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Roadkill hotspots and driver awareness for endemic herpetofauna conservation in Western Thailand

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Abstract. *Duangta P, Klubchum T, Piyapan P, Sukhontapatipak C, Sawangproh W. 2025. Roadkill hotspots and driver awareness for endemic herpetofauna conservation in Western Thailand. Biodiversitas 26: 6025-6038.* University campuses, dense mosaics of roads, buildings, and small habitat patches, are rarely assessed for Wildlife-Vehicle Collisions (WVCs) despite predictable internal traffic and proximity to biodiverse areas. We addressed this gap at Mahidol University Kanchanaburi Campus (MUKA), Thailand, using a year-long, twice-daily carcass survey across four routes, supplemented by community reports and a concurrent driver questionnaire. We documented 170 carcasses from 31 species, dominated by reptiles (109, 64%) and amphibians (55, 32%), with few mammals (4, 3%) and birds (2, 1%). Spatial analysis revealed significant variation in roadkill incidence across routes (Kruskal-Wallis, H: 22.94, df: 3, p<0.0000424), with Route B identified as the primary hotspot adjacent to ponds and forest edges. Chi-square tests detected no association in taxonomic composition with distance to water, time of day, or season, yet roadkill incidents clustered near water (≤200 m), at night, and during the rainy season, indicating ecologically meaningful tendencies despite non-significant group-wise differences. The driver survey (n: 85) revealed a qualitative size-based bias, with greater caution toward larger mammals compared with small, less conspicuous herpetofauna. Notably, records included Thai endemics (*Jarujinia bipedalis*, *Gekko nutaphandi*), underscoring conservation urgency where even low absolute losses can affect micro-endemic populations. We propose targeted mitigation measures—night/monsoon speed management, frog/snake icon signage before pond-adjacent bends, pilot micro-culverts with drift fencing, and wildlife-sensitive lighting only where crash risk warrants—and recommend exploring an Other Effective Area-Based Conservation Measure (OECM) approach for the Route B corridor to develop a transferable model for biodiversity-sensitive campus roads. Integrating these measures into campus planning could position MUKA as a model for biodiversity-sensitive infrastructure in the tropics, directly benefiting evolutionarily distinct and micro-endemic species.

Keywords: Biodiversity management, campus ecology, driver awareness, habitat fragmentation, road ecology, wildlife-vehicle

INTRODUCTION

Wildlife-Vehicle Collisions (WVCs) contribute to biodiversity loss in human-modified landscapes, with significant impacts on populations, communities, and ecosystem processes (Coffin 2007; Bíl et al. 2019; Dean et al. 2019). Small-bodied herpetofauna, including reptiles and amphibians, are disproportionately affected due to their movement ecology and low detectability, leading to concentrated mortality along roads (Heigl et al. 2017; Morelli et al. 2024). Despite significant research on highways and rural-urban gradients (Hobday and Minstrell 2008; González-Gallina et al. 2013; Kent et al. 2021), university campuses (compact areas with buildings, secondary forests, water bodies, and service roads) remain underexplored, even though they offer opportunities for mitigation and conservation education (Krasny and Delia 2015; Simon et al. 2020; Zhao et al. 2023).

In tropical regions, the consequences are even more critical. Southeast Asia is home to exceptional reptile and amphibian diversity, coinciding with rapid road expansion (Healey et al. 2020). Tropical herpetofauna typically exhibit slow movement, nocturnal or crepuscular activity, dependence on warm road surfaces for thermoregulation, and seasonal migrations during the rainy season, which increase their vulnerability to vehicles (Andrews 2015; Bhagarathi et al. 2024; Mizsei et al. 2024). These traits create predictable risk patterns, such as clustering near water bodies, higher mortality at night, and peak incidents during the rainy season (Zevgolis et al. 2023). Even low mortality rates can be ecologically significant, especially when range-restricted or micro-endemic species are involved (Healey et al. 2020).

Driver behavior plays a crucial role in roadkill risk, with differences in risk perception based on taxon, size, and detectability (Su et al. 2023). On campuses, drivers differ from those on highways, typically involving students and staff on short, frequent trips. The well-documented bias toward larger animals (resulting in greater caution for mammals and less for small, cryptic herpetofauna) amplifies mortality for frogs and small reptiles, even at modest speeds (Collinson et al. 2019). This perceptual mechanism can be tested in campus settings (e.g., night driving, bends near ponds, and inconsistent speed culture) and used to design targeted interventions, such as speed caps and icon-based signage, informed by driver behavior (Collinson et al. 2019; Su et al. 2023).

The Mahidol University Kanchanaburi Campus (MUKA) in Western Thailand provides an ideal setting for studying WVCs. Situated within a mix of deciduous forest, limestone outcrops, and ponds (Sawangproh 2024), it hosts diverse herpetofauna, including Thai endemics like Jarujin's two-legged skink (*Jarujinia bipedalis*) and Nutaphand's red-eyed gecko (*Gekko nutaphandi*) (Bauer et al. 2008; Chan-ard et al. 2011). These species are micro-endemic, with small population sizes that make them highly vulnerable to roadkill (Marsh and Jaeger 2015). The campus road network intersects natural habitats, offering a unique opportunity for fine-scale analysis of roadkill hotspots and targeted mitigation strategies (Zevgolis et al. 2023).

This study involved a year-long, twice-daily survey across four representative routes at MUKA, complemented by community reports and a driver questionnaire. Our research questions focus on (i) spatial and temporal variation in roadkill incidents, (ii) the role of environmental correlates (distance to water, time of day, season) in structuring taxon-specific mortality patterns, and (iii) the alignment between driver perceptions and observed mortality, as well as actionable mitigation options. By combining carcass detection with driver behavior, the study aims to develop targeted, evidence-based interventions to reduce roadkill.

This study contributes to filling gaps in Southeast Asian WVC research, particularly in tropical regions outside protected areas and highways, where empirical studies remain scarce (Grilo et al. 2021). First, it provides one of the few assessments of WVCs on a Southeast Asian university campus, integrating species-level carcass records, hotspot mapping, and driver behavior in a tropical monsoon environment. Second, it underscores conservation urgency by documenting mortality in range-restricted endemics and highlighting recurrent hotspots near ponds and forest edges, areas often overlooked in previous studies. Third, it demonstrates the importance of addressing size-based perceptual biases in drivers, supporting behavior-informed mitigation, such as speed caps and icon-based signage. Finally, by examining WVCs within a university campus, this study positions campuses as model systems for understanding wildlife-road interactions in small, manageable landscapes, offering valuable insights for mitigation planning and community engagement in biodiversity conservation.

