Ecological and Climatic Drivers of Wildlife Road Mortality in Kenya's Athi-Kapiti Plains

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Abstract

Roads and habitat fragmentation pose significant conservation challenges for many animals, yet the environmental factors that influence roadkill risk remain poorly understood. In Kenya, the Nairobi–Mombasa Highway cuts through the ranges of numerous wildlife species within one of the country's most biodiverse regions, the Athi-Kapiti Plains. To investigate the environmental factors influencing roadkill risk in this region, we combined remote sensing data on long-term drought (Standardized Precipitation Evapotranspiration Index, SPEI) and vegetation greenness (Normalized Difference Vegetation Index, NDVI) with 6,240 km of road transect surveys conducted in 2023 and historical roadkill records from 2020–2022. We recorded 218 wildlife roadkills involving 11 species, predominantly plains zebras (*Equus quagga*, 69%), spotted hyenas (*Crocuta crocuta*), and Maasai giraffes (*Giraffa camelopardalis* tippelskirchi). Prolonged drought, reduced vegetation productivity, and wildlife use intensity emerged as key predictors of roadkill risk along the Nairobi–Mombasa Highway across the Kenya's Athi-Kapiti Plains. These factors interact to increase animal movement across roads, especially during dry periods when animals seek water and forage. We also found roadkills to be clustered near artificial water points, suggesting these sites may function as ecological traps by concentrating wildlife in high-risk zones. Our findings suggest that drought-driven declines in food availability may force animals to travel farther and cross roads in search of resources, increasing roadkill risk. This interaction between drought and road mortality is particularly concerning, as both represent significant threats that may intensify under climate change. Our results highlight how climatic stress, habitat degradation, and wildlife use intensity jointly shape roadkill patterns.

1. Introduction

Linear infrastructure such as roads, railways, and pipelines is essential for socioeconomic development, yet it often incurs significant ecological costs, including habitat fragmentation, loss of ecological connectivity, and direct wildlife mortality (Laurance et al. 2014). Among these impacts, direct wildlife mortality from vehicle collisions is a frequently overlooked but substantial driver of population decline, particularly for wide-ranging and migratory species (Seiler and Helldin 2006; Loss et al. 2014). In some regions, roadkill exceeds natural predation or poaching as the leading cause of mortality for certain species (Forman et al. 2003). Roads not only fragment habitats physically but also facilitate human encroachment, increase human-wildlife conflict, and create barriers to movement that threaten long-term population viability. These effects are especially concerning in biodiversity-rich areas, where expanding infrastructure intersects with critical wildlife habitats and migratory corridors (Forman et al. 2003).

In Kenya, road networks have expanded by 50% over the past four decades, increasingly ncroaching on ecologically sensitive regions such as the Athi-Kapiti Wildlife Conservancies along the Mombasa highway. The Athi-Kapiti landscape is recognized as a biodiversity hotspot, supporting endangered species such as the Maasai giraffe (*Giraffa tippelskirchi*) and migratory herds of wildebeest (*Connochaetes taurinus*) and elands (*Taurotragus oryx*) (Damania et al. 2019). This vital corridor of private and communal conservancies connects Nairobi National Park to the Amboseli, Tsavo, and

Serengeti ecosystems. The ecological integrity of the Athi-Kapiti landscape is increasingly compromised by the Nairobi-Mombasa Highway. This high-traffic highway has fragmented habitats and elevated collision risks for wildlife, underscoring the urgent need to reconcile infrastructure development with biodiversity conservation.

The Athi-Kapiti landscape supports diverse ecological communities, including large herds of herbivores such as zebras, wildebeest and eland, which rely on seasonal migrations to access forage and water. The movements of these species are closely synchronized with rainfall patterns, leading to cyclical shifts in road-crossing behaviour (Birkett et al. 2012). Wildebeest, for example, traverse vast distances during dry seasons in search of diminishing resources (Martin et al. 2015), while elands, Africa's largest antelope, are often funnelled into hazardous roadside zones by habitat fragmentation and edge effects (Lee and Bond 2018). The Nairobi–Mombasa Highway exacerbates these risks, functioning as both a physical barrier and a demographic filter (Clevenger and Wierzchowski 2006; Jacobson et al. 2016). Scavengers such as spotted hyenas (*Crocuta crocuta*) and critically endangered white-backed vultures (*Gyps africanus*) are also vulnerable to road mortality, as their reliance on roadkill carcasses increases their exposure to vehicle collisions (Ogada et al. 2012; Naciri et al. 2023). Such losses not only threaten population viability but also disrupt key ecosystem functions, including seed dispersal, nutrient cycling, and predator–prey dynamics (Beasley et al. 2019)

Roadkill risk is therefore shaped by a combination of species traits, behavioural patterns, and environmental conditions. For herbivores such as wildebeest and zebra, risk is elevated during resource-scarce dry seasons when road-crossings increase in search of forage and water (Bolger et al. 2008; Martin et al. 2015), while browsers such as giraffe and eland face risks year-round due to fragmented roadside vegetation (Kioko et al. 2008; Lee and Bond 2018). Vegetation structure can impact roadkill risk at multiple scales. At a landscape scale, it can influence large-scale movement patterns, increasing likelihood or road crossing (Blackburn et al. 2022) and at more local scale it can influence risk of collision by obscuring visibility (Canal et al. 2019). Remote sensing indices like the Normalized Difference Vegetation Index (NDVI), a proxy for vegetation productivity, have proven useful in capturing these seasonal habitat dynamics, with low NDVI values associated with periods of heightened roadkill risk in other systems (Ascensão et al. 2019). Rainfall patterns and proximity to water sources similarly influence crossing behavior, as animals traverse roads to reach ephemeral waterholes during dry periods (Valeix et al. 2011; Sánchez-Montoya et al. 2023).

Here, we present the first study in the Athi-Kapiti region to integrate remote sensing indices; Normalized Difference Vegetation Index (NDVI), Standardized Precipitation Evapotranspiration Index (SPEI) with systematic field-based roadkill surveys. We investigated the spatio-temporal drivers of wildlife roadkills along a 60-kilometre segment of the Nairobi–Mombasa Highway, which traverses the Athi-Kapiti Conservancies. Specifically, we aimed to:(1) identify the species most vulnerable to vehicle collisions, (2) map seasonal and spatial variation in roadkills across three sections with differential levels of collision risk, and (3) quantify the effects of vegetation structure, drought severity, and wildlife use intensity on collision rates. Our findings aim to inform specific mitigation actions such as the construction of wildlife overpasses, speed bumps, implementation of seasonal speed restrictions, and habitat restoration initiatives, to support Kenya's infrastructural development while safeguarding wild animals and their habitats.

2. Methods

2.1 Study area

Our study was conducted in the Athi-Kapiti Plains Conservancies, located at latitude – 1.467663° and longitude 37.101091° (Fig. 1). The area encompasses the Swara Plains Conservancy, the International Livestock Research Institute (Kapiti Estate), Maanzoni Conservancy, Mwambi Hill Conservancy, Malinda Conservancy, and adjacent community lands. Theconservancies, constituting the Athi Kapiti Plains, are situated south of Nairobi city and Nairobi National Park, extending east into Machakos County and south toward Amboseli National Park via the gently descending Emarti Valley (Said et al. 2016).

