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Amphibian and Reptile Roadkill Incidents Along Butuan City–Las Nieves Road, Philippines, with Notes on Temporal and Spatial Mortality Distribution

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ABSTRACT

Roads significantly impact biodiversity, and animal roadkill may be one of the most crucial human-caused mortality factors for some species. This study aimed to document amphibian and reptile roadkill incidents along a 25.5-kilometer stretch of the Butuan to Las Nieves Road from June 2021 to February 2022. A total of 214 carcasses were recorded from three amphibian species (n=204), namely, *Kaloula pulchra, Polypedates leucomystax* and *Rhinella marina,* and five reptilian species (n=10), namely, *Dendrelaphis philippinensis, Lycodon capucinus, Naja samarensis, Coelognathus erythrurus,* and *Malayopython reticulatus*. In this study, most roadkill victims were invasive alien species, and the cane toad, *R. marina*, exhibited the greatest mortality among species (roadkill rates= 7.76 ind./km). The high roadkill incidence of the invasive species could unintentionally aid in reducing and managing its population in the affected areas. However, since roadkills are incidental, it is not a reliable control measure. Although minimal, we recorded some endemic species impacted by vehicle collisions, which could also affect their population. The highest recorded herpetofauna roadkill incidents were in June and September (n=35). A significant difference in roadkills was recorded across sampling months (p<0.000). The acquired rainfall data indicated peak rainfall levels in November and December 2021 (284.2mm and 627.4mm, respectively). The study's results showed no significant relationship between roadkill mortality and rainfall (p-value= 0.412, r^2= -0.313). The spatial pattern of roadkills was analyzed using the Kernel Density Estimation (KDE) in Quantum Geographic Information System, and three roadkill hotspots were identified. Most roadkill hotspots within the heatmap were located on road portions near forested and plantation areas and waterways. Analyzing habitat suitability and connectivity might improve the capacity to anticipate the location of roadkill hotspots. This study is the first to report on herpetofauna roadkill incidents in Butuan City and the Caraga Region.

Keywords: *Herpetofauna, Hotspots, Monitoring, Roadkill, Rainfall*

1 Introduction

Amphibians and reptiles are vulnerable to roadkill incidents due to their seasonal migrations, slow movement, and specific habitat needs, threatening their populations worldwide (Jones et al. 2024). Amphibians, for instance, frequently crossroads to reach breeding sites, especially during rainy seasons or times of the year when they migrate in large numbers, leading to high mortality rates on highways that intersect their natural habitats (Beebee 2013). In temperate regions, where amphibians are influenced significantly by temperature, particularly during spring and fall, experienced a high rate of roadkill mortality. Notable roadkill events have detrimental impacts on herpetofauna populations (Jones et al. 2024, Langen et al. 2009, van der Ree et al. 2015). The roadkill incidents have led to the construction of tunnels and barriers for amphibians and other herpetofauna to mitigate population declines. Similarly, reptiles, including turtles and snakes, frequently crossroads to access areas for mating, feeding, or sunbathing, which increases the possibility of vehicle collisions (Row et al. 2007).

Road mortality can be very devastating to these species because many amphibians and reptiles have low reproduction rates and delayed maturation. Hence, population recoveries from even slight increases in adult mortality are unlikely (Gibbs & Shriver 2002). Amphibians are vulnerable to environmental changes because their permeable skin and reliance on aquatic and terrestrial habitats make them especially vulnerable to habitat fragmentation and pollution. These often tend to be factors exacerbated by roads and accompanying infrastructure (Hels & Buchwald 2001). In other countries, such as tropical regions where seasonal amphibian migrations are prominent, roads showed fragmented habitats significantly and reduced the species' genetic flow and population resilience (Beebee 2013, Hartel et al. 2010, Allentoft & O'Brien 2010).

Roadkill incidents can both aid and impede the spread of invasive alien species. High mortality among invasives may temporarily reduce their population in affected areas. However, if these species are adaptive, roadkills may inadvertently assist the spread by encouraging broader dispersal and enabling surviving individuals to establish new habitats (Santos et al. 2011). In tropical areas, the population of invasive alien species continues to increase despite the frequent records of roadkill incidences, underscoring the complexity of managing these populations (Shine 2010; Shine et al. 2018).