MATERIALS AND METHODS

Study area

MUKA is situated in Western Thailand (14.1295659°N, 99.1583598°E), covers approximately 10 km², and comprises a mosaic of mixed deciduous forests, limestone hills, ponds, and semi-urban developments. The region has a tropical monsoon climate with three seasons, cool (November-February), hot (March-May), and rainy (June-October). Long-term climate records report means annual rainfall of ~900-2,200 mm and a mean temperature of ~22°C (Monprapussorn 2014). Four road segments (Routes A-D), totaling 5.9 km, were selected to represent the entire set of primary routes used for entering, exiting, and circulating within the campus (Figure 1). These four segments encompass all major habitat interfaces and traffic conditions on campus, including mixed forest, forest edges, water bodies, agricultural plots, and built-up areas.

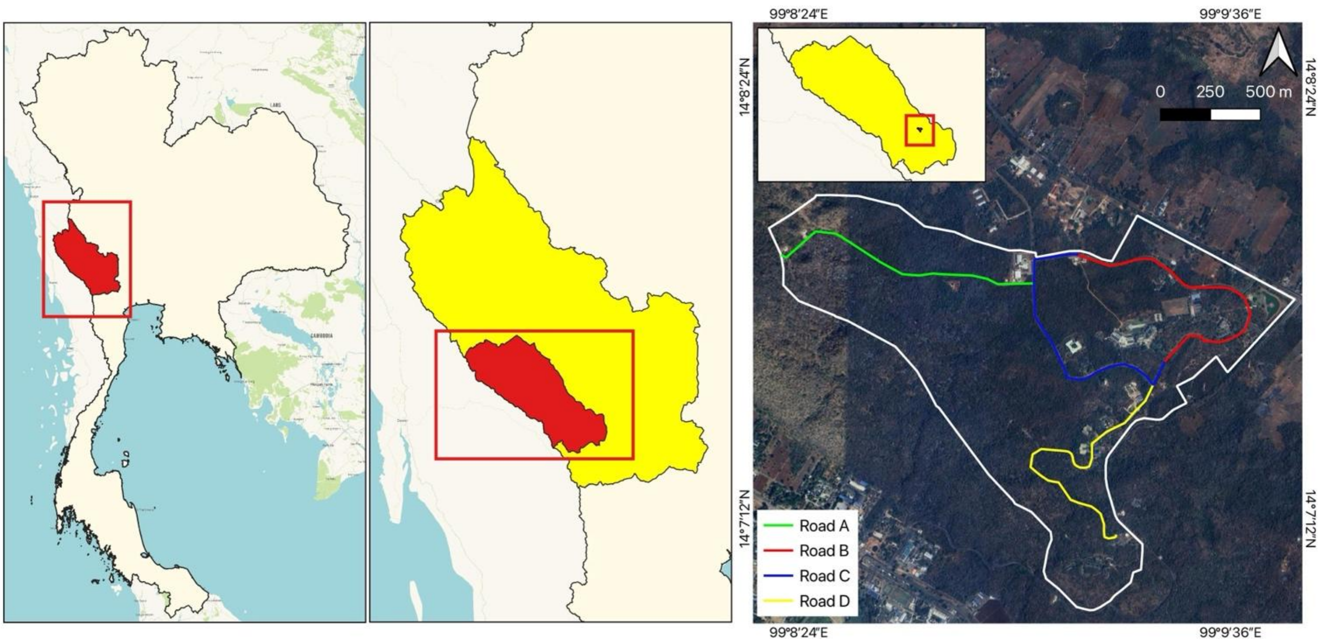

Figure 1. Map of the four surveyed routes within the campus area on Mahidol University Kanchanaburi Campus, Western Thailand

The routes exhibit distinct structural and ecological contrasts: Route A traverses mixed deciduous forest with gentle curves; Route B borders ponds and forest edges, providing multiple potential crossing points for amphibians and semi-arboreal reptiles; Route C runs between forest patches and academic buildings with relatively straight sight lines; and Route D contains steep slopes, limestone outcrops, shaded forest sections, and sharp bends adjacent to riparian zones. Together, Routes A-D cover all high-use internal roads as well as the main access corridors linking the campus to surrounding areas. A summary of route attributes (including road surface, traffic volume, posted speed limits, and adjacent habitats) is provided in Table 1 and the complete details are in Table S1.

Roadkill survey

The study was conducted over a one-year period (August 2022-July 2023), during which we documented WVCs through systematic field surveys supplemented by submissions received via the integrated Wildlife Report of MUKA online system (see below). Field surveys were conducted twice daily (07:00 and 16:30) along the four designated routes, with surveyors walking both sides of each road. The survey effort was divided into 10 evenly spaced sampling periods of approximately one month each. During every period, all routes were surveyed on two consecutive days, yielding 8 survey days per period and 80 survey days in total. During each pass, observers recorded species, GPS coordinates, date, time, weather, and road-surface conditions, and carcasses were removed immediately to prevent duplicate counts (Guinard et al. 2015). This immediate removal enabled each twice-daily pass to be treated as an independent sampling occasion, minimizing re-counting and temporal autocorrelation. Altogether, the systematic component comprised 160 structured passes (2 passes per day × 80 survey days), covering approximately 944 km. When combined with verified submissions from the online reporting system, this design provided one of the most comprehensive assessments of WVCs conducted on a tropical university campus, enabling robust detection of route-level differences and fine-scale ecological patterns.

Driver survey, integrated wildlife reporting system, and ethics

During the same study period, driver behavior data and WVC reports were collected through the integrated Wildlife Report of MUKA portal, which served as both the questionnaire interface and the wildlife reporting mechanism. Respondents were recruited through an open, census-style approach: a Google Form link to the questionnaire was distributed via the university's pooled email system, which sends announcements to all staff, students, and residents registered on the official campus mailing list. This ensured that every individual who regularly drives on campus had equal opportunity to participate, making the selection process transparent and fully repeatable. Participation was voluntary, restricted to adults aged 18 years or older, and fully anonymous. A total of 85 valid questionnaire responses were obtained (≈10.6% of the campus population), a rate appropriate for exploratory cross-sectional studies and non-parametric analyses.

