



Research Article

Spatio-Temporal Dynamics and Species Richness of Vertebrate Road Mortality on Four Major Highways in Jigawa State, Nigeria

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ABSTRACT

Vertebrate roadkill is a growing conservation concern in Nigeria, yet baseline data from Sahelian regions such as Jigawa State remain scarce. This study examined the spatio-temporal dynamics of vertebrate road mortality and species richness on four major highways in Jigawa State: Dutse–Jahun–Gujungu, Dutse–Ringim, Dutse–Balagu–Kafin Hausa, and Dutse–Birnin Kudu. Weekly surveys were conducted from a slow-moving vehicle (≤ 40 km/h) over six months with some randomly additional trips within the months (1 April to 30 September 2025), spanning the dry and wet seasons and covering 4,800 km. Carcasses were identified to the lowest possible taxonomic level and geo-referenced using GPS. A total of 246 vertebrate roadkills were recorded: mammals (58.9%), amphibians (19.9%), reptiles (17.1%), and birds (4.1%). Roadkill frequency differed significantly among taxa between seasons ($\chi^2 = 62.71$, $df = 9$, $p < 0.001$), and mortality was significantly higher in the wet season (178 individuals, 72.4%) than in the dry season (68, 27.6%) ($\chi^2 = 49.19$, $df = 1$, $p < 0.001$). The Dutse–Ringim highway was the deadliest, accounting for 42.3% of records. Mammals showed the highest species richness and abundance, with the four-toed hedgehog (*Atelerix albiventris*) and Egyptian toad (*Sclerophrys regularis*) contributing the largest wet-season increases. Although the affected species are not currently classified as globally threatened, sustained, localised road mortality poses long-term ecological risks. These baseline data can guide conservation policy, road planning, and mitigation measures such as speed regulation, wildlife crossings, and season-specific interventions.

Keywords: Roadkill; Vertebrate road mortality; Spatio-temporal dynamics; Species richness; Seasonal variation; Jigawa State; Sahel; Wildlife conservation

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INTRODUCTION

Roads are among the most pervasive forms of anthropogenic infrastructure altering natural landscapes, and their ecological consequences habitat fragmentation, altered animal movement, and direct mortality from vehicle collisions are increasingly recognised as major drivers of wildlife decline worldwide (Taylor & Goldingay, 2010).

Seasonal variation influences wildlife movement, and the timing of vertebrate road mortality often reflects the differing ecological requirements of species, such as the dependence of some amphibians and birds on seasonal water sources (Gibbs & Shriver, 2005), or seasonal shifts in activity associated with brumation in reptiles, hibernation in some mammals, or aestivation in amphibians (Garriga *et al.*, 2017;

Fernández-López *et al.*, 2022). Roads also alter wildlife behaviour and spatial utilisation at multiple ecological scales (Ascensão *et al.*, 2014; Poessel *et al.*, 2014), with knock-on effects for community and ecosystem composition, structure, and dynamics (Laurance *et al.*, 2014).

Despite a growing global literature on road ecology, empirical data from West Africa remain scarce, even though the region's road network has expanded rapidly alongside agricultural and urban development, increasing the likelihood of wildlife-vehicle interactions along rural highways. Much of the available evidence on seasonal roadkill patterns originates from temperate and Mediterranean systems (Garriga *et al.*, 2017; Fernández-López *et al.*, 2022), where activity cycles and highway conditions differ markedly from those of the Sudano-Sahelian savanna characteristic of northern Nigeria. In Jigawa State, rapid road expansion connecting Dutse to surrounding local government areas has coincided with a lack of baseline data on the ecological cost of these highways to resident vertebrate fauna, constraining evidence-based mitigation planning. Comparative evidence from elsewhere in sub-Saharan Africa underscores both the scale of this threat and its taxon-specific variability. On highways bisecting protected areas in eastern Ethiopia, systematic surveys recorded 128 roadkills of 44 species over five months, with birds (46.9%) and mammals (45.3%) dominating the assemblage (Mulualet *et al.*, 2023). On the Arusha Highway in northern Tanzania, a ten-day baseline survey recorded 101 roadkills of 37 species, again with birds as the most frequently killed taxon (50%), followed by mammals (30%), reptiles (17%), and amphibians (3%) (Kioko *et al.*, 2015); a similarly bird-dominated pattern (60.8% of records) was reported along gravel roads through the Serengeti ecosystem (Lyamuya *et al.*, 2021). These East African, protected-area studies contrast with the mammal-dominated pattern more typical of agricultural and peri-urban roadsides in temperate systems (Arca-Rubio *et al.*, 2023), highlighting that the taxonomic composition of roadkill assemblages is strongly shaped by the surrounding land use and habitat matrix rather than being a fixed regional pattern. Comparable systematic, season-stratified data have, however, remained unavailable for Nigeria and the wider West African Sahel prior to this study, which surveyed the Dutse–Jahun–Gujungu, Dutse–Ringim, Dutse–Balagu–Kafin Hausa, and Dutse–Birnin Kudu highways in Jigawa State.