Extrinsic factors influencing road mortality vulnerability can be both spatial (e.g., surrounding environments (Caro et al. 2000) and temporal (e.g., seasonal changes) in nature. The time series of road deaths are often correlated with seasonality. The influence of different seasons has variable effects on the frequency of roadkills depending on the location. For instance, seasonal temperature changes in temperate zones dictate the timing of amphibian migrations and associated road mortality peaks (Coelho et al. 2012). In contrast, in tropical countries such as the Philippines, rainfall patterns are more significant drivers of herpetofauna activity and roadkill occurrences (Oddone Aquino and Nkomo 2021). Therefore, landscape factors, road infrastructure, traffic volume, speed, niches, species behavior, and seasonality influence roadkill.

Although amphibians and reptiles are far more vulnerable species than mammals or birds, Fahrig and Rytwinski (2009) claim that little study has been done on the consequences of roads on their populations. On a landscape scale, the consequences of road networks on amphibian and reptile populations are rarely examined. Some road-killed species disappear quickly, coupled with the intricate network of roads making road-killed animals difficult to distinguish (Heigl et al. 2017). In the Philippines, studies of roadkills have been limited. Documented cases include anurans in an urbanized area in Davao City (Gersava et al. 2020) and freshwater turtles in Palawan (Bernando 2019). Beyond these studies, no other published research on roadkills has been conducted in the Philippines to date.

One crucial national secondary road in Agusan del Norte is the Butuan City to Las Nieves road. Agricultural farms and secondary forest habitats surrounded it. It is a key site connecting the Municipality of Las Nieves to the City proper, making it a potentially significant site for roadkill impacts on local wildlife. Unlike temperate countries with significant seasonal migrations, the roadkill patterns in this area are influenced by tropical rainfall patterns and human-modified landscapes. Hence, this study focused on amphibian and reptile roadkill incidence from Barangay Maguinda, Butuan City, to Barangay San Roque, Las Nieves road. Roadkill data can be a valuable tool for monitoring amphibian and reptilian population dynamics and movement patterns. The information may help with the protection and conservation of endemic species and the creation of efficient mitigation plans for invasive species. This study provides a unique perspective on roadkill impacts in the Philippines, particularly within the Butuan and Caraga regions, where such data are scarce.

2 Materials and Methods

Description of the Study Area

The amphibian and reptile roadkill incidence monitoring was conducted from Barangay Maguinda, Butuan City, to Barangay San Roque, Las Nieves Agusan del Norte, Philippines (initial coordinates 8°49'32.1"N, 125°35'41.3"E; last point coordinates 8°42'4.9"N, 125°39'54.2"E). It is a two-lane national secondary road supporting the primary national roads by directly linking Las Nieves to Butuan City. The survey route covers a total distance of 25.5 km. The area was chosen because of its forested nature and proximity to the Agusan River. The region's climate is defined as hot, oppressive, and overcast. The temperature ranges typically from 25°C to 31°C throughout the year, with temperatures rarely falling below 23°C or rising above 32°C. Outlying areas were open farmland like rice, coconut, corn, and rubber farms (Phil Atlas 2021).

Data Collection and Sampling

The chosen route was surveyed from June 2021 to February 2022. We used a motorcycle to track the defined path at 20-25 km/h, conducting observations twice monthly from 0800 to 1200 hours with a two-week interval between surveys. These surveys were carried out on fair weather. The survey route started in Las Nieves, proceeded to Butuan City, and then returned to the starting point covering both sides of the road. Two people monitored the amphibian and reptile roadkill found on the roads. The carcasses were photo-documented, and distinguishing characteristics were noted to aid identification. Features that are peculiar to each species include body size, coloration, patterning, and distinctive markings. Other factors, such as the surrounding habitat and the condition of the carcass (e.g., degree of decomposition), were also noted to provide additional information for species identification. The journals of Sanguila et al. (2016) and Diesmos

