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Wildlife roadkill in Southwestern Ethiopia: Hotspots, drivers, and victim species

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ABSTRACT

Wildlife-vehicle collision (WVC) is one of the major causes of wildlife mortality and a concern for conservationists worldwide. The study of roadkill data that can be used to develop appropriate measures and strategies for both wildlife conservation and traffic safety to mitigate the WVC and animals' mortality. Extensive studies have been conducted in the developed countries on the identification of WVC hotspots and its potential impact; however, less attention is given in developing countries. Because of this, the problem is not well understood in developing countries. This study was intended to identify victim species, hotspot areas for roadkill, and factors that contribute to WVC in Jimma Zone, along three roads leading from Jimma City. Data were collected using a citizen science approach and a skilled man power road survey (March–September 2022) to document the number and type of species killed. Three road segments (135 km in total) were surveyed weekly as a baseline for future research. All statistical analyses were carried out using R-software. In the present study, a total of 84 roadkill specimens were collected from 16 different mammal species, of which 85.7% were medium-sized carnivores. The findings showed that Jackals (*Canis mesomalis and Canis adustus*) were the most frequently killed species (25%, n is 21), followed by *Civettictis civetta* (22.62%, n is 19). The study revealed that the major factors causing collisions include habitat type (forest cover) and wildlife behavior (nocturnal or diurnal). Further, the study revealed that the majority of WVC occurred at night (dusk) and at dawn in areas that are covered with dense forests. To minimize the potential risks of WVC and animals' mortality, we suggest putting warning signs in hotspot areas where roadkill usually occur frequently. In addition, we recommend creating awareness among drivers, traffic police, and all communities about the negative impacts and consequences of collisions on the ecological and economic value of wildlife.

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1. Introduction

Wildlife vehicle collisions (WVC) are among the serious impacts of roads and transportation that cause both human and wildlife deaths as well as injuries [1–4]. In this regard, WVC has been identified as one of the determining factors that negatively affect the population dynamics of wildlife species [1,5]. The impacts of roads on wildlife can be through roadkill (i.e., vehicles killing wild animals) and indirectly through forming habitat fragmentation that causes a barrier to wildlife movement [1,6]. Vehicle speed, road width, visibility, and roadside barriers are key causal factors for animal roadkill [7]. However, the type and level of seriousness vary depending on the variation in habitat types, wildlife species behavior, and community awareness of wildlife's ecosystem value. Aside from its impact on wildlife conservation, WVC is hazardous to humans. By hitting larger animals, it can cause extensive danger and serious damage to the vehicles, the drivers, and the passengers [8]. In addition, in areas where a large number of wildlife (either small or large animals) cross the road, a driver who drives at high speed can cause a traffic accident while trying to stop the vehicle suddenly to avoid hitting an animal.

Most of the studies regarding wildlife-vehicle collisions (WVC) have been conducted and reported in developed countries [9,10]. For instance, meta-analysis on roadkill shows that about 40% killed in United States, followed by Canada, Australia, Spain, the United Kingdom, Brazil, Germany, and Sweden, which cover 2–10% [11]. The studies focused on wildlife road kill patterns [12], and identified roadkill hotspot areas, the most exposed species to roadkill, and assessed the strategies and measures for the mitigation of roadkill. Developing countries experience a high level of roadkill even though their weekly traffic volume is lower than that of developed nation. This could be due to lack the necessary infrastructure (e.g., wildlife crossings, fencing, and warning signs) and resources to implement effective measures for wildlife protection.

Despite the expansion of various road networks in and near wildlife habitats, there is very limited understanding of the effects of roads on wildlife in Africa [12]. In WVC, the victim species are different from place to place. In Africa, among some of the studies on WVC, the study which was conducted in Zimbabwe between 2003 and 2013reported that 'of the total 96 road surveys, 47 mammals were recorded to have been killed. This comprised of 11 species (such as African buffalo, leopard, and impala) [13]. According to studies, birds were the most frequently killed species (50%), followed by mammals (30%), reptiles (17%), and amphibians (3%) [12].

Studies related to WVC in Ethiopia are almost non – existent except trials of very few and fragmented studies here and there. In this regard, the study on WVC in northern Ethiopia in the Tigray region, recorded 143 individuals from 20 species, including amphibians, reptiles, mammals, and birds [14].