This study therefore aimed to (i) document the taxonomic composition, abundance, and species richness of vertebrate roadkills along four major highways in Jigawa State; (ii) quantify seasonal (dry versus wet) variation in roadkill frequency across taxa; and (iii) evaluate the implications of these patterns for road planning and wildlife conservation policy in the region. We hypothesised that roadkill frequency would be significantly higher during the wet season, when amphibian breeding migration and vegetation-driven food availability increase the mobility of amphibians and small mammals near roadsides, and that mammals would show the greatest overall species richness and abundance owing to their generally higher mobility and broader habitat use.

MATERIALS AND METHODS

This study was conducted in Jigawa State, north-western Nigeria (state centroid approximately 12°00'N, 9°45'E; total land area 23,154 km²), a Sudano-Sahelian state characterised by a hot semi-arid (Köppen BSh) climate with a short unimodal wet season (June–September) and a longer dry season, and a landscape dominated by rain-fed and irrigated farmland interspersed with seasonal fadama wetlands, scattered rocky outcrops, and remnant Sudan-savanna woodland along roadsides and field margins. Surveys were centred on Dutse (11°42'04"N, 9°20'31"E), the state capital, from which four major highways radiate: the Dutse–Jahun–Gujungu 105.8Km, Dutse–Ringim 79Km, Dutse–Balagu–Kafin Hausa 124Km, and Dutse–Birnin Kudu 51Km roads (Figure 1). Roadkill surveys followed the vehicle-transect approach standardised for wildlife-vehicle collision monitoring by Collinson, Parker, Bernard, Reilly, and Davies-Mostert (2014), in which a slow-moving vehicle (≤40 km/h, within the range shown to give high carcass-detection probability) is driven along fixed routes while trained observers scan both road shoulders. Surveys were conducted along four major highways in Jigawa State, Dutse–Jahun–Gujungu, Dutse–Ringim, Dutse–Balagu–Kafin Hausa, and Dutse–Birnin Kudu (Figure 1) once weekly from 1 April to 30 September 2025 with some randomly additional trips within the month covering the local dry season (April–May) and wet season (June–September) and giving a cumulative survey distance of 4,800 km.

To avoid double-counting a carcass across consecutive weekly surveys, each carcass was removed from the road verge immediately after identification, photography, and GPS geo-

referencing, following the carcass-removal protocol recommended by Santos, Carvalho, and Mira (2011). Carcass condition (fresh, moderately decomposed, or skeletal) was also recorded at each encounter as a qualitative check on detection bias, since persistence and detectability decline with scavenger activity and decomposition (Santos *et al.*, 2011); carcasses judged older than the survey interval were excluded from that week's count.

Carcasses were identified to the lowest possible taxonomic level using standard field guides, then geo-referenced and photographed for verification (Figures 3–11). Records were categorised by species and by season. Seasonal variation in roadkill frequency was tested using a chi-square test of independence (species $\times$ season) and a chi-square goodness of fit test comparing dry- versus wet-season totals, computed in R statistical software.