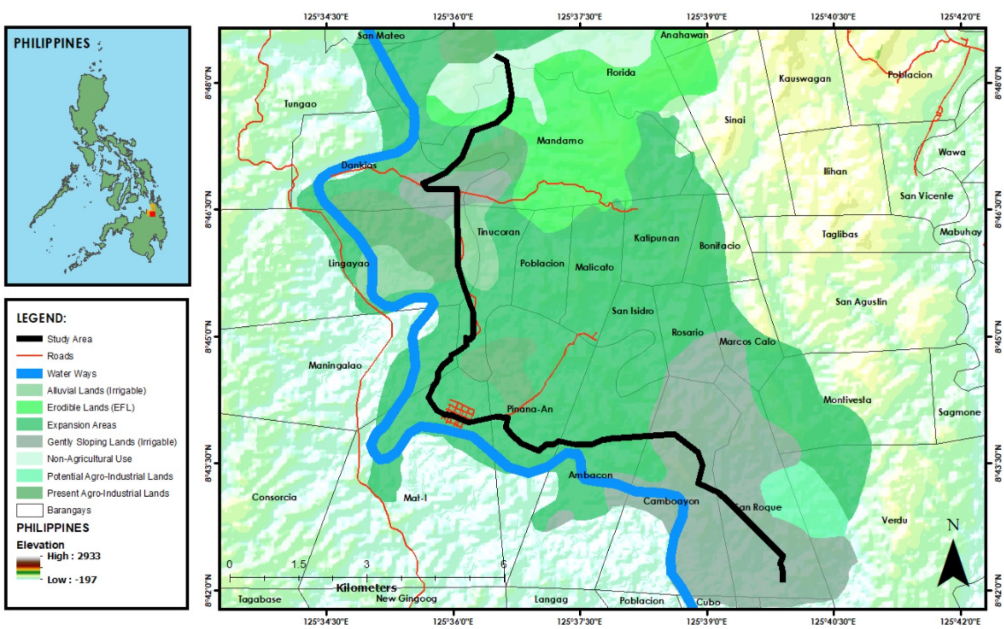

Figure 1. Location of the study route from Brgy. Maguinda, Butuan City to Brgy, San Roque, Las Nieves, Agusan del Norte, Philippines.

et al. (2015) were used to determine the lowest possible identification. Geographic coordinates were recorded at each incidence to record the exact location of each sample. We removed all carcasses off the road to avoid duplicate counting. The daily rainfall data of Butuan City to Las Nieves was obtained from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAG-ASA), Butuan City.

Heat Map Generation

Quantum Geographic Information System Software (QGIS Software) was used to analyze and create heat maps of herpetofauna roadkills. QGIS uses Kernel Density Estimation (KDE) to generate heat maps. This method applies a kernel function to each data point to calculate density. After calculating the overlapped kernels, this program creates a continuous surface with low densities in blue and high densities in red. The resulting heatmap shows the concentration of points across the geographic area under study.

Data Analysis

The roadkill rates of amphibians and reptiles were calculated using the formula:

$$Roadkill\ Rates = \frac{Number\ of\ individuals\ killed}{Distance\ traveled}$$

T-test was used to examine whether the number of roadkills varied across months of survey using Paleontological Statistics Software (PAST 4.15). The relationship between rainfall and roadkills was examined using a correlation test ($p<0.05$) with the number of roadkills recorded per month as the dependent variable using SPSS v28. The graphs were generated using Python version 3.13 and the Matplotlib and Seaborn libraries for visualization.

3 Results and Discussion

Roadkill species registered

We recorded 214 roadkill incidences, accounting for 204 amphibians and ten reptile individuals during the nine months of monitoring along the Butuan - Las Nieves Road, Agusan del Norte, Philippines. Of the 214 carcasses, 95% represented three amphibian species. Families include Microhylidae (0.46%, n = 1 spp.), Bufonidae (92.52%, n = 1 spp.), Rhacophoridae (1.40%, n = 1 spp.), and an unidentified species (0.93%, n = 2 spp.). The remaining 5% represented five reptile species from Family Colubridae (2.33%, n=3 spp.), Elapidae (1.40%, n = 1 spp.), Pythonidae (0.46%, n = 1 spp.), and unidentified (0.46%, n = 1 spp.) (Table 1 and Figure 2). Most of the casualties found were globally classified as Least Concern by the IUCN (2021). Table 1 shows that the Cane toad, *Rhinella marina* (92.52%), Oriental wolf snake, *Lycodon capucinus* (1.40%), and the Visayan cobra, *Naja samarensis* (1.40%) were the dominating roadkill victims. Due to advanced decomposition, three carcasses (two amphibians and one reptile) could not be identified, which obscured key physical features necessary for accurate identification.