The questionnaire consisted of four sections: (i) demographic information; (ii) driving behavior, including vehicle type, travel routes, and time-of-day patterns; (iii) reactions to wildlife encounters measured on a 5-point Likert scale (1: strongly disagree to 5: strongly agree); and (iv) preferences for WVC mitigation strategies such as signage, lighting, and speed control. Likert-scale responses were analyzed using descriptive statistics, including frequency distributions and percentage agreement.

The same platform also enabled users to report roadkill encountered during routine travel. Each submission required a photograph and location, and no personal identifiers were collected. Species identifications were verified using regional field guides (Francis and Barrett 2008; Napitaphat et al. 2018; Niyomwan et al. 2019). These opportunistic submissions complemented the systematic surveys by documenting carcasses in areas and at times not covered by scheduled walking passes. Combined with systematic field-survey data, the final dataset comprised 170 carcasses from 31 species, including 109 reptiles, 55 amphibians, 2 birds, and 4 mammals.

Ethical considerations

Because the study involved anonymous, minimal-risk questionnaire and reporting activities, formal ethics approval was not required under Mahidol University's policy for low-risk research. Participants provided electronic informed consent, could skip questions or withdraw at any time, and all procedures adhered to institutional human-subject research guidelines and the principles of the Declaration of Helsinki relevant to survey-based studies.

Table 1. Characteristics of surveyed routes at Mahidol University Kanchanaburi Campus, Western Thailand

Route	Length (km)	Surface	Traffic (vehicles/day)	Speed limit (km/h)	Adjacent habitats	Notable features
A	1.3	Paved (asphalt)	Low (<50)	None posted	Mixed deciduous forest, bamboo	Minimal human structures
B	1.5	Paved (asphalt)	Moderate (50-200)	40	Forest edges, agricultural plots	Proximity to ponds (water sources)
C	1.5	Paved (asphalt)	Low (<50)	30	Forest edges, institutional buildings	Artificial lighting near labs
D	1.6	Paved (asphalt)	Very low (<20)	None posted	Natural forest, dormitories	Steep slopes, sharp curves, Proximity to small water concrete wells

Mapping and WVC rate

Roadkill was mapped in ArcMap 10.4.1. Wildlife-Vehicle Collision (WVC) rates per route were computed as:

$$\text{WVC rate} = \frac{\text{Number of carcasses}}{(\text{Distance surveyed} \times \text{Days})}$$

Statistical analyses and hypothesis testing

Daily carcass counts were discrete and non-normal (Shapiro-Wilk; Levene tests, $p<0.05$), so non-parametric tests were used.

To examine route-level differences in wildlife-vehicle collision (WVC) frequency, we used a Kruskal-Wallis test (n: 80 route-days; df: 3). H_0: Roadkill frequency does not differ among Routes A-D, H_1: At least one route has a different roadkill frequency.

To assess whether traffic rhythm influenced carcass counts, we applied a Mann-Whitney U test, comparing survey days that occurred during the teaching period (regular semester weeks when classes were in session; n_2: 16) with those during the non-teaching period (university break months with no scheduled classes; n_1: 6). H_0: Roadkill frequency does not differ between the non-teaching period and the teaching period, H_1: Roadkill frequency differs between the non-teaching period and the teaching period.

To evaluate the influence of distance to water on taxonomic composition, we used a chi-square test of independence on 121 records arranged in a 3×3 table (df: 4). H_0: Taxonomic composition is independent of distance to water, H_1: Taxonomic composition varies with distance to water.

To test whether time of day structured taxonomic composition, we conducted a chi-square test using a 3×2 contingency table (n: 121; df: 2). "Day" referred to animals found as roadkill during the day or detected during the late-afternoon survey, whereas "night" referred to animals presumed to have been hit during nighttime hours or found during the early-morning survey. H_0: Taxonomic composition is independent of time of day, H_1: Taxonomic composition differs between day and night.

To examine seasonal patterns, we performed a chi-square test on a 3×3 table representing cool (November-February), hot (March-May), and rainy seasons (June-October) (df: 4). H_0: Taxonomic composition is independent of season. H_1: Taxonomic composition differs among seasons.

Independence of observations was ensured through immediate carcass removal, non-overlapping passes, and standardized twice-daily surveys, which minimized temporal autocorrelation (Guinard et al. 2015). All analyses were two-tailed (α: 0.05) and performed in R version 4.5.0.

RESULTS AND DISCUSSION

Results

Species diversity and abundance of wildlife roadkill

Across the 31 species documented (Table 2), reptiles and amphibians overwhelmingly dominated campus roadkill, together accounting for 164 of 170 carcasses (96%). Amphibians (Order Anura; 55 individuals) were concentrated mainly along pond-adjacent segments of Route B and forest edges on Routes C and D, with common Asian toad (27) and northern tree frog (20) being the most frequently recorded. Reptiles (Order Squamata; 109 individuals) were broadly distributed across mixed forest edges, limestone slopes, and built-up areas, led by mountain bronzeback (16), oriental garden lizard (14), and tokay gecko (12). Notably, three Thai micro-endemic reptiles—Jarujin's two-legged skink (*J. bipedalis*; 3), Nutaphand's red-eyed gecko (*G. nutaphandi*; 3), and *Dixonius hangseesom* (1)—occurred along forest-pond interface habitats on Routes B-D, underscoring their conservation sensitivity despite low absolute counts. Mammals (4) and birds (2) were rare and restricted to forest-edge habitats. Representative species, including *Polypedates megacephalus*, *Calotes versicolor*, *J. bipedalis*, and *G. nutaphandi*, are shown in Figure 2 to support identification confidence and highlight the conservation relevance of these taxa within the campus network. This habitat-linked summary provides the basis for subsequent analyses of route-level and ecological correlates of roadkill patterns.

Variations in wildlife roadkill across four survey routes

The distribution of roadkill incidents differed significantly among routes, as confirmed by a Kruskal-Wallis test using 20 sampling occasions per route (H: 22.94, df: 3, p: 0.0000424). Median counts reflected a strong spatial gradient (Route A: 0, Route B: 3, Route C: 1, Route D: 2), with Route B recording the highest number of incidents (66; ~56%), followed by Route D (32; ~27%), Route C (19; ~16%), and Route A (1; ~1%) (Figure 3). Species composition also varied along this gradient: Route B was dominated by amphibians and reptiles (e.g., the northern tree frog and the oriental garden lizard); Route C had a higher proportion of arboreal snakes (e.g., the golden tree snake *Chrysopelea ornata*) and the only bird records; and Route D was led by the common Asian toad (*Duttaphrynus melanostictus*). Roadkill frequencies between non-teaching and teaching periods likewise differed significantly, with the teaching semester showing higher median counts (median: 4.0 vs. 1.0), as indicated by the Mann-Whitney U test (U: 16.50, p: 0.0215).