The Athi-Kapiti Plains are ecologically significant, supporting a diverse assemblage of wildlife and livestock within a semi-arid savannah landscape. The region receives an average annual rainfall of 550 mm and sits at an elevation of 1,650 to 1,900 meters above sea level. The soils are predominantly black cotton in the plains and red cotton in the ridges, supporting a variety of savannah grasses and tree species. Common grasses include *Themeda triandra* (Thatching grass), *Cenchrus stramineus* (Sandhill millet), *Cynodon dactylon* (Bermuda grass), and *Cyperus rotundus* (Purple nutsedge). Prominent tree species include *Balanites aegyptiaca*, *Acacia xanthophloea, Acacia drepanolobium*, *Grewia kakothamnos*, and *Commiphora kataf* (Kapiti Brochure, 2020). The Athi-Kapiti Plains supports a rich diversity of wildlife, including the Maasai giraffe (*Giraffa tippelskirchi*), common zebra (*Equus quagga*), common eland (*Taurotragus oryx*), wildebeest (*Connochaetes taurinus*), impala (*Aepyceros melampus*), and kongoni (*Alcelaphus buselaphus cokii*). Predators such as cheetah (Acinonyx jubatus), lion (*Panthera leo*), leopard (*Panthera pardus*), and spotted hyena (*Crocuta crocuta*) are also present. It serves as a critical wildlife dispersal and migration corridor, linking Nairobi National Park to larger ecosystems such as Amboseli, Tsavo, Magadi and Natron, underscoring their ecological importance (Ogutu et al. 2014; Sircely et al. 2020).

The Nairobi-Mombasa Highway, a major transportation corridor connecting Nairobi to the port city of Mombasa, bisects the Athi-Kapiti Plains. The highway is a two-lane road that transitions into a single lane at Makutano Junction. It experiences heavy traffic, with an estimated daily flow of over 31,000 vehicles according to the Kenya Roads Board. Speed limits are set at 80 km/h for commercial and passenger vehicles and 110 km/h for private vehicles, as per Kenya's Traffic Act (CAP 403). The high traffic volume and speeds creates significant risks for wildlife, particularly where the highway intersects known movement corridors.

2.2 Roadkill Data Collection

We conducted roadkill surveys between January and December 2023, covering both wet and dry seasons (Duethmann et al. 2020). Two road transect surveys were conducted each week along a 60 km stretch. Surveys were carried out by a single observer driving at a low speed of 30–40 km/hr) to maximize detection probabilities. The protocol established by (Santos et al. 2011), was followed, with surveys taking place early in the morning at sunrise to optimize roadkill detection before scavengers removed the carcasses or decay set in (Hels and Buchwald 2001). Upon detecting a carcass, the location was recorded by taking coordinate, using a handheld Global Positioning System (GPS). Information on species name, sex, age group, date, and time of the carcass was documented, and the carcass removed from the road to prevent double counting. Additional secondary roadkill data from 2020 to 2022 were provided by the Kenya Wildlife Service (Machakos Station) and included information on the date, GPS coordinates, species, age, and sex of the animals, which was merged with data collected during the study.

2.3 Defining Roadkill Hotspots and Sampling Zones

To better understand spatial variation in roadkill risk, we performed a kernel density analysis to identify high-incidence sections along the 60km segment of the Mombasa Highway where roadkills occurred (Lala et al. 2021; Galinskaitė et al. 2022). We imported the collected roadkill data (coordinates, species, sex, age, date, time) into ArcGIS Pro and used the Kernel Density tool to visualize roadkill intensity along the highway. This process was used to define three sections with varying levels of roadkill density, in order of highest to lowest: Swara-Maanzoni Interface (A), Kapiti-Mwambi Transition (B) and Community Edge Zone (C), hereafter referred to as A, B, and C, respectively (Fig. 3) (Lala et al. 2021).

2.4 Sampling Site-level Landscape and Habitat Characteristics

We calculated five ecological characteristics for each site ID using data collected from field surveys: (1) wildlife use intensity, (2) woody vegetation density, (3) herbaceous vegetation cover, (4) visibility, and (5) artificial water source density. The first four characteristics were sampled using two parallel transects (3 km long and 2 km wide) established on either side of the highway, resulting in six transects across the three sections. Sampling points were systematically placed at 200-meter intervals along each transect, yielding 30 points per section and 90 points in total. At each of the 90 points, we sampled woody vegetation density, herbaceous vegetation cover, wildlife use intensity and visibility. Artificial water source density was assessed separately by recording the coordinates of artificial water points using a handheld GPS. To explore potential spatial clustering, these coordinates were used to generate a heatmap of water point density in ArcGIS Pro, which was then visually overlaid with roadkill hotspot locations.

Woody vegetation density was measured using a Point-Cantered Quarter (PCQ) method. The area around each sampling point was divided into four 90° quadrants, and the distance to the nearest tree was measured in each quadrant following (Silva et al. 2017), where the distance from the quadrat centre to the nearest tree with a height of 1.3 m and above (≥ 1.3m) was measured. For each tree, diameter at

Breast Height (DBH) was recorded, and species were identified. Measurements were taken using a tape measure and range finder (Kiani et al. 2013; Wainscott 2015). Additionally, all the trees within 20m radius of the quadrats were counted. Woody vegetation density (D) was calculated assuming a random spatial distribution using the following formula: $D = 1/\bar{r}^2 \cdot \pi$. Where $\bar{r}$ is the mean distance to the nearest tree (in meters), and $\pi \approx 3.1416$. Density was expressed as individuals per square meter (ind/m²)

Herbaceous vegetation cover

At each of the 90 sampling points, eight 1 × 1 m quadrats were randomly placed, yielding a total of 720 quadrats. Within each quadrat, herbaceous species and their heights were recorded. Herbaceous vegetation cover at each sampling point was estimated by averaging the cover values from the eight quadrats.

Visibility was measured by calculating the mean distance to the nearest line-of-sight obstruction. At each sampling point, distances were recorded in 24 directions from the centre using a rangefinder (Riginos 2015). The 24 measurements were then averaged to obtain a visibility value for each point.

Wildlife use intensity: Wildlife presence at each of the three sections (A, B and C) was assessed by counting dung pellet groups within 50 m × 4 m belt transects placed at 200-meter intervals along each 3 km transect. This yielded 15 sampling points per transect, resulting in 30 points per section and 90 points across all sections. Dung counts were used instead of direct observations to minimize disturbance (Takenoshita and Yamagiwa 2008) and to detect species that are present but not easily observable (Eggert et al. 2003). Wildlife use intensity was calculated as dung density using the formula: Dung Density = Number of Dung Groups/Area of the Transect, where: Area of Transect = Length × Width = 50m × 4m = 200 m². We used total dung per plot as a relative assay of individual herbivore species use of the different plots. Thus, our approach averts issues related to inferring population densities from dung counts, such as differential decomposition rates across seasons and habitats (Nchanji and Plumptre 2001; Hema et al. 2017). There is ample evidence from our study system (Augustine 2003; Young et al. 2005; Riginos et al.) and elsewhere (Cromsigt et al. 2009; Hema et al. 2017) that dung counts are robust for comparing relative habitat use by large mammals within a species.