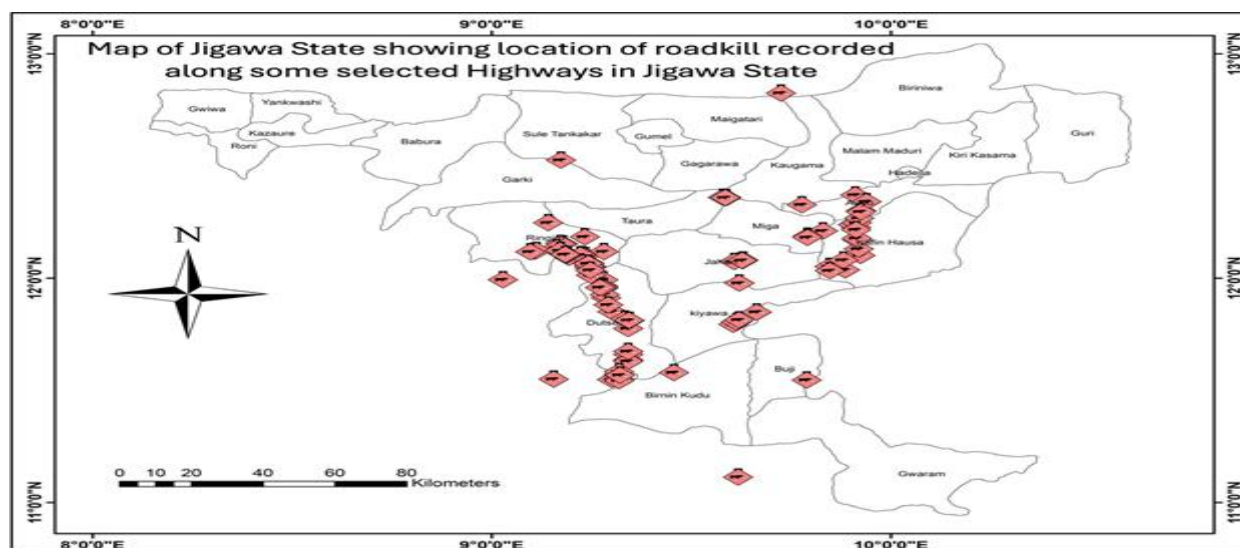


Figure 1: Map of Jigawa State showing the spatial distribution of vertebrate roadkill records (red diamonds) along the four surveyed highway corridors (Dutse–Jahun–Gujungu, Dutse–Ringim, Dutse Balagu–Kafin Hausa, and Dutse–Birnin Kudu)

Local government area boundaries and settlement names are shown for reference; scale bar and north arrow are as indicated.

RESULTS AND DISCUSSION

The roadkill data presented in Table 1 reflect a complex and concerning pattern of wildlife mortality along the four major highways in Jigawa State. A total of 246 vertebrate roadkills, spanning ten taxa, were recorded over the six-month survey period.