Environmental correlates of roadkill

Distance to water (Figure 4.A). Taxonomic composition showed no significant association with distance to the nearest water source (χ^2: 2.47, df: 4, p: 0.650). Roadkill incidents were most frequently recorded within 0-200 m of water, where amphibians accounted for 25 of 42 observations (59.5%) and reptiles for 40 of 73 observations (54.8%). Counts declined at 200-400 m (amphibians: 11, reptiles: 15) and at >400 m (amphibians: 6, reptiles: 18). Records of birds and mammals were scarce (n: 3), with one observation in each distance category.

Time of day (Figure 4.B). No association was detected between taxonomic composition and time of day (χ^2: 3.24, df: 2, p: 0.197). Across all groups, roadkill incidents occurred more frequently at night: amphibians (36/42; 85.7%), reptiles (52/73; 71.2%), and birds/mammals (2/3; 66.7%). Daytime counts were comparatively lower (amphibians: 6, reptiles: 21, birds/mammals: 1).

Season (Figure 4.C). Taxonomic composition also showed no significant seasonal association (χ^2: 5.62, df: 4, p: 0.230). However, overall counts were highest during the rainy season, when amphibians represented 81.0% of their annual observations and reptiles 64.4%.

Driver behavior, attitudes, and factors influencing wildlife roadkill

The survey included university personnel (38.4%), students (59.3%), and other campus members such as vendors and research assistants (2.4%). Students represented a broad range of academic programs, with the largest groups from Conservation Biology (29.4%) and Geoscience (23.5%), and were primarily in Year 3 (43.1%) or Year 2 (29.4%). Among respondents who reported their mode of transport, motorcycles were the most common (58%), followed by passenger cars (37%), with only a small number using four-wheel trucks/vans (4%) or the campus tram (1%). Driving speeds varied by vehicle type: motorcycle riders most frequently traveled at 30-40 km/h, while car drivers were distributed across 30-40 km/h and 41-50 km/h. Route-use patterns showed that Route B had the highest daily usage (64%), whereas Route A was rarely used, with 61% of respondents reporting they never used it.

Figure 2. Representative wildlife species found as roadkill on Mahidol University Kanchanaburi Campus, Western Thailand: A. The northern tree frog (*Polypedates megacephalus*), representative amphibian; B. The oriental garden lizard (*Calotes versicolor*), representative reptile; C. Jarujin's two-legged skink (*Jarujinia bipedalis*), a reptile species endemic to Western Thailand; D. Nutaphand's red-eyed gecko (*Gekko nutaphandi*), a reptile species endemic to Western Thailand

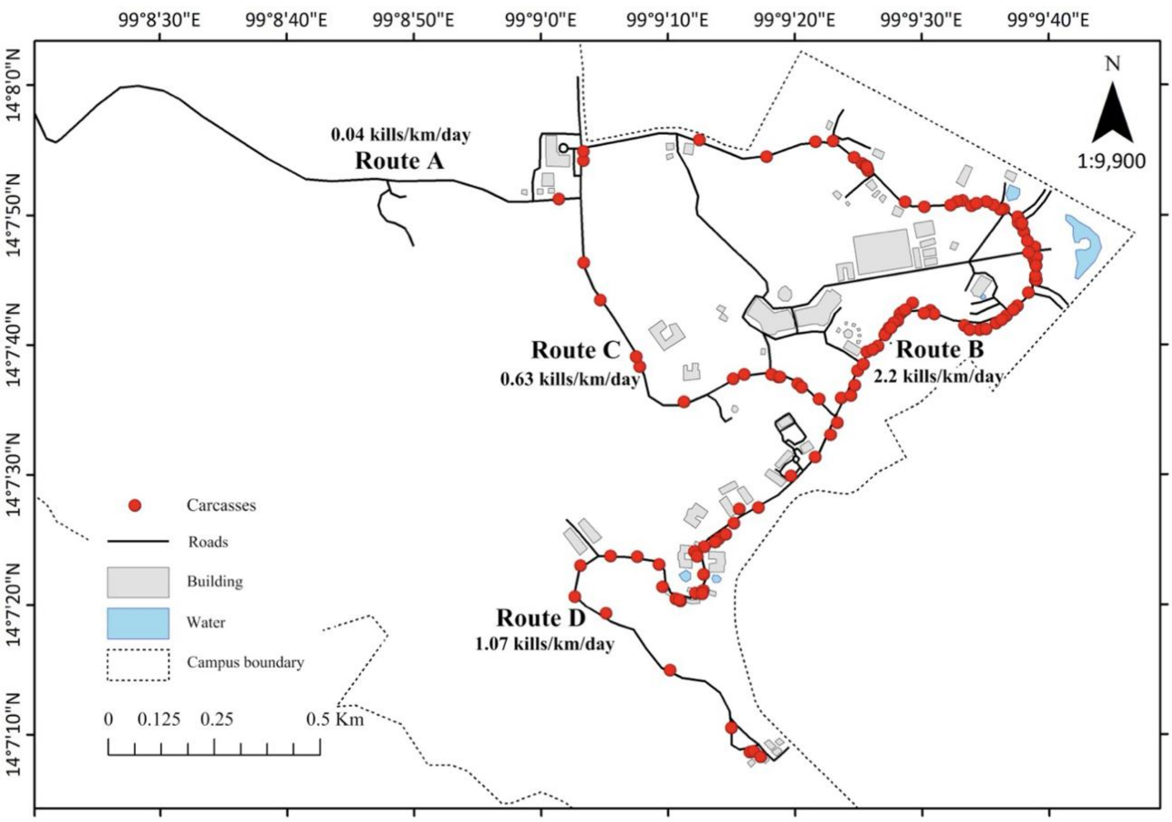

Figure 3. Spatial distribution of roadkill incidents across four routes on Mahidol University Kanchanaburi Campus, Western Thailand

Table 2. Summary of roadkill incidents on Mahidol University Kanchanaburi Campus, Western Thailand (August 2022-July 2023)