2.5 Remote Sensing Data and Spatial Data Processing

Environmental covariates were derived for each site using a combination of remote sensing data from Google Earth Engine (GEE) as well as R (v4.5.0) packages: terra, and sf (Haviv et al. 2025). Drought conditions were assessed using the Standardized Precipitation Evapotranspiration Index (SPEI), derived from ERA5 climate reanalysis datasets (Keune et al. 2025). SPEI as an integrative drought index that is calculated by subtracting potential evapotranspiration from precipitation providing a more comprehensive measure of climatic water availability than precipitation alone (Nosrati 2014). Positive SPEI values indicate wetter than average conditions and negative values indicate drier than average conditions. SPEI values were calculated at 1, 3, 6 and 12-month accumulation intervals to capture both short- and long-term water stress (Keune et al. 2025). We extracted SPEI values from ERA5-derived

NetCDF layers and calculated the monthly mean SPEI for each section using a 2km buffer on either side of the highway (consistent with the methodology for field data collection).

Vegetation productivity was evaluated using the Normalized Difference Vegetation Index (NDVI), derived from Sentinel-2 surface reflectance imagery between 2020 and 2023. The analysis focused on a 2 km-wide corridor along both sides of the Mombasa Highway. Monthly NDVI composites were generated in Google Earth Engine (GEE) by spatially filtering imagery using the digitized extent polygon and temporally selecting specific monthly intervals. Scenes with more than 15% cloud cover were excluded using the CLOUDY_PIXEL_PERCENTAGE metadata. NDVI was computed for each image using the standard formula: NDVI = (B8 – B4) / (B8 + B4), based on the Near-Infrared (Band 8) and Red (Band 4) bands. Monthly mean NDVI rasters were then generated using a mean reducer, exported as GeoTIFFs, and processed in R. We then calculated the monthly mean NDVI within the polygon for each zone (2km buffer on each side of the highway).

3. Statistical Analysis

To estimate the relationship between road kills and our environmental variables, we used a set of Bayesian hurdle Poisson regression models using the brms package in R (Bürkner 2021). Hurdle models accommodate excess zeros (as is common in event data such as roadkills) by modeling both the occurrence (zero vs non-zero) and the count of roadkills where they occur. The response variable, roadkill counts (n_roadkills), was regressed against two climatic stress variables SPEI and NDVI in separate models. For SPEI, we ran four separate models using accumulation periods of 1, 3, 6, and 12 months to evaluate differences in the effects of short-term water stress versus long-term drought. All models included an indicator variable for site ID (i.e., A, B, C) to account for spatial variation of road kills. This allowed us to indirectly assess the influence of ecological factors such as wildlife use intensity, visibility, and vegetation cover (herbaceous and woody) by relating the effects of site ID to measurements from transect surveys post hoc. The models were specified as:

1. *SPEI model*: log(n_roadkills) ~ spei+ site_ID
2. *NDVI model*: log(n_roadkills) ~ ndvi_std + site_ID,

with a binomial hurdle component (hu) estimating zero-inflation.

Weakly informative priors were applied: Normal (0, 1) for fixed effects (climatic variables, density terms), Normal (0, 1.2) for intercepts, and Beta (1, 1) for the hurdle probability. Four Markov chains were run (2,000 iterations, 1,000 warmup) using cmdstanr (v0.7.1), with convergence confirmed by Rhat <1.01 and effective sample sizes >1,000. Model fit was evaluated via posterior predictive checks. Analyses were conducted in R (v4.3.1) with tidybayes and ggplot2 for visualization.

We used the Kruskal–Wallis test to compare wildlife use intensity, herbaceous vegetation cover, woody vegetation density, and visibility across the six sampling points selected along the highway based on roadkill intensity. Dunn's test was applied for post hoc pairwise comparisons to identify statistically significant differences among groups.

4. Results

4.1 Species-specific and temporal trends in roadkill incidences along the Mombasa Highway in the Athi-Kapiti Region

A total of 11 animal species were involved in roadkills. Zebras had the highest incidents of roadkills, accounting for 69% of the total followed by the spotted hyena at 11%, and the Maasai giraffe at 8% (Table 1). The total roadkills recorded between the year 2020 and 2023 were 218. Year 2020 had the lowest kills with 6 carcasses while 2023 had the highest with 84 carcasses (Fig. 2).

Table 1
Animal species killed during the study and their percentage along Mombasa Highway in Athi- Kapiti Plains Conservancies

Number	Species Name	Total roadkill	Percentage Roadkill
1	Cheetah	2	0.92
2	Duiker	1	0.46
3	Eland	7	3.21
4	Giraffe	17	7.8
5	Hyena	23	10.55
6	Impala	2	0.92
7	Kongoni	1	0.46
8	Ostrich	1	0.46
9	Serval Cat	1	0.46
10	Wildebeest	13	5.96
11	Zebra	150	68.81
	Total	218	100

4.2 Roadkill risk highly impacted by drought conditions and vegetation greenness

We found that long-term drought severity and reduced vegetation productivity led to more predicted road kills. Specifically, we observed a considerable negative relationship between road kill frequency and both

SPEI (β_{SPEI_6} = -0.61[-0.79,-0.42]) and NDVI (β_{NDVI} = -0.92[-1.21,-0.64]) (Fig. 3 and Fig. S1). The strength of the negative drought effect (SPEI) increased considerably from the 1-month to the 3-month timescale, and again from 3 to 6 months, but no clear difference was observed between the 6-month and 12-month timescales (Fig. 4).

4.3 Ecological characteristics across sites: Swara-Maanzoni Interface (A), Kapiti-Mwambi Transition (B) and Community Edge Zone (C).

Wildlife use intensity varied significantly across the three sections (χ^2 = 41.6, df = 2, p < 0.001), with section A having the highest mean wildlife use intensity (0.0765 ± 0.0493), followed by B (0.0410 ± 0.0558) and C (0.0090 ± 0.0120). Pairwise comparisons showed that wildlife use intensity was significantly higher in A compared to both B (p < 0.001) and C (p < 0.001), while B was also significantly higher than C (p = 0.0206) (Fig. 5)).

Herbaceous vegetation cover also differed significantly among the three sections (χ^2 = 20.9, df = 2, p < 0.001), with section B exhibiting the highest mean herbaceous vegetation cover (81.4 ± 14.6%), followed by C (64.6 ± 17.4%) and A (63.4 ± 13.4%). Herbaceous vegetation cover was significantly higher in B compared to both A (p < 0.001) and C (p < 0.001), while A and C did not differ significantly (p = 1.000) (Fig. 5).

Visibility was significantly different across the three sections (χ^2 = 54.0, df = 2, p < 0.001), with C having the highest visibility (437.0 ± 262.0), followed by A (69.3 ± 64.3) and B (54.0 ± 34.1). Visibility in C was significantly higher than both A (p < 0.001) and B (p < 0.001), while A and B did not differ (p = 1.000) (Fig. 5).

