	1	0.001
	Chestnut Weaver	*Ploceus rubiginosus rubiginosus*	7	0.009
	Common Bulbul	*Pycnonotus tricolor*	1	0.001
	Common Fiscal	*Lanius collaris humeralis*	1	0.001
	Common Quail	*Coturnix coturnix erlangeri*	2	0.003
	Dove spp.	*Streptopelia* spp.	2	0.003
	Grey-backed Camaroptera	*Camaroptera brachyura*	3	0.004
	Harlequin Quail	*Coturnix delegorguei*	1	0.010
	House Sparrow	*Passer domesticus indicus*	1	0.001
	Lesser Striped Swallow	*Hirundo abyssinica unitatis*	1	0.001
	Lilac-breasted Roller	*Coracias caudatus*	1	0.001
	Long-tailed Fiscal	*Lanius cabanisi*	1	0.001
	Northern Masked Weaver	*Ploceus taeniopterus taeniopterus*	2	0.003
	Rattling Cisticola	*Cisticola chiniana*	1	0.001
	Red-backed Shrike	*Lanius collurio*	2	0.003
	Red-billed Quelea	*Quelea quelea aethiopica*	5	0.007
	Ring-necked Dove	*Streptopelia capicola somalica*	1	0.001
	Speckled Mousebird	*Colius striatus kikuyuensis*	2	0.003
	Yellow-crowned Bishop	*Euplectes afer ladoensis*	2	0.003
	Yellow-fronted Canary	*Crithagra mozambica*	2	0.003
	Unknown bird spp.	–	8	0.011
Total			49 (49%)	0.065
Mammals	African hedgehog	*Atelerix albiventris*	22	0.029
	African sheath-tailed bat	*Coleura afra*	1	0.001
	Black-backed jackal	*Canis mesomelas*	1	0.001
	Cape hare	*Lepus capensis*	2	0.003
	Common genet	*Genetta genetta*	1	0.001
	Olive baboon	*Papio anubis*	1	0.001
	Spotted hyena	*Crocuta crocuta*	1	0.001
	Domestic dog	*Canis lupus familiaris*	1	0.001
	Domestic cat	*Felis catus*	2	0.003
Total			32 (32%)	0.043
Reptiles	Central African rock python	*Python sebae*	2	0.003
	Flap-necked chameleon	*Chamaeleo dilepis*	3	0.004
	Helmeted terrapin	*Pelomedusa subrufa*	8	0.011
	Southern African rock python	*Python natalensis*	2	0.003
	Spotted blind snake	*Typhlops punctatus*	2	0.003
Total			17(17%)	0.023
Amphibians	Guttural toad	*Bufo gutturalis*	3 (3%)	0.004
Total species			101	0.130

The guttural toad (*Bufo gutturalis*; $n = 3$) was the only amphibian detected.

Relationship between the occurrence of roadkill and animal activity

Diurnal species constituted the majority (77.1%) of species compared to nocturnal species 22.9%. This difference was statistically significant ($\chi^2 = 10.31$, df = 1, $p < 0.001$). Birds were the majority diurnal species encountered (81%). When birds were excluded from the analysis (due to their high abundance), there were significantly more ($\chi^2 = 4.08$, df = 1, $p = 0.043$) nocturnal than diurnal amphibians, reptiles and mammals killed (65%). Helmeted terrapins (53%) were the most common diurnal species killed on the road, with African hedgehog (67%) being the most common nocturnal roadkill.

Relationship between habitat characteristics and roadkill occurrence

Roadkill occurrence was substantially influenced by roadside habitat (Figure 2). Roadkill were found more often than expected in open bushland habitat (Jacob's index = 0.14) than in closed bushland habitat (Jacob's index = 0.05). Roadkill frequency was lower than expected in open grassland habitat (Jacob's index = −0.18).

Effect of protection status on roadkill occurrence

There were significantly more roadkill on road sections adjacent to the protected areas (77.3%) than in sections adjacent to non-protected areas ($\chi^2 = 28.96$, df = 1, $p < 0.001$).

Discussion

Species composition of roadkill

Birds and mammals were the most frequently detected taxonomic groups killed on the Arusha Highway. The Chestnut Weaver was the most frequently detected bird roadkill, likely due to its gregarious behaviour observed mainly during the breeding period (Herremans et al. 1997; Zimmerman et al. 1999) and its nesting preference for *Vachellia* spp. trees along the road (Harrison et al. 1997). Similarly, the high incidence of Red-billed Quelea roadkill may be due to their high abundance and activity during this period (Zimmerman et al. 1999).