Order	Family	Scientific name	Common name	International Union for Conservation of Nature (IUCN) status	Counts of roadkills			Remarks
					Direct count from each route i.e., A, B, C, and D	Count from public report	Total count (% of total)	
Amphibian								
Anura	Dicroglossidae	*Fejervarya limnocharis*	Asian grass frog	LC	B(1)	0	1 (0.59)	
	Microhylidae	*Kaloula pulchra*	Asian painted frog	LC	B(2), C(1), D(2)	1	6 (2.96)	
	Bufonidae	*Duttaphrynus melanostictus*	Common Asian toad	LC	B(6), C(1), D(10)	10	27 (15.88)	
	Rhacophoridae	*Polypedates megacephalus*	Northern tree frog	LC	B(13), C(1), D(3)	3	20 (11.76)	
		Polypedates sp.	Tree frog		B(1)	0	1 (0.59)	
Total							**55 (32%)**	
Reptile								
Squamata	Agamidae	*Calotes mystaceus*	Blue-crested lizard	LC	B(2), C(1)	2	5 (2.94)	
		Calotes versicolor	Oriental garden lizard	LC	B(10), C(1), D(2)	1	14 (8.24)	
		Calotes sp.	Lizard		B(2)	0	2 (1.18)	
	Pareidae	*Pareas carinatus*	Keeled slug-eating snake	LC	A(1), B(1), C(2)	1	5 (2.94)	
		Pareas margaritophorus	White-spotted slug snake	LC	B(2)	0	2 (1.18)	
	Colubridae	*Coelognathus radiatus*	Copperhead rat snake	LC	B(2)	1	3 (1.76)	
		Chrysopelea ornata	Golden tree snake	LC	B(1), C(3), D(2)	3	9 (5.29)	
		*Lycodon capucinus**	Common wolf snake	LC		2	2 (1.18)	
		Oligodon taeniatus	Striped Kukri snake	LC	B(1), D(1)	7	9 (5.29)	
		Oligodon fasciolatus	Small-banded Kukri snake	LC	B(2), C(1), D(1)	0	4 (2.35)	
		Ahaetulla fusca	Indochinese long-nosed whip snake	LC	B(1)	0	1 (0.59)	
		Ahaetulla prasina	Green vine snake	LC	B(3)	1	4 (2.35)	
		Dendrelaphis subocularis	Mountain bronzeback	LC	B(6), D(1)	9	16 (9.41)	
		Ptyas mucosa	Oriental rat snake	LC	C(1)	1	2 (1.18)	
		*Ptyas korros**	Indo-Chinese rat snake	LC		1	1 (0.59)	
	Scincidae	*Jarujinia bipedalis*[#]	Jarujin's two-legged skink	LC	B(1), C(1), D(1)	0	3 (1.76)	Endemic to Thailand
		Lygosoma quadrupes	Short-limbed supple skink	LC	B(1)	0	1 (0.59)	
		Mabuya macularia (now *Eutropis macularia*)	Variable skink	NE	B(1)	1	1 (0.59)	
	Elapidae	*Naja kaouthia*	Monocellate/ monocled cobra	LC	D(1)	1	2 (1.18)	
		Calliophis maculiceps	Speckled coralsnake	LC	C(1)	0	1 (0.59)	
	Gekkonidae	*Dixonius hangseesom*[#]	Orange-tailed leaf-toed gecko	LC	C(1)	0	1 (0.59)	Endemic to Thailand
		Hemidactylus sp.	House gecko		B(3), D(1)	1	4 (2.35)	
		Gekko gecko	Tokay gecko	LC	B(2), C(1), D(4)	5	12 (7.06)	
		Gekko nutaphandi[#]	Nutaphand's red-eyed gecko	LC	C(1), D(2)	0	3 (1.76)	Endemic to Thailand
		Gekko sp.	Gekko		B(2)	0	2 (1.18)	
Total							**109 (64%)**	

Aves							
Passeriformes	Muscicapidae	*Muscicapa dauurica*	Asian brown flycatcher	LC		1	1 (0.59)
	Pycnonotidae	*Pycnonotus aurigaster*	Sooty-headed bulbul	LC	C(1)	0	1 (0.59)
Total							**2 (1%)**
Mammals							
Rodentia	Sciuromorpha	*Tamiops mcclellandii*	Burmese striped tree squirrel	LC	D(1)	0	1 (0.59)
		*Callosciurus caniceps**	Grey-bellied squirrel	LC		1	1 (0.59)
	Muridae	*Rattus* sp.	Rat		C(1)	0	1 (0.59)
Chiroptera	Vespertilionidae	*Myotis muricola**	Wall-roosting mouse-eared bat	LC		1	1 (0.59)
Total							**4 (3%)**
Grand total							**170 (100%)**

Note: *: The data come from reports within the campus, outside the surveyed routes. #: Endemic species of Western Thailand. IUCN Status: LC: Least Concern, NE: Not Evaluated. (1)-(4): The number of counts of roadkills