Woody vegetation density varied significantly across the three sections (χ^2 = 20.9, df = 2, p = 0.0000284), with section B exhibiting the highest mean woody vegetation density (0.0360 ± 0.0364), followed by A (0.0296 ± 0.0392), and C having the lowest (0.0634 ± 0.139). Post-hoc comparisons indicated that C had significantly lower woody vegetation density than both A (p = 0.00171) and B (p = 0.0000446), while there was no significant difference between A and B (p = 1.000) (Fig. 5)).

4.4 Roadkill risk impacted by spatial variation in wildlife use intensity and ecological characteristics across sites

Roadkill frequency varied significantly across sites. Compared to site A, site B had a markedly lower rate of road kills (β_B: -1.18 [-1.87 to -0.61]), and site C had the lowest roadkill frequency (β_C: -1.98 [-3.20 to -0.99]). These estimates indicate that, conditional on NDVI and SPEI, road kills at site B and C were approximately 69% and 86% lower, respectively, than at site A.

Transect measurements revealed that site A (the highest roadkill risk) was associated with the highest wildlife use intensity, while site C (the lowest roadkill risk) had the greatest visibility and lowest woody vegetation cover. Site B (moderate roadkill risk) was characterized by the highest herbaceous vegetation cover (Fig. 5 and Fig. 6).

5. Discussion

This study highlights how prolonged drought, vegetation degradation, and wildlife use intensity interact to influence roadkill patterns in the Athi-Kapiti Plains. The increasingly strong negative association between roadkills and SPEI with longer accumulation periods suggests that sustained drought (see Fig. S2), rather than short dry spells, prompts extensive wildlife movement that increases road exposure and ultimately leads to higher roadkill rates. During exceedingly dry periods, access to water and forage becomes limited and unevenly distributed, causing animals to expand their ranges and encounter roads more frequently (Mulero-Pázmány et al. 2022). The concentration of roadkills near permanent water sources further emphasizes roads as lethal barriers to critical resources during droughts, exacerbating mortality in fragmented landscapes (Clevenger and Wierzchowski 2006; Okita-Ouma et al. 2016).

At the same time, low NDVI values indicated reduced vegetation greenness and declining forage availability, especially among herbaceous species (Egeru et al. 2015). These conditions fragmented suitable feeding areas and extended the distances animals needed to travel, increasing the likelihood of road encounters leading heightened roadkill rates (Ascensão et al. 2019). Together, drought and vegetation loss may have created a reinforcing effect, where animals displaced by poor habitat quality were funnelled into higher-risk areas near roads.

Wildlife use intensity was also a key driver. We observed a strong positive relationship between wildlife abundance and roadkill rates, with no evidence of a threshold beyond which risk plateaus. This suggests that even moderate increases in local intensity can significantly raise the likelihood of collisions, particularly when combined with drought and food scarcity. As competition intensifies in densely populated areas, animals may travel more widely, further increasing their road exposure.

Species-specific traits shaped susceptibility to collisions. Giraffes, although less frequently involved in roadkills, are especially vulnerable due to their tall stature, slow movement, and limited agility (More et al. 2013). Observations during the study showed giraffes foraging on acacia trees near the road, likely because preferred woody browse was less available farther away, especially during dry months (Bond et al. 2016). This behavior increased their proximity to traffic and risk of collisions.

Zebras, which accounted for the majority of roadkill incidents, were especially affected by the loss of herbaceous vegetation and water scarcity during the dry season. During this period, they are forced to traverse roads more frequently in search of remnant forage and water, a behavior intensified by habitat fragmentation (Boyers and Parrini 2024). Their gregarious nature and tendency to move in large herds further increase the likelihood of road crossings, raising the risk of vehicle collisions (Kioko et al. 2015). According to the 2021 Kenya Wildlife Census conducted during the study period, zebras were the most abundant species in the Athi-Kapiti Plains, with a population of 11,355, significantly higher than any other species. Hence there high population density lead to high roadkill mortality.

Spotted hyenas were likely drawn to carcasses along roads, as their scavenging behavior leads them to revisit sites of previous mortality. This creates a feedback loop where roadkills attract scavengers, which then become roadkill themselves (Naciri et al. 2023). As primarily nocturnal animals, hyenas are especially vulnerable during periods of low visibility. These results underscore the importance of implementing carcass removal protocols to reduce attractant cues and prevent cascading mortality (Hager et al. 2012).

Roadkill rates varied across the three study sections. Section A had the highest number of incidents, likely due to high wildlife use intensity, limited forage, and the presence of artificial watering points that drew wildlife closer to the road, particularly during dry seasons. Its open landscape also made it attractive to herbivores seeking visibility to detect predators.

Section B experienced moderate roadkill levels, despite having relatively high vegetation cover. This may reflect its moderate wildlife use intensity, and although higher herbaceous cover may reduce road crossings during wet periods, it can attract grazers as vegetation senesces, creating delayed dry-season hotspots (Munyati 1997). Additionally, both Section A and Section B act as part of a larger conservancy corridor linking Swara Plains, Maanzoni, Mwambi Hill, and Kapiti Plains. These areas maintain intact wildlife populations and minimal anthropogenic disturbance, which likely channels animal movement between protected habitats, creating predictable crossing zones and elevating roadkill risk (HP-Ruffino et al. 2016; Lala et al. 2021).

In contrast, Section C recorded the lowest roadkill frequency. This site had sparse vegetation and higher levels of human activity, which may have discouraged wildlife presence due to habitat degradation and negative human–wildlife interactions (Murray and St. Clair 2015). These conditions likely reduced both the intensity of animals and their need to cross roads in the area. These spatial patterns suggest that conditions even a few kilometres from roads can shape animal movement and influence collision risk.

Using a Bayesian modeling framework enabled us to identify both the probability of roadkill occurrence and the ecological factors that heighten roadkill risk. This approach provided robust inference while explicitly accounting for uncertainty in parameter estimates, which is critical when modeling complex ecological systems. The models identified key ecological drivers specifically, prolonged drought conditions and reduced vegetation productivity that influence roadkill risk which can inform targeted conservation strategies.

Management efforts should prioritize high-risk zones like Section A. Recommended actions include constructing wildlife crossings, restoring vegetation, redistributing water points more evenly across the ecosystem, reducing speed limits during dry seasons, and removing carcasses promptly. Involving local communities in land-use planning and ecological monitoring will be essential to ensure sustainable and effective mitigation.

We demonstrate that drought, habitat quality, wildlife use intensity, and animal behavior jointly influence roadkill risk in savannah ecosystems. In the Athi-Kapiti region, these ecological drivers are further intensified by anthropogenic pressures, reflecting the complex realities wildlife faces in increasingly fragmented landscapes. Our integrated approach combining field-based data with climate and vegetation modeling provides a transferable framework for other arid regions facing similar conditions. As climate change intensifies the frequency and severity of drought, wildlife movements in search of water and forage are likely to rise, leading to greater risk of collisions. These findings underscore the need to incorporate both biodiversity conservation and climate resilience into regional infrastructure planning.