Roadkill hotspot areas are important because road mortality patterns are usually not random but are concentrated at some locations [3,15]. Factors such as traffic flow and speed, road design, the presence of landscape corridors, and the availability of habitat may result in roadkill at different spatial scales. Thus, evaluating road kill spatial distribution and identifying roadkill hotspots are the important steps to implement successful mortality mitigation on the existing roads [16]. The study also revealed that most of the accidents occurred in the early morning and late evening.

With the current fast development of road infrastructure in the pristine natural habitats, the highest impact of roadkill is expected and it has also been started to be observed. To improve safety and to prevent collisions, having data on where wildlife is found, how

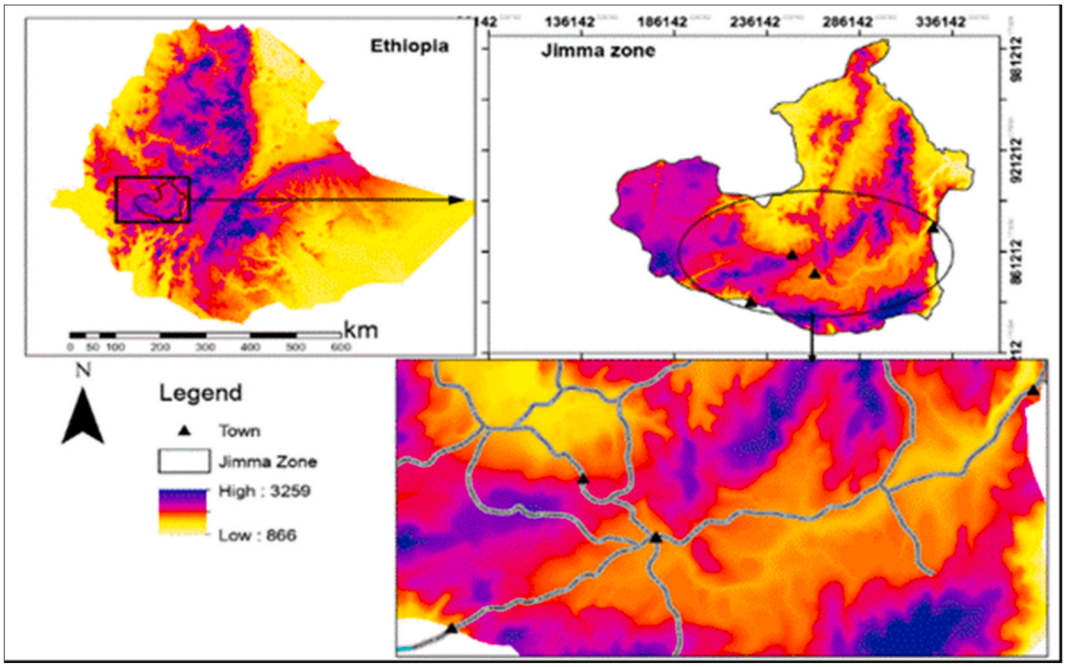

Fig. 1. Map showing the study roads which starts from Jimm city and goes to Agaro, Sokoru, and Shabe direction.

animals are moving, and where conflicts occur are quite important. With diverse wildlife and a large number of protected areas in Africa, vehicle wildlife collisions are more serious and influence conservation, human life, and economies. In the southwestern parts of Ethiopia, forests that have a wide ecological gradient, wildlife diversity, and significant forest cover are found [17]. Of the five Biosphere reserves in Ethiopia, four are confined to this region (i.e., Majang Forest Biosphere Reserve, Sheka Forest Biosphere Reserve, Kafa Coffee Forest Biosphere Reserve and Yayo Coffee Forest Biosphere Reserve). On top of this, the road infrastructure is developing at a fast rate in this area. The southwest region of the country has generally dearth of research, and there is particularly little data on roadkill. On account of the shortage of research and data in the area, it is expected that this high biodiversity in this natural forest will be exposed to roadkill. Hence, identifying the most vulnerable species and roadkill hotspot areas is crucial to find mitigation measures. This study is aimed to identify the victim species, hotspot areas, and factors causing the WVC that can be used as a baseline for wildlife conservation and road safety.