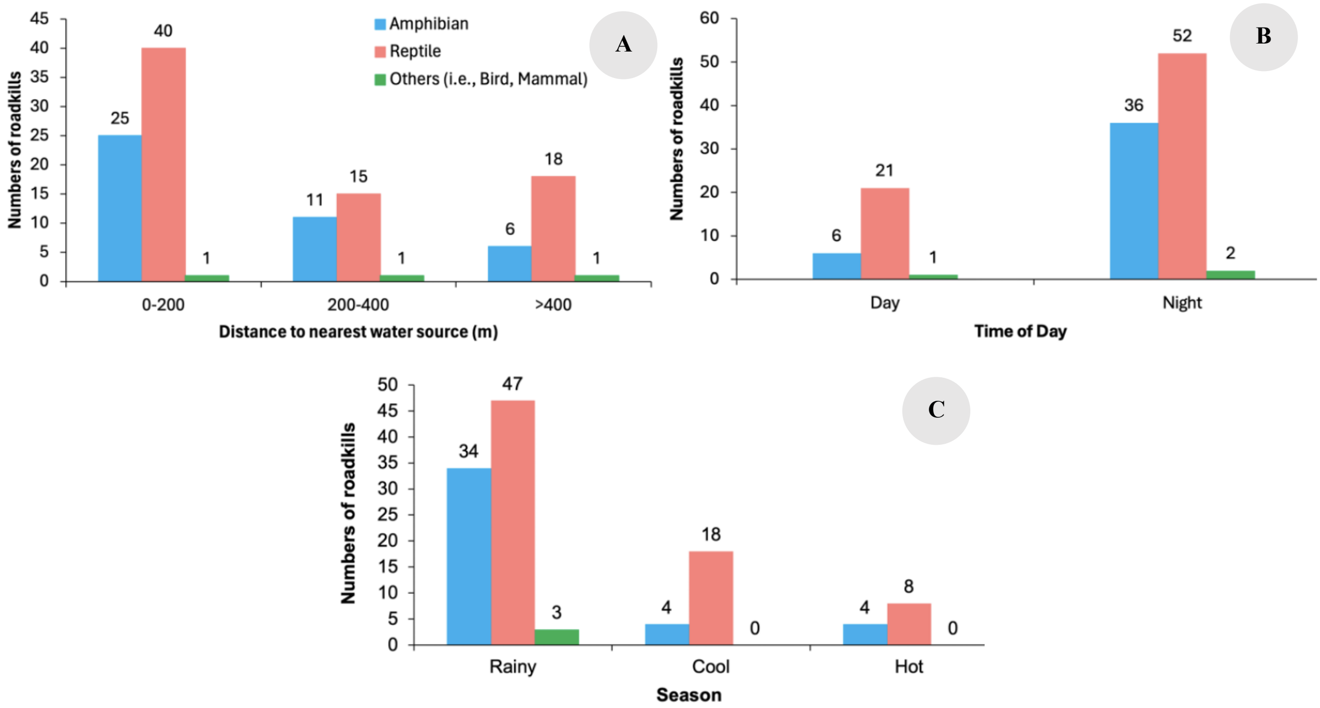

Figure 4. Patterns of roadkill incidents across ecological factors: A. Taxon-specific counts by distance to water, B. Time-of-day variation (day vs. night), C. Seasonal distribution (rainy, cool, and hot seasons)

Wildlife-encounter simulations revealed marked differences among vertebrate groups. Drivers were more protective toward mammals, with ≥61% slowing or stopping for squirrels and monkeys, and ≥34% stopping for large mammals such as wild boar (*Sus scrofa*). In contrast, responses toward small herpetofauna were less cautious, 50% swerved for frogs and only 38% slowed for snakes, mirroring the empirical mortality skew observed on campus. Likert-scale assessments identified darkness as the leading physical factor contributing to roadkill (67.79% strongly agree; Figure 5.A), followed by curved or steep roads (44.52%; Figure 5.B) and adverse weather (27.32%; Figure 5.C). Driving speed was recognized as the dominant human factor (66.78% strongly agree; Figure 5.D). Respondents also acknowledged risky animal behaviors (71.84% agree/strongly agree; Figure 5.E), and 49.58% agreed or strongly agreed that slow-moving animals are particularly vulnerable to roadkill (Figure 5.F). Most drivers reported exercising caution (74% strongly agree) and expressed willingness to adopt safer practices to reduce wildlife mortality (78% strongly agree). Support for mitigation measures was high across all proposed interventions, including speed control (67% strongly agree), wildlife-crossing signage (59% strongly agree), awareness campaigns (60% strongly agree), and improved roadside lighting (79% strongly agree). These perceptions correspond with the spatial hotspot on Route B and the nocturnal and rainy-season clustering of roadkill events (Figures 3 and 4.B-C), supporting targeted interventions such as icon-based frog and snake signage before pond-adjacent bends, night- or monsoon-specific speed caps, and wildlife-sensitive lighting at high-risk sections

Discussion

Our findings demonstrate that WVCs on the MUKA are strongly structured by spatial variation in the road network, with a concentrated hotspot on Route B where roads intersect ponds and forest edges. This segment produced a disproportionately high number of incidents (Kruskal-Wallis, H: 22.94, df: 3, $p<0.0000424$), underscoring how habitat interfaces create short, high-risk zones for small herpetofauna. Framing the campus network, especially Route B and adjacent pond margins, within an OECM (Other Effective Area-Based Conservation Measures) lens helps clarify both mechanism and management: a managed, non-protected area in which targeted, evidence-informed interventions may yield measurable biodiversity outcomes. This perspective enables us to (i) diagnose the ecological drivers of hotspot formation, (ii) interpret species-specific vulnerability, including the repeated occurrence of Thai endemics, (iii) evaluate temporal patterns that, although not statistically shifting taxonomic composition, remain ecologically instructive given the clustering of incidents within 200 m of water, at night, and during the rainy season, and (iv) integrate driver behavior to help prioritize feasible, behavior-informed mitigation strategies. These patterns align with established mechanisms in tropical road ecology, where breeding migrations, nocturnal activity, thermoregulatory movements, and reduced nighttime driver detectability elevate collision risk.

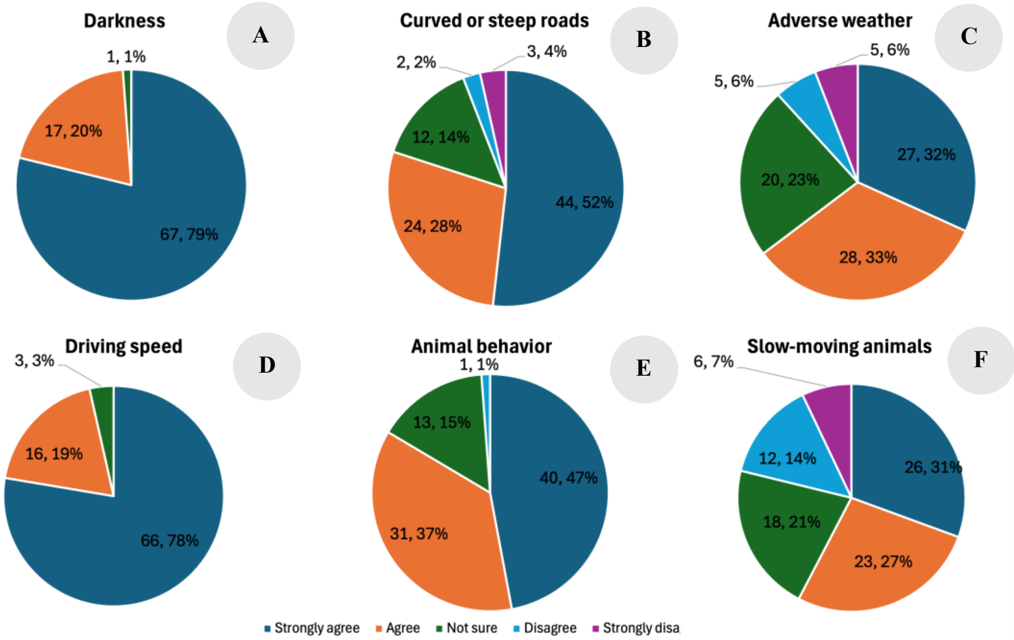

Figure 5. Driver perceptions of factors contributing to WVCs on Mahidol University Kanchanaburi Campus, Western Thailand: A. Darkness, B. Curved or steep roads, C. Adverse weather, D. Driving speed, E: Risky animal behavior, F. Vulnerability of slow-moving animals. For each pie segment, the first value represents the number of respondents, followed by its corresponding percentage of the total sample (n: 85)