Rhinella marina (Figure 2A) was the most recorded amphibian species in the survey area. This species was initially introduced in the Philippines as a biological control agent to curb the rapidly growing population of sugarcane pests. It can be found in severely degraded natural and man-made habitats in low elevations (Diesmos et al. 2006). The abundance of *R. marin*a in habitats near roads can also be attributed to its high tolerance for environmental disturbances and its natural toxins, which make it less vulnerable to predation. One *Kaloula pulchra* (Figure 2B) roadkill was recorded during the survey. Despite its tolerance for habitat disturbance, *K. pulchra* had the lowest recorded roadkill incidence over the nine months of monitoring. This invasive alien species is becoming increasingly abundant in degraded habitats of low elevation, especially in areas near bodies of water like ponds and ditches (Diesmos et al. 2006). Three road-killed individuals of *P. leucomystax* (Figure 2C) were recorded in an agricultural area and banana plantation close to the residential neighborhood. *Polypedates leucomystax* is a native species in Southeast Asia. It is an arboreal species known as “palakang saging” or "banana frog" in the Philippines (Siler et al. 2012). This native species is known to occur in sympatry with alien species in the same habitat (Diesmos et al. 2006).

Furthermore, we recorded one *Malayophython reticulatus* (Figure 2D) road-killed individual on the agricultural road. This highly adaptable snake can be found in various environments, including lowland and lower montane forests, agricultural regions, scrublands, and mangrove edges (Cruz et al. 2018). One juvenile *Coelognathus erythrurus* (Figure 2E) roadkill was recorded in an agricultural area. The Philippine red-tailed rat snake is a nonvenomous indigenous species in the Philippines, particularly Mindanao (Sanguila et al. 2016). Weinell et al. (2019) described adult *C. erythrurus* with a tail that is substantially lighter than the back half of the body; the other back half may or may not be darker than the front half of the body. Three road-killed individuals of *Naja samarensis* (Figure 2F) were recorded. This highly venomous snake, the Samar cobra, is a WHO-listed Category 1 endemic to the southern Philippines. It is distinguished by its black and bright yellow body coloring and is a deadly snake species of medical significance (Palasuberniam et al. 2021). It can also spit (or spray) poison into assailants' eyes, causing

Table 1. List of amphibians and reptiles roadkills recorded along Maguinda, Butuan City to San Roque, Las Nieves Agusan del Norte, Philippines across months of the survey.

Species	IUCN (Population trend)	Distribution Status	Abundance (% of Total Kills)	Roadkill rates (ind./km)
Amphibians				
Bufonidae				
Rhinella marina (Cane toad)	LC ↑	IAS	198 (92.52%)	7.76
Microhylidae				
Kaloula pulchra (Banded bullfrog)	LC -	IAS	1 (0.46%)	0.04
Rhacophoridae				
Polypedates leucomystax (Common Tree Frog)	LC -	N	3 (1.40%)	0.12
unidentified	-	-	2 (0.93%)	0.08
Reptiles				
Colubridae				
Dendrelaphis philippinensis (Philippine bronzeback treesnake)	LC -	PE	1 (0.46%)	0.04
Coelognathus erythrurus (Philippine Trinket snake)	LC -	PE	1 (0.46%)	0.04
Lycodon capucinus (Oriental wolf snake)	LC -	IAS	3 (1.40%)	0.12
Elapidae				
Naja samarensis (Southern Philippine Cobra)	LC ↓	PE	3 (1.40%)	0.12
Pythonidae				
Malayopython reticulatus (Reticulated Python)	LC *	N	1 (0.46%)	0.04
unidentified	-	-	1 (0.46%)	0.04
Total			**214**	

Legend: IUCN = Least Concern (LC); Population trend= increasing (↑), stable (-), unknown (*); Distribution Status = Invasive Alien Species (IAS); Philippine Endemic (PE); N (Native to Southeast Asia)