2. Methodologies

2.1. Study area

This study is conducted in Jimma Zone (Fig. 1), southwestern Ethiopia, which is located about 345 km from Addis Ababa, the capital city of the country. It covers a total area of 19,305 km^2. The zone is situated at an altitude range from 1000 to 3360 m above sea level. The average temperature ranges from 25 to 30 °C at its highest and 7–12 °C at its lowest. It receives high amount of rainfall (1200–2800 m m) per year. The rivers located in the zone are Didessa, Ghibe, and their tributaries, which created valleys suitable for wildlife. Savanna grassland, forest, reverie, and bush lands are the major vegetation types in the areas. The agro-ecology of Ethiopia was classified as lowland-500–1500 m above sea level (m.a.s.l) and midland-1500–2300 m.a.s.l. The region is part of the Afromontane Biodiversity Hotspot [18], and the landscape encompasses natural forest, coffee forest, cropland, reverie wetland, and human settlements [17]. Forest remnants are surrounded mainly by coffee agriculture and settlements. Coffee is the most dominant land cover in Jimma Zone. The Zone has a complex topography. It is knownfor its high diversity of mammals and birds [17].

3. Methods

3.1. Methods

The data on wildlife roadkill incidents were collected from all (four) major roads connecting Jimma City to surrounding towns and cities: 1) Jimma City to Mettu Town route - event surveyed up to Agaro town, 2) Jimma City to Addis Ababa route - event surveyed upto Sekoru, and 3) Jimma City to Bonga Town route - roadkill event surveyed upto Shebe. During the survey, the researchers collected data from a total of 135 k m. roads. These roads pass through a variety of habitats and land use types, including forests (e.g., shade coffee forest, plantation), subsistence farms, and rural and urban settlements. The preliminary survey showed that large and medium-sized mammals were determined to be the most victim animals in the research area. Therefore, the researchers looked only at medium and large mammals for this study.

For data collection, the researchers used two methods: citizen science [19] and direct field road surveys. The researchers and trained field assistants conducted a direct roadkill survey across the study area both in dry and wet seasons (ranging from March to September). We did not, however, compare seasonal differences in the analysis because it requires more long-term data. Researchers visited each road once a week to record the quantity and kind of species killed. Volunteer community members (e.g., drivers, farmers, students, development agents) reported animal-vehicle accident events, including wildlife species (i.e., local name), location of the event (i.e., forest, farmland, rural settlement and urban area, name of the village), time of day (i.e., morning or night), numbers killed, and a picture of the species (where possible). Citizen science is widely used to cover large area with minimum cost [19].

For the sake of simplicity of analysis, the researchers divided the species into three groups based on their feeding habits: carnivores (which use meat as their primary food source), herbivores (i.e., feed primarily on plants), and omnivores (i.e., feed on both plants and animals). Furthermore, we classified the wild mammals as medium-sized (weighing between 2 and 15 k g.) or large-sized (weighing more than 15 k g.) [20].

3.2. Data analysis

A chi-square goodness-of-fit test was used to compare the frequency of differences in species killed by WVC. In addition, we used a chi-square goodness-of-fit test to assess whether roadkill were evenly distributed across the roads. The effect of habitat type on the occurrence of roadkill was determined using a logistic regression model. All the statistical analyses were carried out in R Software version 3.3.1 [21].

4. Results

4.1. Vulnerable species to roadkill

The study revealed that 84 wild mammals representing 16 species were killed in vehicle collisions in Jimma Zone, Southwestern Ethiopia (Fig. 2; Table S 1). The most common roadkill mammals were jackals (black-backed *Canis mesomelas* and side-striped *Canis*

adusta), followed by African Civet cats *Civettictis civetta*.

4.2. Spatial and temporal wildlife-vehicle collisions in southwestern Ethiopia

4.2.1. Habitat type

The results revealed that the majority of wild mammals collided with vehicles are in the forest cover, and natural and coffee shade forest (Fig. 3a). However, non-human primates (*Papio anubus, Colobus guereza* ssp*, Chlorocebus aethiops*), and spotted hyenas (*Crocuta crocuta*), for example, have been killed in human settlement areas, and Road kill differed significantly ($X^2 = 91.419$, DF = 3, P = 0.001) by habitat type (Table 1; Figure S 1).With respect to road route, the greatest share of road kill was reported from Shabe roads, followed by Agaro, while Sokorru road had the lowest (Fig. 3b; Table 2). Similarly, the highest roadkill for all species were recorded during night (Fig. 3c).