Declarations

Statements and Declarations

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

Aggrey W. Chemwa: Conceptualization (equal), Data curation (lead), Formal analysis (lead), Methodology (equal), Writing – original draft (lead), Writing – review and editing (equal); Flora N. Namu: Conceptualization (equal), Methodology (equal), Writing – review and editing (equal); Odd T. Jacobson: Conceptualization (equal), Data curation (equal), Formal analysis (equal), Methodology (equal), Writing – review and editing (equal); Genevieve E. Finerty: Conceptualization (equal), Formal analysis (equal), Methodology (equal), Writing – review and editing (equal); Duncan M. Kimuyu: Conceptualization (equal), Formal analysis (equal), Methodology (equal), Writing – review and editing (equal).

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Data Availability

The datasets generated and analysed during the current study are publicly available in the Figshare repository at https://doi.org/10.6084/m9.figshare.29373971.

Ethical Compliance

This study did not involve direct handling of animals.

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Figures

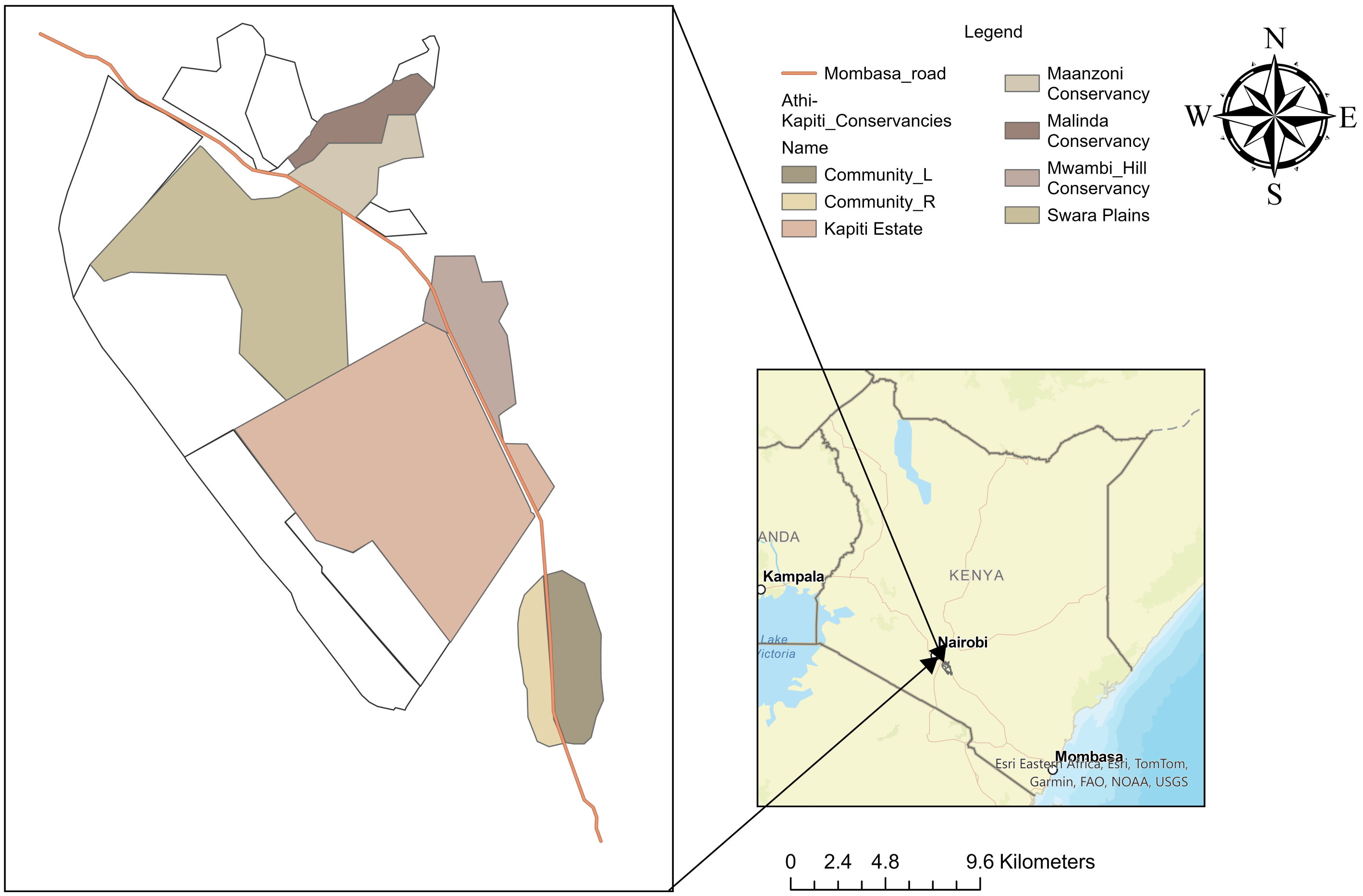

Figure 1

Map of the study area showing the Mombasa Highway intersecting Athi-Kapiti Plains conservation area

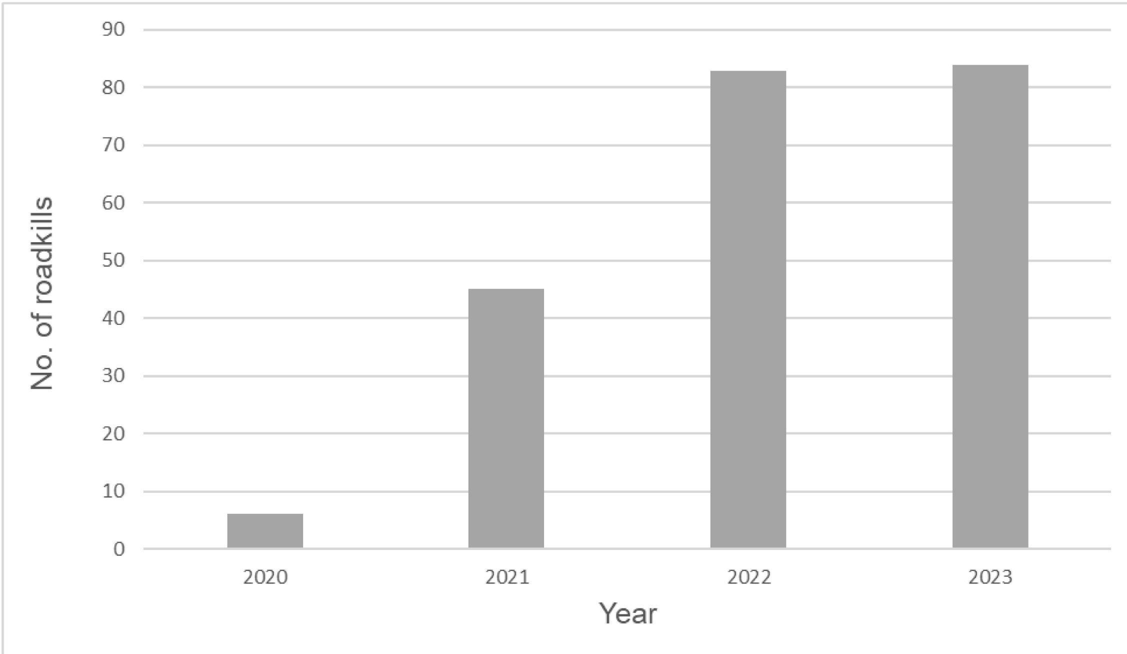

Figure 2

Annual wildlife roadkill totals recorded along the Mombasa Highway in the Athi-Kapiti Plains from 2020 to 2023 showing the highest incidents in 2022 and 2023 and the lowest in 2020