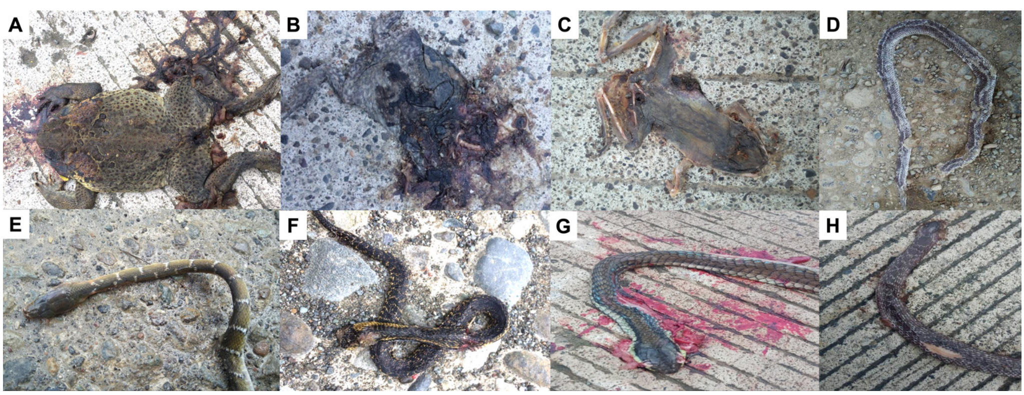

Figure 2. Amphibian and reptile roadkills from Brgy. Maguinda, Butuan City to Brgy, San Roque, Las Nieves, Agusan del Norte, Philippines during the survey period: A. *Rhinella marina*, B. *Kaloula pulchra*, C. *Polypedates leucomystax*, D. *Malayophython reticulatus*, E. *Coelognathus erythrurus*, F. *Naja samarensis*, G. *Dendrelaphis philippinensis*, and H. *Lycodon capucinus*.

venom ophthalmia (Cruz et al. 2018). This snake lives in various habitats, from lowlands to highlands (up to 800 meters), and may be locally common in agricultural areas or near human habitation. One *Dendrelaphis philippinensis* (Figure 2G) was identified. It is an entirely arboreal, diurnal colubrid unique to the Philippines and is one of the *D. caudolineatus* polytypic groups. *Dendrelaphis philippinensis* is found across the Mindanao Pleistocene Aggregate Island Complex (PAIC), with historical records from the small islands of Dinagat and Siargao in the northeast region of Mindanao PAIC (Sanguila et al. 2016). We recorded three *Lycodon capucinus* (Figure 2H) carcasses, one from the residential road and two in the agricultural area. The Oriental wolf snake is a widespread invasive alien species in the Indo-Australian Archipelago. This snake is common in agricultural and urban areas across Southeast Asia. It has brown dorsal skin striped with yellowish patterns that produce a 'reticulate' pattern (Sanguila et al. 2016).

Amphibian and Reptile Roadkill Incidences

Roadkill incidences of amphibians and reptiles significantly differ across months ($p < 0.000$). The heatmap in Figure 3 shows the survey's total roadkill occurrences per month. Amphibians were presented in the top row and reptiles in the bottom row. Darker shades indicate a higher number of roadkill counts. Most amphibian roadkill incidences were highest in June (N = 34) and September (N = 33), with February being the least (N = 13). Reptile roadkill remains relatively low throughout the months.

The presence of invasive alien species during the survey indicates that these species might be more widespread in the area and may increase pressure on native herpetofauna populations. The high roadkill incidence of the invasive alien species *Rhinella marina* (92.52%, 7.76 ind./km) along the Butuan to Las Nieves Road is noteworthy. Although roadkill is an unintentional outcome of vehicle collisions, it is potentially beneficial in controlling populations of invasive species, particularly in the case of *R. marina*, which can outcompete native animals for food and space and has few natural predators (Diesmos et al. 2006). Therefore, by eliminating individuals from the ecosystem, these roadkill incidents may indirectly aid in population control.

More amphibian individuals were recorded than reptiles because amphibians are more likely to cross roads during seasonal migrations (Galoyan et al. 2017). Additionally, amphibians tend to live close to water sources, typically at intersections with roads, making it more likely that they will come into contact with vehicles. Especially during rainy seasons, certain anuran species, particularly those that nest in vernal pools, lay