4.2.2. Hotspot areas

The study identified three road kill hotspots; the number of road kills were significantly different ($p < 0.05$) roads along Shabe and Agaro (Table 1; Fig. 4). Shabe having the highest number of road kill (about 21 individuals) incident (Fig. 3b). The road from Jimma to Shabe crosses Belete Gera forest, a national forest priory area. The second is Yabbu areas, a coffee shade forest where about 19 road kill incident were recorded. According to the study, forest cover and topographic conditions of the area were the leading causes of roadkill in all of the identified hotspot areas (Fig. 3).

5. Discussion

5.1. Species

This is the first study to focus on roadkill in the Afromontane Forest of southwestern Ethiopia. Among all recorded wildlife, medium-sized carnivores were the most common roadkill victims. This finding is similar to those reported from Kenya's Tsavo Ecosystem, where small to medium-sized mammals were the most common roadkill [9]. This could be explained by their ecological behavior, such as their large home range and night time feeding (i.e., nocturnal behavior).

Because of their large body size and high dispersal capacity, mammalian carnivores are especially vulnerable to roadkill events. Furthermore, carnivore spend more time foraging for food and travel longer distances and making them more susceptible to roadkill [22]. Carnivores were vulnerable to road kill because of their feeding experience on dead animals and the other foods thrown from people on roads [14]. Other studies confirmed that carnivores have a higher chance of being involved in WVC due to their larger home ranges than herbivore mammals of the same size [23]. Of the carnivores identified, two jackal species (striped jackal and black-backed jackal) were the most individuals recorded, while African civet was the second victim of roadkill. Coffee shade forests in southwestern Ethiopia are home to jackals and African civets [17,24]. This might be one of the reasons why they are the most frequently killed by cars.

5.2. Spatial and temporal roadkill

Wildlife-roadkill was irregularly distributed on the road, with the highest number in the forest cover areas, followed by farmland areas. This is due to the forest cover that is able to provide a good habitat for this species and a good location for resting and breeding as the forest can provide protection from human attack [25]. At the same time, the agriculture farm in the area can provide food for the species [12]. The lowest record was in urban areas. With its shade coffee and natural forest, Jimma zone is ideal for forest dwelling wildlife such as jackals and African civet. The roadkill number was higher during the night, probably due to the animals' frequent movements for feeding. In this regard, our finding is highly compatible with previous studies in which nocturnal species were recorded and reported as the most victims of WVC [9,12,26] and this may be associated with their nature since they can be easily blinded to strong vehicle headlights. However, in order to fully understand the impact of season and other factors on roadkill in the Afromontane

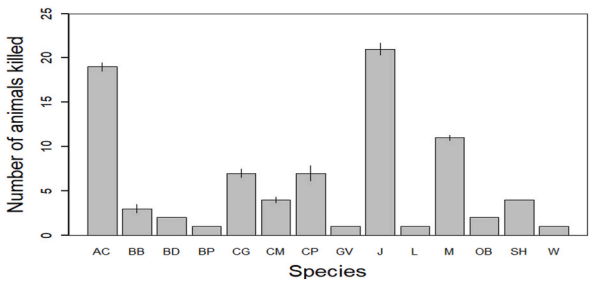

Fig. 2. Average number (with standard error bar) of mammal species carcasses killed due to vehicle collision in the study area from March to September 2022. Note: African civet is AC; jackal is J; Bushbuck is BB; Bush duiker is BD; Bush pig is BP; Common genet is CG; Grivet Monkey is GV; Crested porcupine is CP; Marsh mongoose is M; Spotted hyena is SH; Olive Baboon is OB; Warthog is W; Leopard is L.