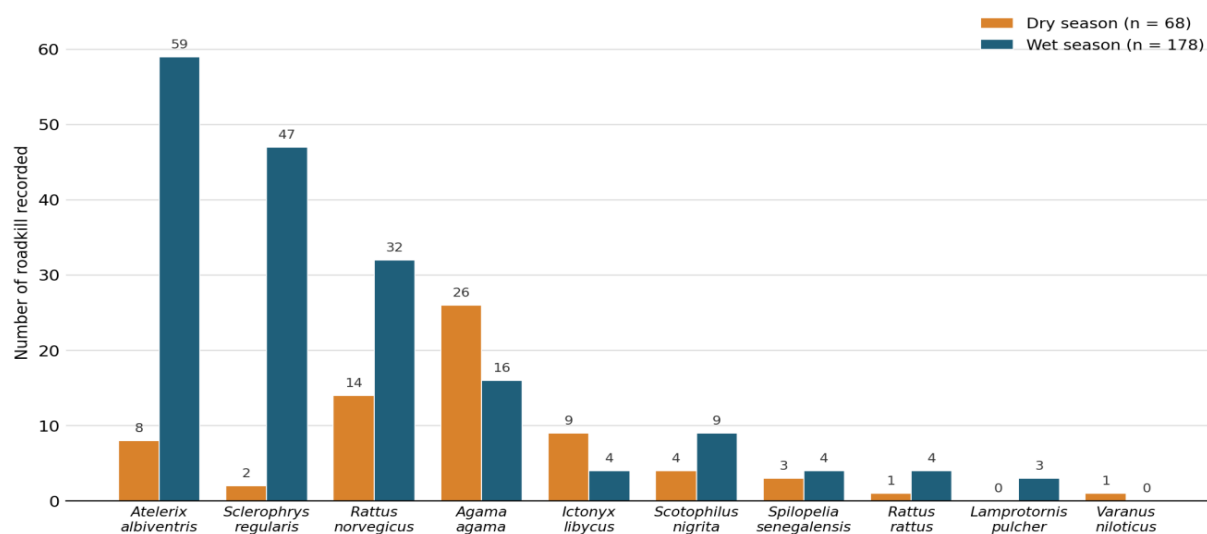
Of the ten taxa recorded, all were identified to species level. Mammals were the most diverse class (six taxa: *Atelerix albiventris*, *Ictonyx libycus*, *Rattus norvegicus*, and *Scotophilus nigrita*, plus *Rattus rattus*), followed by birds (two species: *Lamprotornis pulcher* and *Spilopelia senegalensis*), while reptiles (*Agama agama* and *Varanus niloticus*) and amphibians (*Sclerophrys regularis*) were each represented by a single species.

Roadkill counts differed markedly among the four highways (Tables 2 and 3). The Dutse–Ringim highway was the deadliest, accounting for 104 of the 246 records (42.3%), more than twice the total on any other corridor, followed by Dutse–Birnin Kudu (51; 20.7%), Dutse–Balagu–Kafin Hausa (48; 19.5%), and

Dutse–Jahun–Gujungu (43; 17.5%). Nine taxa were recorded on each of the Ringim and Kafin Hausa highways and eight on each of the Birnin Kudu and Jahun–Gujungu highways. Wet-season mortality predominated on every corridor, but its share was greatest on the Ringim highway (81.7%; 85 of 104 records), followed by Kafin Hausa (70.8%), Jahun–Gujungu (65.1%), and Birnin Kudu (60.8%). Assemblage composition also varied among highways: *Atelerix albiventris* was the most frequently recorded species on the Ringim (34) and Kafin Hausa (21) highways and, together with *Rattus norvegicus*, on the Jahun–Gujungu highway (10 each), whereas *Agama agama* (18) was the most frequent on the Birnin Kudu highway, followed by *Sclerophrys regularis* and *R. norvegicus* (12 each). *Scotophilus nigrita* was largely confined to the Ringim highway (11 of 13 records). Monthly totals peaked in July on the Birnin Kudu (14) and Jahun–Gujungu (12) highways, in August on the Kafin Hausa highway (13), and in September on the Ringim highway (32).

Table 1: Roadkill Species Recorded by Season along Selected Major Highways in Jigawa State

Species	Dry	Wet	Total	Percentage (%)
<i>Agama agama</i>	26	16	42	17.07
<i>Atelerix albiventris</i>	8	59	67	27.24
<i>Varanus niloticus</i>	1	0	1	0.41
<i>Ictonyx libycus</i>	9	4	13	5.28
<i>Lamprotornis pulcher</i>	0	3	3	1.22
<i>Rattus rattus</i>	1	4	5	2.03
<i>Rattus norvegicus</i>	14	32	46	18.69
<i>Sclerophrys regularis</i>	2	47	49	19.92
<i>Scotophilus nigrita</i>	4	9	13	5.28
<i>Spilopelia senegalensis</i>	3	4	7	2.85
Total	68	178	246	100.00

Seasonal dynamics of vertebrate roadkill by species on four major highways in Jigawa State, Nigeria**Figure 2: Seasonal dynamics of vertebrate roadkill by species along the four surveyed highways in Jigawa State, Nigeria****Table 2: Roadkill counts by species, highway and season, April–September 2025**