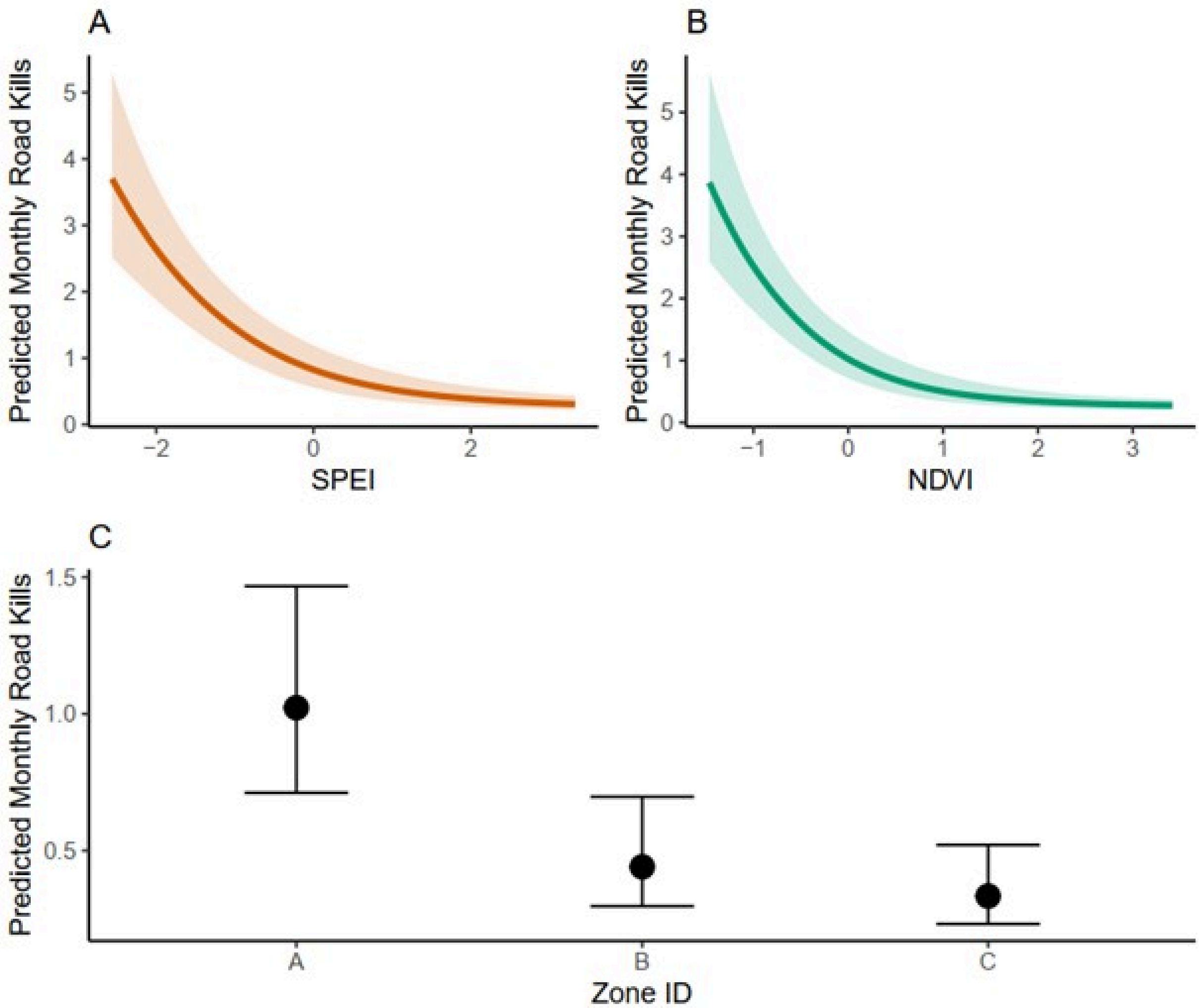

Figure 3

Predicted number of roadkills as a function of environmental variables and location. (A) Relationship between the 6-month accumulation Standardized Precipitation-Evapotranspiration Index (SPEI) and predicted roadkill frequency. (B) Relationship between Normalized Difference Vegetation Index (NDVI) and predicted roadkill frequency. (C) Comparison of predicted roadkill numbers across three different plots (A, B, and C), with plot A exhibiting significantly higher predicted roadkill counts compared to plots B and C. Error bars represent 95% credible intervals. Shaded areas in panels A and B represent the 95% credible intervals around the predicted means from the fitted models.