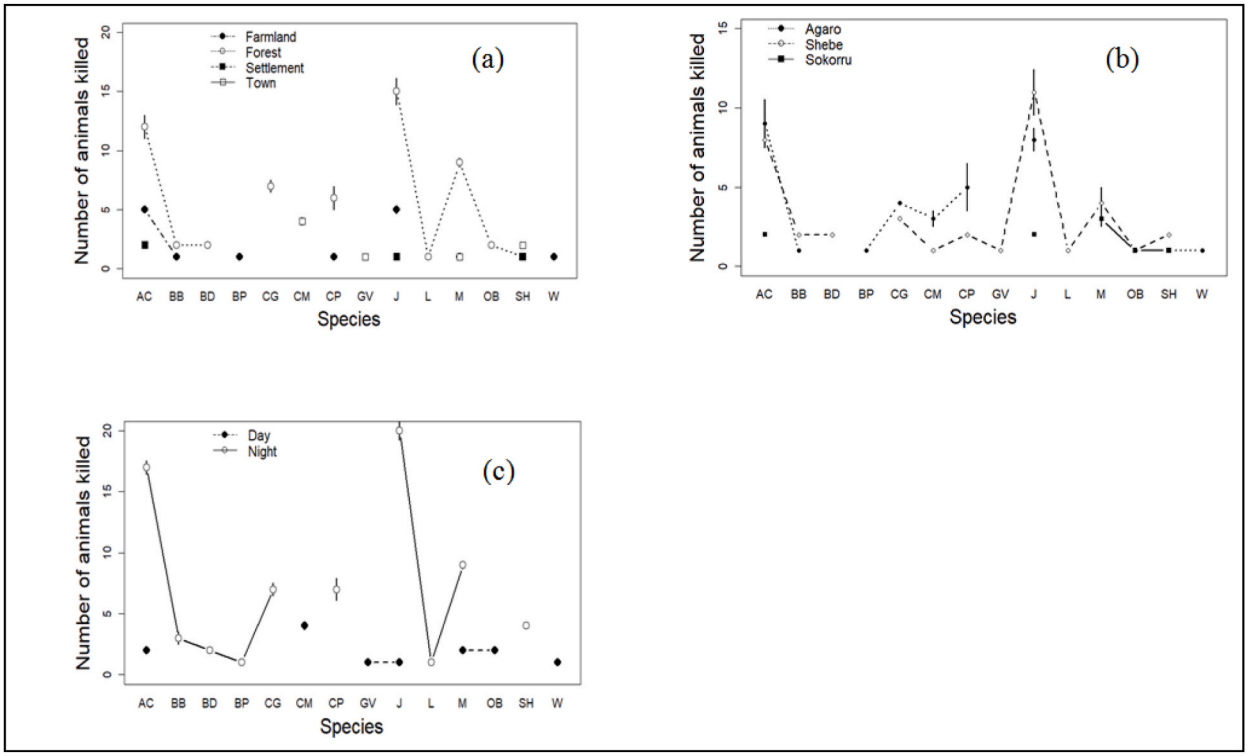

Fig. 3. Average number (with standard error bar) of mammal species roadkill (Note: African civet is AC; Jackal is J; Bushbuck is BB; Bush duiker is BD; Bush pig is BP; Common genet is CG; Grivet Monkey is GV; Crested porcupine is CP; Marsh mongoose is M; Spotted hyena is SH; Olive Baboon is OB; Warthog is W; Leopard is L): (a) in different habitats/land use types-farmland, forest, settlement and Town; (b) in three roads - Jimma to Agaro, Jimma to Shebe nad Jimma to Sekoru, (c) in day and night.

Table 1
The interaction effects of habitat/land use type and road on the number of mammals killed through vehicle collision.

Variables	DF	χ2	P value
Habitat	39	575.661	<.0001*
Shabe*Habitat	39	563.456	<.0001*
Agaro*Habitat	39	180.166	<.0001*
Sokoru*Habitat	26	14.198	>.05

Table 2
Multiple linear regression analysis for the effects of roads across different habitat/land use types on roadkill.

	Coeff.	Std.error.	T	P	R^2
Constant	0.11	0.12	0.89	0.3	
Sokorru	−0.04	0.33	−0.13	0.47	0.32
Shebe	0.82	0.12	7.61	0.001	0.67
Agaro	0.83	0.08	10.6	0.001	0.67

forest of southwest Ethiopia, long term research is needed to account for the variability. Moreover, some studies reported that there is a seasonal variation in the number of wildlife road kills [27,28].