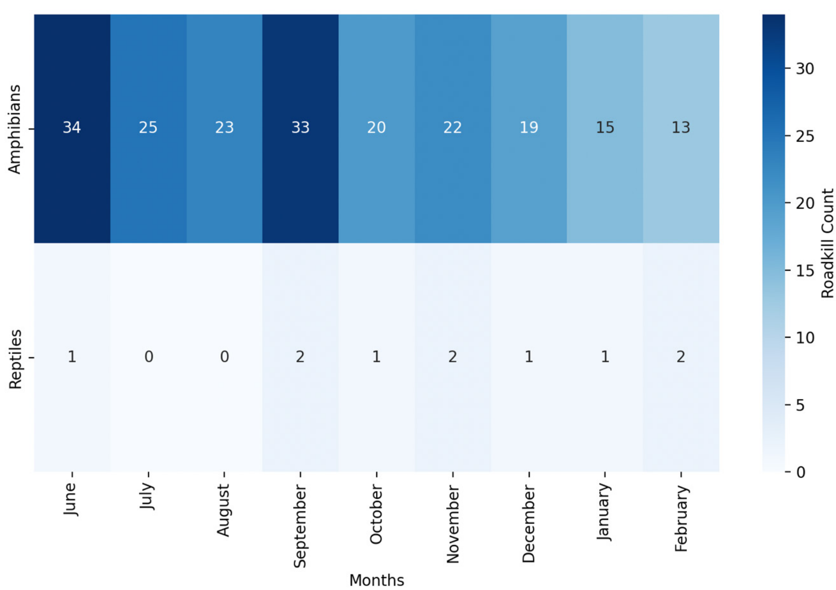

Figure 3. Monthly roadkill counts of amphibians and reptiles on the road from Brgy. Maguinda, Butuan City to Brgy, San Roque, Las Nieves, Agusan del Norte, Philippines.

their eggs in temporary pools that occur in roadside ditches and obstructed drainages (Dimauro and Hunter 2002). Amphibians' slower movement and relatively small size limit driver visibility and increase the likelihood of accidental collisions with vehicles (Elzanowski et al. 2009).

Roads are among the warm surfaces that reptiles, especially snakes and lizards, frequently deliberately seek to sunbathe on. However, many reptiles can move quickly when disturbed (Alexander 2012). Their ability to sprint, climb, and even make abrupt direction changes is partially attributed to their physical structure, which includes stronger, more developed limb and tail muscles (Alexander 2012) compared to amphibians. The study recorded carcasses of five snake species without any carcasses of lizards or skinks. Snakes are observed on sun-warmed surfaces like roads, providing an ideal thermoregulation heat source to maintain body temperature, significantly increasing their risk of road mortality, as they are more likely to encounter vehicles while basking (Kioko et al. 2015; Ashley and Robinson 1996).

Temporal Patterns of Roadkill

Roadkill trends may be impacted by rainfall, which has been proposed as a climatic indicator that affects seasonal variations in species abundance and behavior (Teixeira et al. 2013). Figure 4 shows that roadkill incidents were high from June to September 2021 despite low rainfall rates. In addition, despite the heavy rainfall, there were few roadkill records between November 2021 and January 2022. The high rainfall in December 2021 is due to the impact of Typhoon Odette. The correlation analysis revealed a weak and non-significant relationship between rainfall and mortality rates (amphibians: p-value = 0.399; r^2 = -0.321 and reptiles: p-value = 0.839; r^2 = -0.079).

While rainfall can influence animal behavior, the intersection of several factors, such as environmental conditions, road features, and species behavior, determines the likelihood of roadkill. Environmental factors that can influence roadkill rates on amphibians and reptiles can be temperature (Meek 2009), seasonality (Fahrig et al. 1995), light conditions (Garriga et al. 2012), flooding (Ashley and Robinson 1996), climate and weather conditions (Oddone Aquino and Nkomo 2021). Also, the low roadkill rates during rainy seasons may be explained by heavy rainfall frequently lowering road traffic volumes because of reduced motor and vehicle travel. During rainy seasons, drivers also prefer to slow down and increase following distances, resulting in fewer road accidents (Peng et al. 2018, Rahman and Lownes 2012). Road visibility also decreases; hence, traffic density decreases (Peng et al. 2018). Non-essential trips are also frequently avoided, which lowers the likelihood of wildlife encounters and roadkill incidents. Other factors influencing roadkills are spatial proximity, infrastructure, traffic volume and speed, and landscape features (Oddone Aquino and Nkomo 2021). Roadkill hotspots are often linked to habitat proximity and species-specific movement patterns rather than rainfall alone (Clevenger