Species-specific patterns

Reptiles and amphibians dominated our dataset, consistent with tropical road-ecology patterns (Andrews et al. 2006; Helldin and Petrovan 2019; Kouris et al. 2024). Their elevated vulnerability likely reflects small body size and low driver detectability, nocturnal/crepuscular activity, and rainy-season movements, with additional exposure from using warm road surfaces for thermoregulation (Morelli et al. 2024); these mechanisms are supported by our counts, with herpetofauna comprising the vast majority of carcasses and mortality peaking during the wet season. Conservation concern is heightened by two Thai endemics—Jarujin's two-legged skink (*J. bipedalis*) and Nutaphand's red-eyed gecko (*G. nutaphandi*)—whose micro-endemic distributions mean that even a handful of roadkills may have population-level consequences; *J. bipedalis* is a fossorial skink with specialized morphology (Greer 1997; Chan-ard et al. 2011), while *G. nutaphandi* is restricted to limestone caves (Bauer et al. 2008).

In practical terms, several mitigation measures shown to be effective in comparable systems could be considered for pond-adjacent segments on the campus. Amphibian-scale micro-culverts paired with drift fencing have demonstrated measurable reductions in amphibian and small-reptile mortality and improved crossing success (Helldin and Petrovan 2019). Nighttime speed reductions during the monsoon have been associated with declines in herpetofaunal roadkill in low-speed networks (Anđelković and Bogdanović 2022). Such measures may be most effective when paired with ongoing monitoring to verify performance and refine placement over time (Zevgolis et al. 2023).

These features (water adjacency, edges, moderate traffic) match hotspot mechanisms reported elsewhere; our campus evidence extends these patterns to short internal road segments, showing that localized high-risk road sections can drive campus-scale mortality, an under-reported setting in the tropics. Relative to studies on highways, the emergence of a hotspot under lower travel speeds suggests that detection distance and driver attention may be at least as influential as speed itself in campus contexts.

Spatial hotspots

Route B emerged as the primary hotspot, driven by its close intersection with ponds, forest edges, and adjacent agricultural patches, ecological features that concentrate animal movements even under moderate traffic levels. While broader road-ecology studies note that hotspots often form where habitat interfaces meet road networks (Lin 2016; Meza-Joya et al. 2019; Sukhontapatipak et al. 2025), our findings extend this pattern to short internal campus roads, highlighting that short, high-risk road segments can generate substantial wildlife mortality in localized settings. Evidence-based mitigation options (including reduced nighttime speed limits, speed bumps, and targeted warning signage) have been shown to reduce roadkill by up to 40% when appropriately deployed (Rytwinski et al. 2016). More intensive measures, such as fencing and small underpasses, may be considered where micro-endemic species occur, although feasibility and scale must match the campus context.

Environmental correlations

Although proximity to water, time of day, and seasonality did not show statistically significant associations with taxonomic composition, the ecological patterns underlying these variables remain informative rather than merely descriptive. Amphibians were most frequently recorded near water and during the rainy season, a pattern consistent with breeding migrations and moisture dependence (Ochoa-Ochoa and Whittaker 2014). Reptiles occurred across habitats and seasons but showed higher nighttime detections, which aligns with reduced driver visibility and their broader thermal tolerances (Roth-Monzón et al. 2018). These clustering tendencies, near water, at night, and during the monsoon, highlight periods where movement behavior and detectability interact to elevate collision risk, even in the absence of compositional differences. While these patterns are not conclusive, they provide ecologically grounded hypotheses for future research rather than definitive conclusions. Multi-year datasets and larger sample sizes would help determine whether the tendencies observed here represent consistent ecological signals or reflect sampling variation.

Driver behavior

Drivers reported markedly less caution toward amphibians and small reptiles than toward mammals, indicating a potential size-based perception bias that qualitatively aligns with the dominance of herpetofauna in our carcass records. Because self-reported behavior is subject to social desirability effects, with respondents potentially overstating their cautiousness or pro-conservation tendencies, these patterns should be interpreted cautiously. Although we did not conduct a formal correlation test between driver perceptions and taxon-level mortality, the discrepancy between stated caution and the overrepresentation of small-bodied taxa in carcass records suggests, rather than confirms, that detection-related factors such as visibility, perceived risk, and the cryptic nature of small species contribute to higher mortality. This perception-risk mismatch implies that generic “wildlife” signage may have limited impact. Instead, icon-based warnings featuring frogs or snakes placed before pond-adjacent bends on Route B, combined with monsoon- and night-specific speed reductions, may provide more taxon-relevant interventions. While many respondents supported mitigation measures such as signage, lighting, and speed control, their effectiveness depends on context-specific deployment; for example, additional lighting may improve driver visibility but can also disrupt nocturnal wildlife (Falcón et al. 2020). Wildlife-sensitive lighting may therefore be suitable only at segments with demonstrated risk, complemented by speed management in other high-use areas. Tailoring educational materials and signage to highlight small, cryptic taxa (rather than relying solely on general “wildlife” warnings) may further enhance driver awareness at hotspot locations. Encouragingly, despite the possibility of socially desirable responding, the strong pro-conservation attitudes reported by drivers provide a feasible foundation for behavior-informed, community-based roadkill reduction initiatives.