The three identified roadkill hotspots were associated with forest cover such as shade coffee forest particularly, forests in rugged topography, implying that they are vital animals crossing the point.

6. Conclusion

In sum, our work provided strong evidence of the most vulnerable species to roadkill and roadkill hotspot areas in the forests of southwestern Ethiopia, where mitigation strategies need to be implemented to reduce roadkill.To reduce traffic speeds, particularly in high-traffic areas, installing wildlife warning signs and wildlife fences, is needed to prevent wildlife from accessing the road network.

Fig. 4. Roadkill hotspot areas identified in the study area.

In addition, drivers need to recognize that they share the road with wildlife in the forest (i.e., protected area) just as they share it with cyclists and pedestrians in the city. Since this study provides initial information on roadkill of wildlife in Afromontane forest landscapes, additional research that takes into account vehicle speed, landscape variables, road condition, season, and driver behaviour on the incidence of roadkill in the study area is necessary. Besides, we recommend conducting a road kill survey on all major roads in Ethiopia, particularly those that cross protected areas.

Author contribution statement

Tariku Mekonnen Gutema, Abebayehu Aticho and Nils C Stenseth: conceived and designed the study, analyzed and interpreted the data, and wrote the paper.

Diress Tsegaye: contributed in data analysis, interpretation and writing the paper.

Alemneh Mersha, Dessalegn Obsi Gemeda, Shiferaw Diriba, Tibebu Alemu, Dejene Gemechu, Tadese Habtamu, Dagne Tiruneh Dinsa: contributed in data interpretation and writing the paper.

Data availability statement

Data included in article will be obtained from the first author upon request.

Declaration of competing interest

The authors declare that they have no known competing financial or personal interests that could interfere with the work presented in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e19783.

References

[1] R.D. Lyamuya, E.J. Munisi, K.M. Hariohay, E.H. Masenga, J.K. Bukombe, G.G. Mwakalebe, M.L. Mdaki, A.K. Nkwabi, R.D. Fyumagwa, Patterns of Mammalian Roadkill in the Serengeti Ecosystem, Northern Tanzania, 2022.