Species	BKD		JHG		KHB		RNG		Total
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	
<i>Atelerix albiventris</i>	0	2	1	9	2	19	5	29	67
<i>Sclerophrys regularis</i>	0	12	0	7	2	7	0	21	49
<i>Rattus norvegicus</i>	5	7	3	7	3	2	3	16	46
<i>Agama agama</i>	13	5	5	1	4	1	4	9	42
<i>Ictonyx libycus</i>	1	0	5	2	1	2	2	0	13
<i>Scotophilus nigrita</i>	0	0	0	1	0	1	4	7	13
<i>Spilopelia senegalensis</i>	0	3	1	0	1	1	1	0	7
<i>Rattus rattus</i>	1	1	0	1	0	0	0	2	5
<i>Lamprotornis pulcher</i>	0	1	0	0	0	1	0	1	3
<i>Varanus niloticus</i>	0	0	0	0	1	0	0	0	1
Total	20	31	15	28	14	34	19	85	246

BKD = Dutse–Birnin Kudu; JHG = Dutse–Jahun–Gujungu; KHB = Dutse–Balagu–Kafin Hausa; RNG = Dutse–Ringim. Dry includes nine transitional (dry/wet) records from May, consistent with Table 1.

Table 3: Monthly roadkill counts by highway, April–September 2025

Highway Season	April Dry	May Dry/Wet*	June Wet	July Wet	August Wet	September Wet	Total
BKD	12	8	6	14	9	2	51
JHG	9	6	5	12	7	4	43
KHB	10	4	11	3	13	7	48
RNG	11	8	12	23	18	32	104
Total	42	26	34	52	47	45	246

*May includes 17 dry-season and nine transitional (dry/wet) records. Highway codes as in Table 2.

A chi-square test of independence indicated a significant association between species identity and season ($\chi^2 = 62.71$, $df = 9$, $p < 0.001$), confirming that the relative contribution of taxa to roadkill mortality differed markedly between the dry and wet seasons. Overall, a chi-square goodness of fit test confirmed that total roadkill frequency was significantly higher in the wet season (178 individuals, 72.4%) than in the dry season (68 individuals, 27.6%) ($\chi^2 = 49.19$, $df = 1$, $p < 0.001$), consistent with established ecological patterns linking wildlife activity and movement to seasonal changes (Taylor & Goldingay, 2010). The following sections discuss each major taxonomic group in turn.

Mammals

Mammals were the most abundant and species-rich group recorded (six of the ten taxa; 58.9% of all roadkills). *Atelerix albiventris* (four-toed hedgehog) exhibited the highest seasonal variation of any species, with roadkill frequency rising from 8 individuals in the dry season to 59 in the wet season, together accounting for 67 individuals, or 27.24% of total roadkills recorded across the study. This pattern is consistent with increased hedgehog foraging and breeding activity during wetter months, when insect food resources become more abundant and road-crossing rates rise correspondingly (Haigh, O’Riordan, & Butler, 2014). *Rattus norvegicus* followed a similar trend, with roadkill cases rising from 14 in the dry season to 32 in the wet season (18.69% combined), consistent with the more active dispersal of rodents during humid periods when environmental conditions favour survival and movement (Santos *et al.*, 2011). *Ictonyx libycus* showed the opposite pattern, with more kills in the dry season (9) than the wet season (4; 5.28% combined), suggesting a species-specific movement pattern less dependent on seasonal rainfall. The overall dominance of mammals in our roadkill assemblage mirrors findings from a year-long Mediterranean transect study, where mammals likewise accounted for the largest share of vertebrate roadkill (45.8%), attributed to their comparatively high mobility relative to other vertebrate classes

(Arca-Rubio *et al.*, 2023). Black rat were also recorded (*Rattus rattus*, $n = 5$; *Varanus niloticus*, $n = 1$): four of the five *Rattus rattus* were killed in the wet season, whereas the single *Varanus niloticus* record came from the dry season.