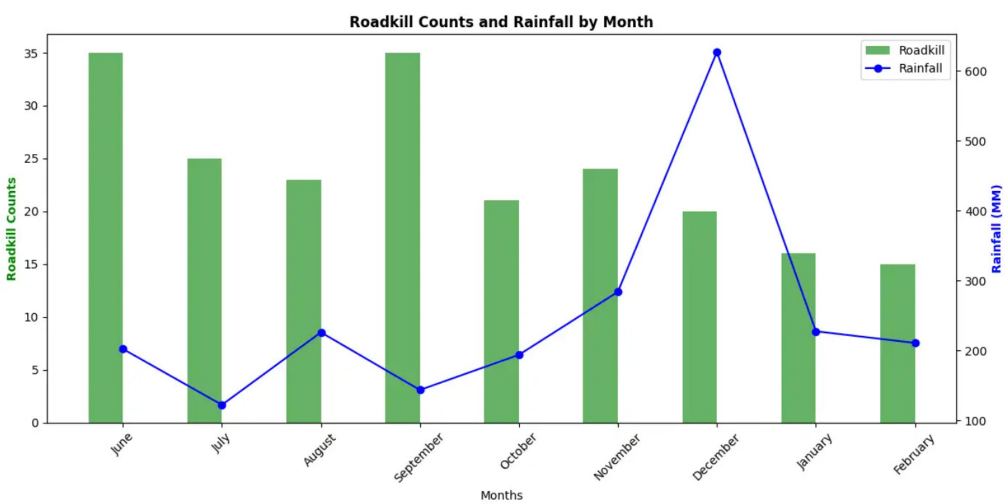

Figure 4. Temporal distribution of herpetofauna roadkills from Brgy. Maguinda, Butuan City to Brgy, San Roque, Las Nieves, Agusan del Norte, Philippines. Roadkill (bar) versus monthly mean rainfall (line).

& Waltho 2000, Oddone Aquino and Nkomo 2021). These reports mean that although rainy nights likely favor some species to cause roadkill, it does not guarantee increased incidents.

Concentration pattern and heat maps

The spatial distribution of amphibian and reptile carcasses across the Butuan to Las Nieves road is shown in Figure 5. The heatmap highlights areas with high species values (indicated by warmer colors) where both amphibians and reptile carcasses are concentrated. The roadkill incidences along the surveyed route showed concentrations of road-killed species in particular locations along the road. A single hotspot in June, August, and October was next to a rice field and rubber plantation, indicating a strong clustering pattern. In July, two hotspots were identified; all hotspots are near forested and agricultural areas with coconut plantations, rice, and corn fields. November has three identified hotspots: one was near the residential area, and the two were near forested and agricultural areas. One hotspot for December, January, and February is near an agricultural area with a banana plantation, coconut plantation, rice and corn fields, and a forested area.

Generally, across months, a total of three hotspots were identified. Dense vegetation, forest patches, and waterways may cause the hotspots recorded in the Las Nieves. Most roadkill hotspots were located on road portions near forested and plantation areas, with fewer roadkill in parts along town areas, which conformed to the reports of Karunarathna et al. (2013), Clevenger et al. (2003) and Vijayakumar et al. (2001). Since roads bisect forested or plantation areas, it can contribute to habitat fragmentation, forcing animals to cross roads to access different parts of their habitat. This increases roadkill risk and disrupts population connectivity, potentially isolating populations (Fahrig 2003, Forman & Alexander 1998). Also, animals with nesting sites next to roadways or adequate habitats across the road may be more likely to become part of mass road-crossing activities, exposing them to roadkill (Riley et al. 2014). Waterways also intersect the surveyed road. Waterways provide crucial resources for amphibians and some reptiles (Jones et al. 2024), but they are also susceptible to pollution and sedimentation from nearby agricultural activities.

Hotspot A was near forested and agricultural areas with coconut tree plantations and corn fields. Most of the carcasses in hotspot A were amphibians. Two *P. leucomystax* individuals were found in hotspot A. Hotspot B was near the agricultural area with rice fields, corn fields, rubber plantations,