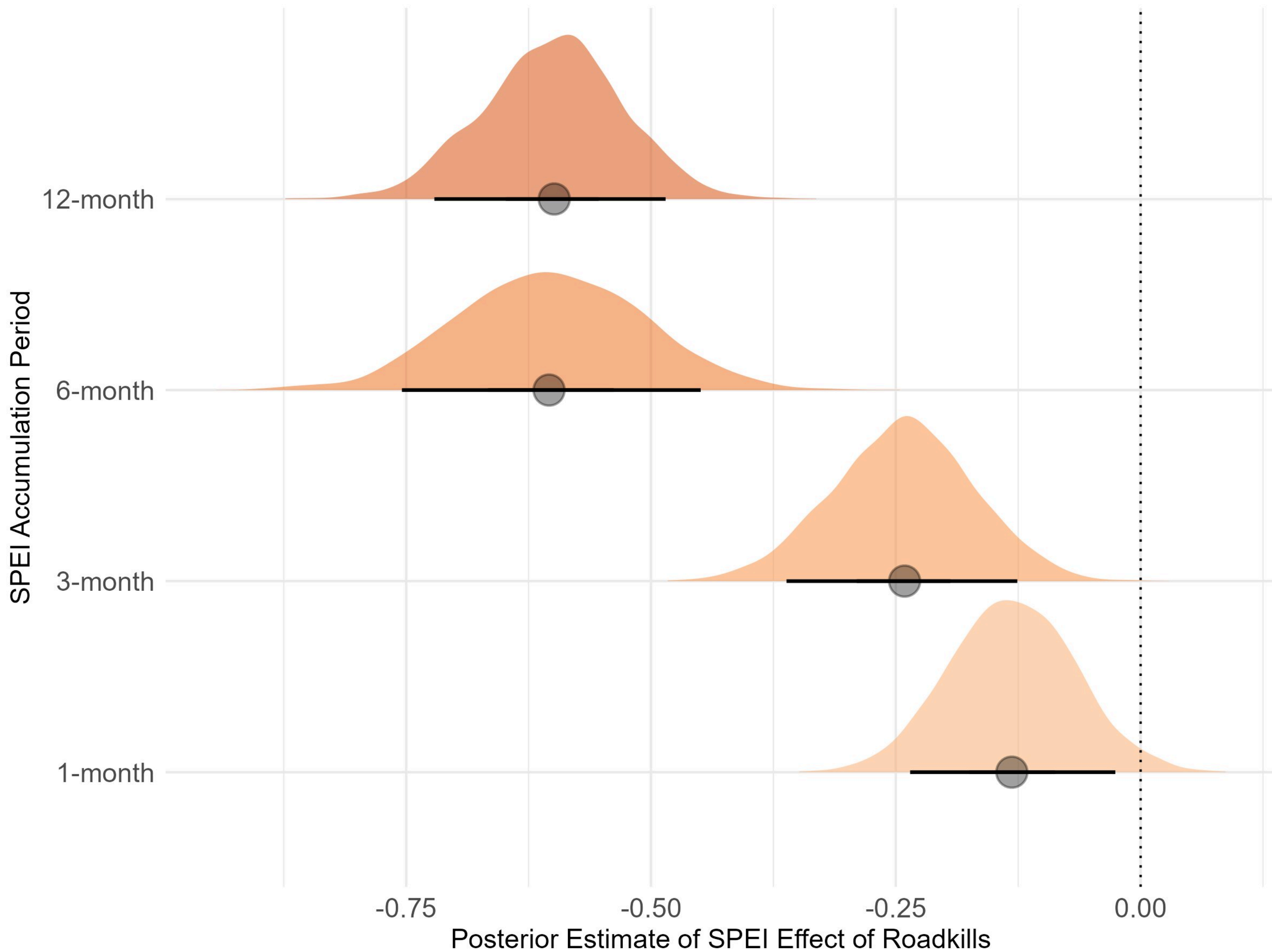

Figure 4

Comparison of posterior estimates for the effect of Standardized Precipitation Evapotranspiration Index (SPEI) accumulation periods (1, 3, 6, and 12 months) on wildlife-vehicle collision rates. Negative values indicate higher roadkill frequency under drier conditions.

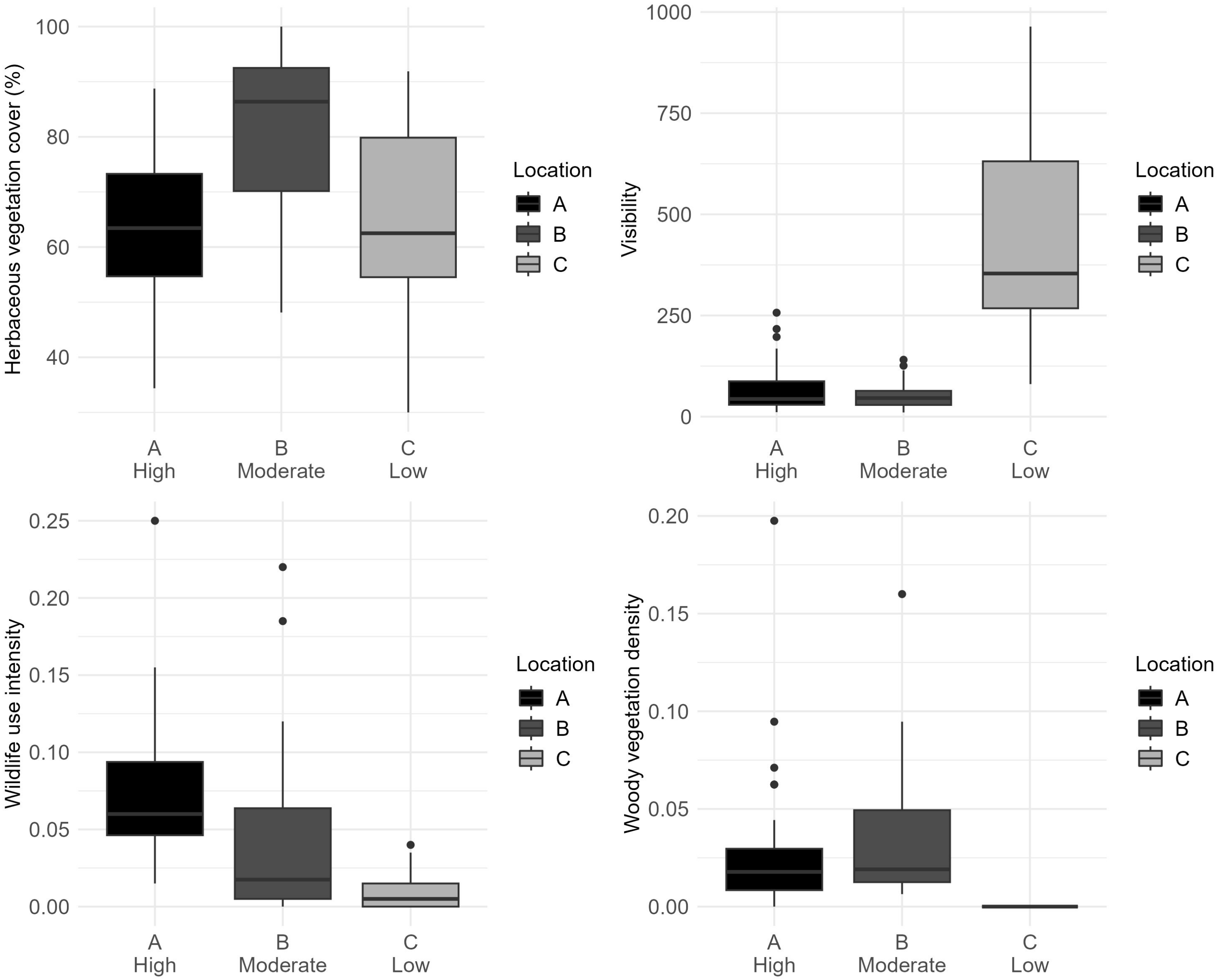

Figure 5

Wildlife use intensity, wooden vegetation density, herbaceous vegetation cover and visibility at Swara-Maanzoni Interface (A), Kapiti-Mwambi Transition (B) and Community Edge Zone (C), along Mombasa road in Athi Kapiti Plains. The x-axis labels display the site ID and relative risk of roadkill (Low, Moderate, and High) according to model predictions.