[2] T.L. Joyce, S.P. Mahoney, Spatial and temporal distributions of moose-vehicle collisions in Newfoundland, Wildl. Soc. Bull. (2001) 281–291.
[3] K.E. Gunson, G. Mountrakis, L.J. Quackenbush, Spatial wildlife-vehicle collision models: a review of current work and its application to transportation mitigation projects, J. Environ. Manag. 92 (4) (2011) 1074–1082.
[4] C. Grilo, J.A. Bissonette, M. Santos-Reis, Spatial–temporal patterns in Mediterranean carnivore road casualties: consequences for mitigation, Biol. Conserv. 142 (2) (2009) 301–313.
[5] A. Asefa, Mountain nyala and Ethiopian wolf mortalities in the northern side of Bale Mountains National Park, Ethiopia, Ethiop. J. Biol. Sci. 7 (2) (2008) 179–184.
[6] T.A. Langen, K.E. Gunson, C.A. Scheiner, J.T. Boulerice, Road mortality in freshwater turtles: identifying causes of spatial patterns to optimize road planning and mitigation, Biodivers. Conserv. 21 (2012) 3017–3034.
[7] A.J. Hobday, Nighttime driver detection distances for Tasmanian fauna: informing speed limits to reduce roadkill, Wildl. Res. 37 (4) (2010) 265–272.
[8] H.O. Eid, F.M. Abu-Zidan, Biomechanics of road traffic collision injuries: a clinician's perspective, Singap. Med. J. 48 (7) (2007) 693.
[9] F. Lala, P.I. Chiyo, E. Kanga, P. Omondi, S. Ngene, W.J. Severud, A.W. Morris, Bump J: wildlife roadkill in the Tsavo Ecosystem, Kenya: identifying hotspots, potential drivers, and affected species, Heliyon 7 (3) (2021), e06364.
[10] C. Grilo, M.R. Coimbra, R.C. Cerqueira, P. Barbosa, R.A. Dornas, L.O. Gonçalves, F.Z. Teixeira, I.P. Coelho, B.R. Schmidt, D.L. Pacheco, BRAZIL ROAD-KILL: a Data Set of Wildlife Terrestrial Vertebrate Road-kills, Wiley Online Library, 2018.
[11] R. Pagany, Wildlife-vehicle collisions-Influencing factors, data collection and research methods, Biol. Conserv. 251 (2020), 108758.
[12] J. Kioko, C. Kiffner, N. Jenkins, W.J. Collinson, Wildlife roadkill patterns on a major highway in northern Tanzania, Afr. Zool. 50 (1) (2015) 17–22.
[13] E. Gandiwa, C. Mashapa, N. Muboko, A. Chemura, P. Kuvaoga, C.T. Mabika, Wildlife-vehicle collisions in hurungwe safari area, northern Zimbabwe, Sci. Afr. 9 (2020), e00518.
[14] W. Kiros, F. Kibrom, P.V. Raman, M. Teferi, K. Solomon, Y. Meheretu, Vehicle–wild vertebrate collision mortality on the highways of Tigray, Ethiopia, implications for conservation, Afr. J. Ecol. 54 (4) (2016) 442–449.
[15] I.P. Coelho, F.Z. Teixeira, P. Colombo, A.V.P. Coelho, A. Kindel, Anuran road-kills neighboring a peri-urban reserve in the Atlantic Forest, Brazil, J. Environ. Manag. 112 (2012) 17–26.
[16] A.P. Clevenger, B. Chruszcz, K.E. Gunson, Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations, Biol. Conserv. 109 (1) (2003) 15–26.
[17] B. Etana, A. Atickem, D. Tsegaye, A. Bekele, M. De Beenhouwer, K. Hundera, L. Lens, P.J. Fashing, N.C. Stenseth, Traditional shade coffee forest systems act as refuges for medium-and large-sized mammals as natural forest dwindles in Ethiopia, Biol. Conserv. 260 (2021), 109219.
[18] R.A. Mittermeier, W.R. Turner, F.W. Larsen, T.M. Brooks, C. Gascon, Global biodiversity conservation: the critical role of hotspots, in: Biodiversity Hotspots, distribution and protection of conservation priority areas, 2011, pp. 3–22.
[19] S. Périquet, L. Roxburgh, A. Le Roux, W.J. Collinson, Testing the value of citizen science for roadkill studies: a case study from South Africa, Frontiers in Ecology and Evolution 6 (2018) 15.
[20] C.M. Francis, P. Barrett, Guide to the Mammals of Southeast Asia, Princeton University Press, 2008.
[21] R-Team, R development core team, RA Lang Environ Stat Comput 55 (2016) 275–286.
[22] J.R. Meijer, M.A. Huijbregts, K.C. Schotten, A.M. Schipper, Global patterns of current and future road infrastructure, Environ. Res. Lett. 13 (6) (2018), 064006.
[23] S.R. de Freitas, A.N. de Oliveira, G. Ciocheti, M.V. Vieira, D.M. da Silva Matos, How landscape patterns influence road-kill of three species of mammals in the Brazilian Savanna, Oecologia Australis 18 (1) (2015).
[24] T. Habtamu, A. Bekele, R. Ahmed, T. Gadisa, B. Birlie, T. Tolemariam, B. Belay, Diets of the African Civet Civettictis civetta (Schreber, 1778) in selected coffee forest habitat, south-western Ethiopia, Afr. J. Ecol. 55 (4) (2017) 573–579.
[25] C. Bueno, M.T. Faustino, S. Freitas, Influence of landscape characteristics on capybara road-kill on highway BR-040, southeastern Brazil, Oecologia Australis 17 (2) (2013) 320–327.
[26] W.J. Collinson, B.K. Reilly, D.M. Parker, R.T. Bernard, H.T. Davies-Mostert, An inventory of vertebrate roadkill in the greater Mapungubwe Transfrontier conservation area, South Africa, African Journal of Wildlife Research 45 (3) (2015) 301–311.
[27] J. Arca-Rubio, G. Moreno-Rueda, Z. Ortega, The distribution of vertebrate roadkill varies by season, surrounding environment, and animal class, Eur. J. Wildl. Res. 69 (3) (2023) 42.
[28] J.E. Hill, T.L. DeVault, J.L. Belant, A review of ecological factors promoting road use by mammals, Mamm Rev. 51 (2) (2021) 214–227.