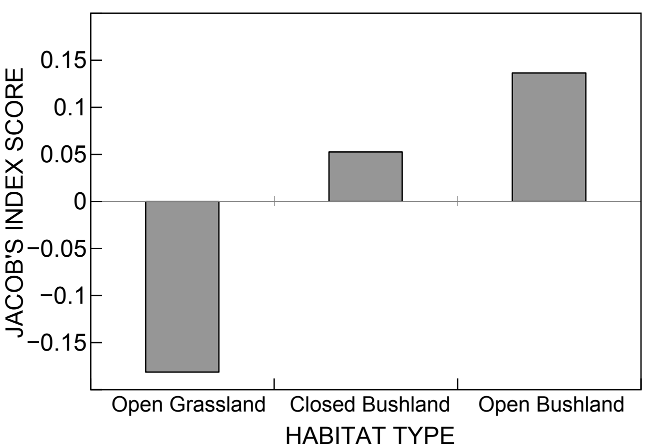

Figure 2: Jacob's index scores indicating roadkill detection in different habitat types on the Arusha Highway in April 2013

The African hedgehog, as with the European hedgehog (*Erinaceus europaeus*; Orlowski and Nowak 2006) is particularly susceptible to collision with vehicles (Smiddy 2002; Hell et al. 2005; Haigh 2011), and was the most frequent mammal roadkill. Facing a threat hedgehogs curl up and stay motionless (Kingdon 1997; Haigh 2011), which makes them frequent victims of vehicle collisions.

Carnivore roadkill detected during our transects, such as spotted hyaena (*Crocuta crocuta*) and black-backed jackal (*Canis mesomelus*), may be due to their wide-ranging foraging and scavenging of existing roadkill carcasses (Estes 1991; Collinson 2013). The high occurrence of reptiles and amphibians encountered during this study was probably largely influenced by the timing of the driven transects (i.e. the wet season). In semi-arid areas, amphibians and many reptile species, aestivate and burrow underground, only making an appearance during the wet season (Branch 2005). Helmeted terrapins seasonally migrate in search of water, often crossing roads (Spawls et al. 2004), and thus roadkill 'hotspots' for reptiles and amphibians are usually associated with wetlands or pools within 100 m of the road (Langden et al. 2009; DeWoody et al. 2010). Many snake species are attracted to paved roads for thermoregulation (Sullivan 1981; Drews 2008). They often seek sources of warmth during the night and early morning when the air temperature is cool, making them vulnerable to road-related mortalities (Row et al. 2007). In addition, some of the snakes such as the African rock python move slowly, which increases their susceptibility to vehicle collisions.

Relationship between the occurrence of roadkill and animal activity

Birds accounted for the highest taxonomic group, in particular, Chestnut Weaver and Red-billed Quelea. These two species are diurnal and tend to flock in large numbers (Zimmerman et al. 1999), meaning a collision with a vehicle can impact 100s of this species at once. In addition, drivers may be indifferent to smaller species on the roads if they are less likely to cause damage to a vehicle or injure the vehicle occupant (Rowden et al. 2008). The high incidence of nocturnal species (excluding birds) can probably be attributed to reduced night-time visibility (Braunstein 1998).

Relationship between habitat characteristics and roadkill occurrence

Most roadkill were found on road sections adjacent to open bushland, with fewer roadkill in sections along closed bushland and open grassland. This is in line with other studies and suggests that road sections along dense vegetative cover are potential hotspots for roadkill (Clevenger et al. 2003). Much of the area adjacent to protected areas in the study area has become increasingly open due to land-use changes (Sechambo 2001; Msoffe et al. 2011) resulting in the degradation of grasslands due to intense livestock grazing (Mwalyosi 1992). These disturbances may make the area less favorable for wildlife and therefore reduce roadkill incidences.

Effect of protected area status

Road sections adjacent to protected areas had higher frequencies of roadkill occurrences than unprotected areas. Similar findings were noted by Garriga et al. (2012) in Spain. Manyara Ranch and Lake Manyara National Park offer safe refuge for wildlife (Kioko et al. 2013) and have higher wildlife numbers than the adjacent non-protected areas. Thus, relative abundance of wildlife is probably a key factor in explaining variation in roadkill frequencies. Olive baboon (*Papio anubis*) and blue monkey (*Cercopithecus mitis*) commonly forage along the road section adjacent to Lake Manyara National Park, which may increase the likelihood of a vehicle collision.

Less roadkill incidences were noted on roads in the agricultural and urban areas (unprotected areas, including the townships of Mto wa Mbu and Makuyuni), despite providing habitat for certain wildlife species (such as olive baboons and rabbits *Sylvilagus* sp.). These are effectively 'disturbance zones' that exclude (de Merode et al. 2000) or are actively avoided by wildlife (Okello and Kioko 2010), explaining the low incidence of roadkill in these sections.

Management implications and recommendations

Our study demonstrates a relatively low frequency for vertebrates (0.13 roadkill km^{-1}) compared to other parts of the world. For example, in southern Brazil, Bager and Rosa (2010) estimated 1.06 roadkill km^{-1} and Collinson (2013) recorded 0.90 roadkill km^{-1} in Limpopo, South Africa. It does, however, provide a baseline for in-depth studies on the long-term effects of roads in TME and highlights the need for such studies in other key wildlife areas in East Africa. It is likely that the increasing road network, if not well planned, may adversely affect wildlife in the long term. We emphasise the need to integrate knowledge of road ecology (e.g. mitigation measures) in the road development planning process to alleviate the adverse effects on wildlife.

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