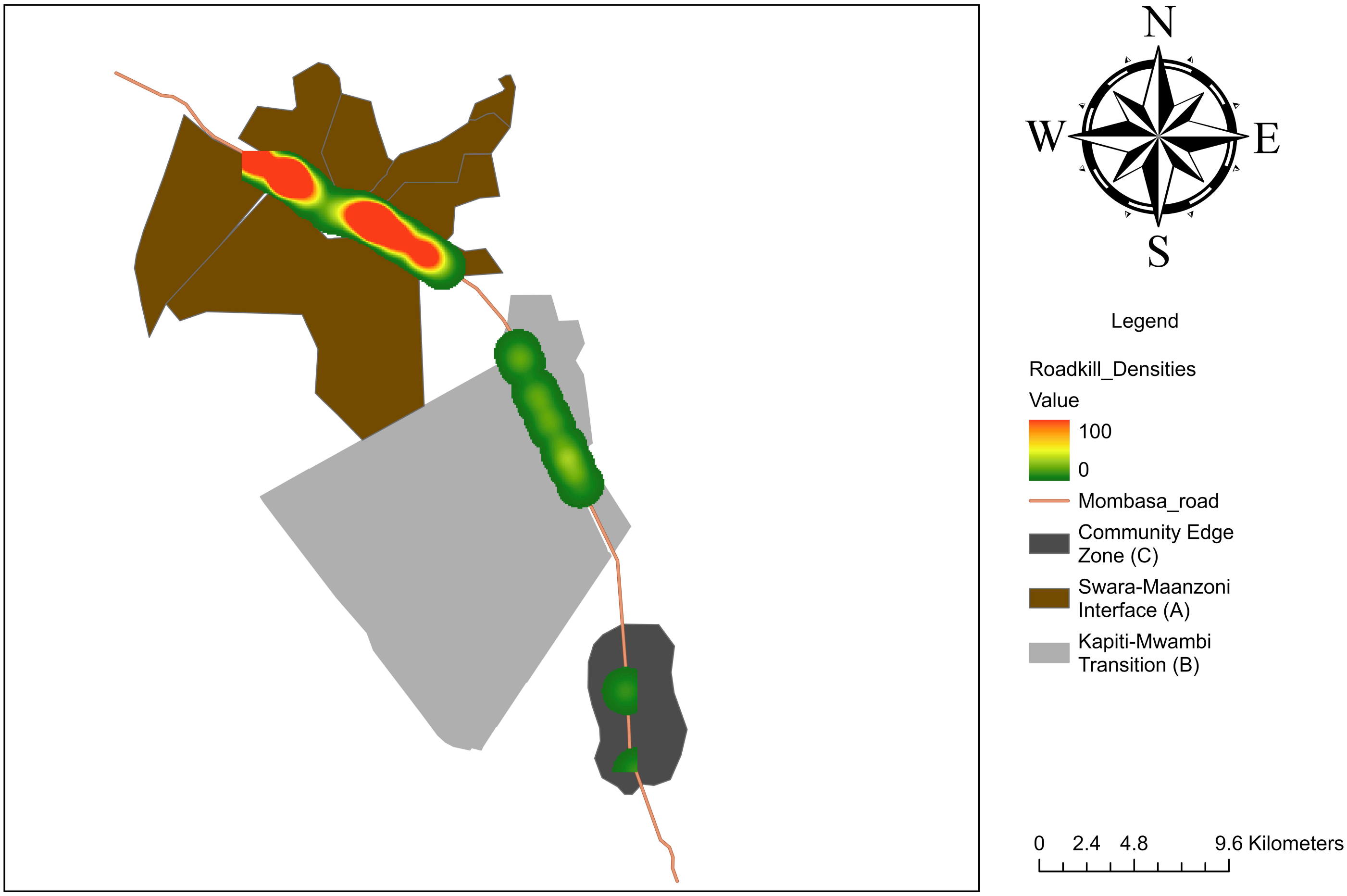

Figure 6

Spatial distribution of wildlife roadkill intensity at Swara-Maanzoni Interface (A), Kapiti-Mwambi Transition (B) and Community Edge Zone (C) along Mombasa Highway in Athi-Kapiti plains.

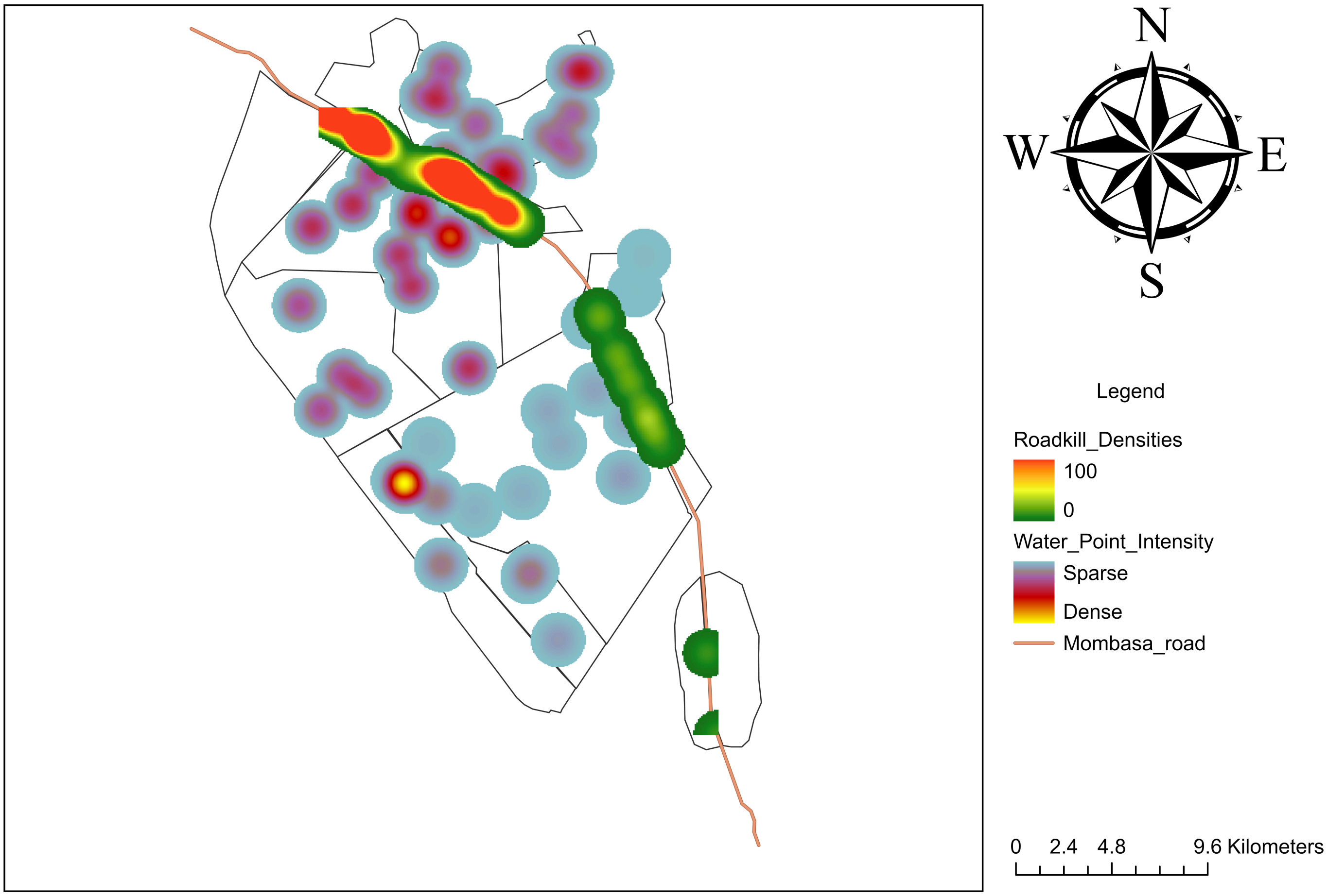

Figure 7

Spatial distribution of roadkill hotspots in relation to watering points along the Mombasa Highway within the Athi-Kapiti Plains Conservancies.

Supplementary Files

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- Fig.S1.jpg
- Fig.S2.jpg