Amphibians

Sclerophrys regularis (Egyptian toad) was the only amphibian recorded, but contributed disproportionately to wet-season mortality, rising from 2 individuals in the dry season to 47 in the wet season (19.92% of the combined total). Amphibians typically undergo peak movement and breeding migration during rainy periods, which brings them onto road surfaces in far greater numbers and makes them especially vulnerable to vehicle collisions (Glista *et al.*, 2008). This wet-season concentration is consistent with amphibian-dominated roadkill assemblages reported near wetland-adjacent roads elsewhere, where amphibians accounted for the large majority of records during the breeding season (Andđelković & Bogdanović, 2022); the comparatively smaller amphibian share recorded here (19.9% of the total assemblage) likely reflects the more limited extent of wetland habitat directly adjacent to the surveyed Jigawa highways.

Reptiles

Reptiles, represented solely by *Agama agama*, showed the reverse seasonal pattern to mammals and amphibians, with more kills in the dry season (26) than the wet season (16; 17.07% of the total). This dry-season peak is consistent with the thermoregulatory basking habits of reptiles, which are more active and visible on open, sun-warmed road surfaces during hot, dry months (Brown & Shine, 2002). A comparable dry-to-transitional-season peak in reptile roadkill, linked to basking behaviour, has been reported in a two-year monitoring study of a wetland-adjacent road in Serbia (Andđelković & Bogdanović, 2022), supporting the generality of this thermoregulation-driven pattern across biogeographic contexts.

Birds

The avian species recorded *Lamprotornis pulcher* and *Spilopelia senegalensis*, together accounted for only 4.1% of total roadkills and showed minimal seasonal variation. This is consistent with findings that birds generally exhibit lower seasonal fluctuation in road mortality than other vertebrate classes, because

many bird species maintain consistent foraging ranges and flight-based escape ability throughout the year, reducing their overall vulnerability to vehicle collision relative to ground-dwelling taxa (Erritzoe *et al.*, 2003).



Figure 3: Four-toed Hedgehog (*Atelerix albiventris*) roadkill in Kiyawa road Jigawa State



Figure 4: Libyan striped weasel/striped polecat (*Ictonyx libycus*) recorded along the Ringim road, Jigawa State.



Figure 5: Brown rat (*Rattus norvegicus*) recorded along Yandutse in Jigawa State



Figure 6: Giant House Bat (*Scotophilus nigrita*) recorded along Yandutse in Jigawa State



Figure 7: Black rat (*Rattus rattus*) recorded along the surveyed highways in Jigawa State



Figure 8: Egyptian toad (*Sclerophrys regularis*) recorded along Duru road in Jigawa State



Figure 9: Rainbow Agama (*Agama picticauda*) recorded along Ringim road in Jigawa State



Figure 10: Laughing dove (*Spilopelia senegalensis*) recorded during the roadkill survey, Jigawa State.



Figure 11: Chestnut-bellied Starling (*Lamprolornis pulcher*) recorded along Yandutse in Jigawa State

Synthesis

Taken together, these taxon-specific patterns indicate that the wet season contributed significantly more roadkill occurrences than the dry season for most groups in the study area, driven by increased animal mobility, breeding activity, and road-crossing frequency, together with denser roadside vegetation

that may reduce driver visibility (Clevenger *et al.*, 2003). The reversed, dry-season-biased pattern observed for reptiles' highlights that a single, season-blind mitigation strategy would be insufficient; instead, the findings support taxon- and season-specific interventions, timed to when each group's road-crossing risk actually peaks.