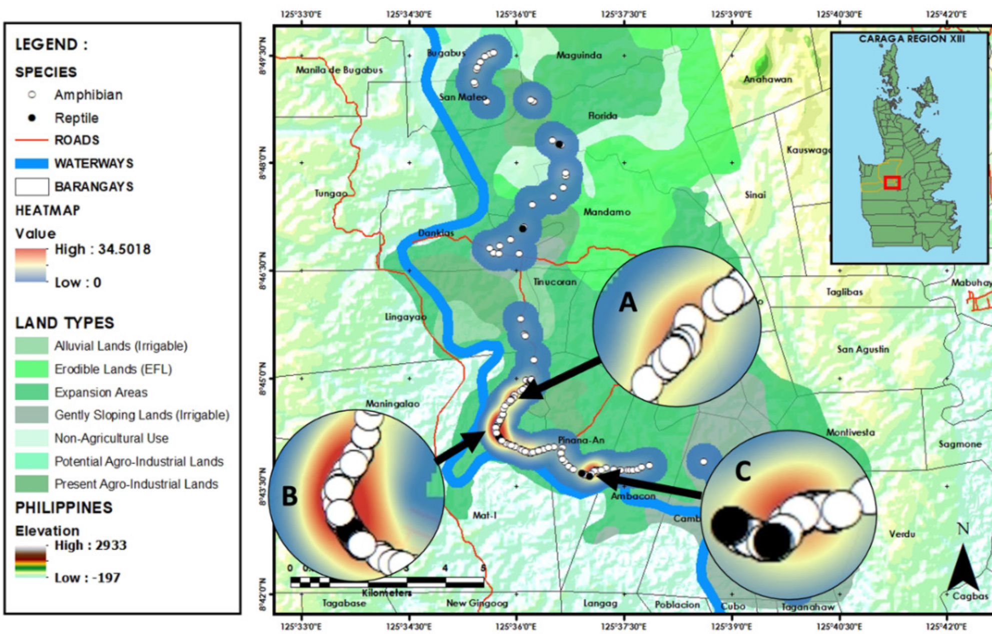

Figure 5. Spatial distribution and heatmap of roadkill from Brgy. Maguinda, Butuan City to Brgy, San Roque, Las Nieves, Agusan del Norte, Philippines during the nine months of monitoring.

and vegetable farms. This hotspot was also near a canal, a potential refuge site for herpetofauna. One reptile species was recorded in the hotspot B area, *C. erythrurus*, and amphibians were the most abundant carcasses in the hotspot. Hotspot C was near the banana plantation, coconut plantation, rice field, corn field, and forested area. Most casualties of carcasses in hotspot C are reptiles and amphibians; two of the *Naja samarensis* and one of *Lycodon capucinus* were notably recorded in hotspot C. Hotspots A and B belong to one barangay in the Las Nieves area, which is dense in agricultural areas.

Understanding amphibian and reptile distribution patterns and populations could be a tool for effective conservation measures. Since most recorded species were invasive alien species, roadkills can be considered an unintentional but helpful strategy to address the increase, spread, and potential impacts of these species on native species. Monitoring the movement patterns of these species can help formulate mitigation strategies.

4 Conclusion and Recommendations

The study monitored the number of roadkill incidents of amphibians and reptiles for nine months, analyzed the relationship between roadkill and rainfall, and created heat maps. The spatiotemporal findings can aid in determining the temporal crash pattern of herpetofauna and predicting the critical periods when such animal-vehicle collisions will occur in a specific location. Movements of herpetofauna during rainy seasons may increase the probability of animal collisions with cars, trucks, and motorcycles. Higher mortality was recorded along the road near dense vegetation and waterways because of adequate habitats and breeding sites, which makes the animals more vulnerable to road incidents. The survey area had high rates of invasive alien species, which could be a management strategy for Invasive Alien Species (IAS) migration. However, roadkill as a mitigation method is not a planned and reliable management approach. In general, invasive species are better managed through deliberate actions, including habitat management, public awareness campaigns, and controlled culling. Roadkill data on IAS can help track movement patterns and population dynamics, which can then help guide mitigation measures. Several limitations in this study, such as corpses remaining on the road and environmental variables relating to reptile and amphibian habitat suitability, are recommended for further research. It is also recommended to gather sufficient data and extend the sampling effort for in-depth analysis and improved sample design. To further enhance the ability to predict the location of roadkill hotspots, a thorough examination of herpetofauna species' habitat suitability and connectivity may be carried out.

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Statement of Conflict of Interest

To ensure impartiality, EF Gamalinda, a member of the JESEG Editorial Board, was excluded from the review process of this article. The authors confirm that there are no conflicts of interest related to the publication of this paper.

Author Contribution

SJ Mulig c*ontributed to the conceptualization, collection, analysis, and interpretation of data*; NJ Naling *focused on data analysis, particularly map generation and illustration*; E.F. Gamalinda was *involved in conceptualization, analysis, interpretation, and writing for publication*; CS Naling played a role in the *conceptualization, analysis, interpretation of data, writing, and supervision.* All authors approved the final manuscript version.

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