Benchmarked against other African roadkill surveys, the overall magnitude of mortality recorded here (246 roadkills over a cumulative 4,800 km survey effort, approximately 0.05 individuals per km) sits within the range reported elsewhere on the continent, but its taxonomic composition differs sharply. Our assemblage was dominated by mammals (58.9%), followed by amphibians (19.9%), reptiles (17.1%), and birds (4.1%). This contrasts with three comparable systematic surveys from eastern and southern Africa, all conducted on roads bordering or bisecting protected wildlife areas, where birds contributed the largest or a near-equal share of records: 46.9% of 128 roadkills in eastern Ethiopia, against 45.3% mammals (Mulualet *et al.*, 2023); 50% of 101 roadkills on the Arusha Highway in northern Tanzania, against 30% mammals, 17% reptiles, and 3% amphibians (Kioko *et al.*, 2015); and 60.8% of 51 roadkills through the Serengeti ecosystem (Lyamuya *et al.*, 2021). We attribute this contrast primarily to land-use context: the Ethiopian, Tanzanian, and Serengeti transects run through or beside protected areas with large resident bird populations and comparatively open sightlines favouring avian roadside foraging, whereas the Jigawa highways traverse a predominantly farmed and settled Sudano-Sahelian matrix in which small, cover-dependent mammals (hedgehogs, rodents) and an amphibian species tied to seasonal fadama wetlands are the more abundant roadside fauna. This distinction reinforces a broader pattern emerging from the

African road-ecology literature: roadkill taxonomic composition tracks the surrounding habitat matrix rather than being fixed, so mitigation priorities identified in protected-area studies elsewhere on the continent cannot simply be transposed onto agricultural highway corridors such as those in Jigawa State without locally grounded baseline data of the kind generated here. Direct comparison with other Nigerian highways was not possible because, to our knowledge, no previously published systematic, season-stratified roadkill survey exists for the country; this study therefore represents a first quantitative baseline against which future Nigerian and wider West African surveys can be benchmarked. The concentration of roadkill on the Dutse–Ringim highway, which recorded 42.3% of all carcasses and the highest wet-season share (81.7%), identifies it as the priority corridor for mitigation. This pattern was driven largely by *A. albiventris* (34 of the 67 hedgehog records) and by *S. nigrita* (11 of 13), and by a late-wet-season surge in September (32 records, 30.8% of that corridor’s total) that was not evident on the other three highways. Because these are raw counts, differences among corridors may partly reflect differences in corridor length, traffic volume, and roadside habitat rather than intrinsic risk per kilometre; standardising counts by surveyed distance and traffic density is therefore an important next step, and the per-corridor lengths requested in the Methods will allow this.



Figure 12: Spatial distribution of *Atelerix albiventris* roadkill recorded along the Arki, Kiyawa and Kafin Hausa road sections, Jigawa State.

CONCLUSION

This study concludes that the major highways connecting Dutse to surrounding local government areas in Jigawa State pose a substantial and statistically demonstrable risk to vertebrate wildlife, with 246 roadkills recorded over six months of systematic survey. Mammals were the most affected taxonomic group in both abundance (58.9%) and species richness, reflecting their greater mobility and broader use of roadside habitats, while the four-toed hedgehog (*Atelerix albiventris*) and the Egyptian toad (*Sclerophrys regularis*) accounted for the largest wet-season increases in mortality. Roadkill frequency was significantly higher in the wet season (178 individuals, 72.4%) than in the dry season (68 individuals, 27.6%) ($\chi^2 = 49.19$, $df = 1$, $p < 0.001$), consistent with increased wildlife activity, breeding migration, and food availability during this period. Although none of

the affected species is currently classified as globally threatened, the scale and concentration of mortality recorded here indicate that sustained, localised road mortality could pose long-term risks to local population viability, particularly for less mobile taxa such as amphibians.

Based on these findings, the following data-driven mitigation measures are recommended: (i) seasonal speed-limit enforcement (≤ 40 km/h) on the Dutse-Ringim and Dutse-Balagu-Kafin Hausa corridors during the wet season (June–September), when amphibian and small-mammal mortality peaks; (ii) installation of low box-culvert wildlife crossings and cautionary signage at the *Sclerophrys regularis* and *Atelerix albiventris* mortality hotspots identified along the Ringim, Gujungu, and Kafin Hausa road sections; (iii) routine carcass removal and monitoring protocols to reduce secondary scavenger mortality and improve carcass-detection accuracy; and (iv) continued long-

term monitoring across additional wet-dry season cycles to determine whether the patterns observed here are consistent from year to year. Implementing these targeted, season-specific measures would reduce wildlife-vehicle collisions while supporting broader biodiversity conservation goals in Jigawa State.

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