Limitations

This study spans a single year, and multi-year monitoring would strengthen our ability to detect interannual variability in roadkill patterns. Community reports may introduce reporting bias due to uneven observer presence along paths and residential areas, and carcass persistence likely varies with weather and traffic intensity, affecting detectability. Although immediate carcass removal minimized double counts, it does not eliminate imperfect detection or the possibility that heavy rain, nocturnal scavenging, or high-traffic periods reduced carcass visibility. Sample sizes for birds and mammals were small, limiting inference for these groups. We also lacked direct measurements of traffic speed, lighting conditions, and micro-weather variation, all of which would help refine mechanistic interpretations. Future work would benefit from applying standardized correction factors for detection probability (such as persistence trials, timed repeat surveys, or hierarchical models) to more accurately estimate true mortality. These limitations do not alter the identification of a clear hotspot on Route B, but they shape how interventions and monitoring should be prioritized moving forward.

Implications for conservation and campus management

Building on the OECM framing introduced above, our results support applying an OECM designation to the Route B corridor and its adjacent pond-edge habitats, an approach well suited to a managed but non-protected area where targeted interventions can meaningfully reduce wildlife-vehicle collisions. Within this framework, practical measures such as time-bound speed limits, amphibian-scale micro-culverts with drift fencing, and taxon-specific icon signage offer feasible, campus-ready tools to mitigate herpetofauna mortality while fitting within existing governance structures. Positioning Route B as an OECM also enables biodiversity-sensitive infrastructure planning without altering land tenure or primary use (Welegerima et al. 2016), while maintaining alignment with broader biodiversity commitments such as Aichi Target 11 and the Kunming-Montreal Global Biodiversity Framework (Bennett 2017).

At the local scale, these core measures may be complemented by seasonal actions (such as temporary speed reductions during peak amphibian activity in the rainy season) and by deploying wildlife-sensitive lighting only where risk assessments justify illumination. Endemic species like *J. bipedalis* and *G. nutaphandi* also warrant attention through safeguarding limestone features and installing culverts near water bodies to facilitate safe movements.

Equally important is fostering behavioral change among road users. Targeted awareness campaigns, taxon-relevant signage, and community workshops that highlight endemic species and high-risk periods can improve driver decisions at hotspot approaches. Citizen-science involvement can expand monitoring capacity and embed conservation values within daily campus life. Over time, enhancing habitat protection, potentially through small, designated natural areas, could strengthen ecological connectivity and support research and teaching. By integrating roadkill mitigation, habitat management, and OECM principles into a coherent campus strategy, MUKA can serve as a practical model for biodiversity-sensitive infrastructure planning within tropical university landscapes.

In conclusion, this study demonstrates that wildlife-vehicle collisions at Mahidol University Kanchanaburi Campus are concentrated among reptiles and amphibians, with a pronounced hotspot on Route B near ponds and forest edges. Roadkill incidents peak at night and during the rainy season, and driver surveys reveal a perceptual bias (greater caution toward large mammals than toward small herpetofauna) mirroring the observed mortality pattern. The presence of Thai endemics such as *J. bipedalis* and *G. nutaphandi* underscores the conservation urgency, as even limited losses can affect population viability. Building on these empirical results, targeted measures (nighttime and monsoon speed management, frog and snake icon signage, and amphibian-scale culverts with drift fencing) may help reduce mortality in high-risk segments. Wildlife-sensitive lighting can be used selectively where visibility gains outweigh ecological costs. Integrating these actions into campus planning, including an OECM-oriented approach for the Route B corridor, highlights the campus's potential to serve as a practical model for biodiversity-sensitive road management in tropical university settings.

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Table S1. The full list of roadkill survey results comprises 170 occurrences in the Mahidol University Kanchanaburi Campus, Western Thailand, gathered through direct surveys and online public reports

Taxon/family (Total counts)	Common name, scientific name	Method of collection	Observed route				Total carcasses	IUCN Red List	Thailand Red Data List
			A	B	C	D			
Amphibian (55)									
Dicroglossidae	Asian grass frog, *Fejervarya limnocharis*	D		1			1	LC	LC
Microhylidae	Asian painted frog, *Kaloula pulchra*	D, P		2	1	2	6	LC	LC
Bufonidae	Common Asian toad, *Duttaphrynus melanostictus*	D, P		6	1	10	27	LC	LC
Rhacophoridae	Northern tree frog, *Polypedates megacephalus*	D, P		13	1	3	20	LC	LC
	Tree frog, *Polypedates* sp.	D		1			1		
Reptile (109)									
Agamidae	Blue-crested lizard, *Calotes mystaceus*	D, P		2	1		5	LC	LC
	Oriental garden lizard, *Calotes versicolor*	D, P		10	1	2	14	LC	LC
	Lizard, *Calotes* sp.	D		2			2		
Pareidae	Keeled slug snake, *Pareas carinatus*	D, P	1	1	2		5	LC	LC
	White-spotted slug snake, *Pareas margaritophorus*	D		2			2	LC	LC
Colubridae	Copperhead racer snake, *Coelognathus radiatus*	D, P		2			3	LC	LC
	Golden tree snake, *Chrysopelea ornata*	D, P		1	3	2	9	LC	LC
	Common wolf snake, *Lycodon capucinus**	P					2	LC	LC
	Striped Kukri snake, *Oligodon taeniatus*	D, P		1		1	9	LC	LC
	Banded Kukri snake, *Oligodon fasciolatus*	D, P		2	1	1	4	LC	LC
	Indochinese long-nosed whip snake, *Ahaetulla fusca*	D		1			1	LC	LC
	Green vine snake, *Ahaetulla prasina*	D, P		3			4	LC	LC
	Mountain bronzeback, *Dendrelaphis subocularis*	D, P		6		1	16	LC	LC
	Oriental rat snake, *Ptyas mucosa*	D, P			1		2	LC	LC
	Indo-Chinese rat snake, *Ptyas korros**	P					1	LC	LC
Scincidae	Jarujin's two-legged skink, *Jarujinia bipedalis*[#]	D		1	1	1	3	LC	VU
	Short-limbed supple skink, *Lygosoma quadrupes*	D		1			1	LC	LC
	Variable skink, *Mabuya macularia*	D		1			1	NE	LC
Elapidae	Monocellate/ monocled cobra, *Naja kaouthia*	D, P				1	2	LC	LC
	Speckled coralsnake, *Calliophis maculiceps*	D			1		1	LC	LC
Gekkonidae	Orange-tailed leaf-toed gecko, *Dixonius hangseesom*[#]	D			1		1	LC	LC
	House gecko, *Hemidactylus* sp.	D		3		1	4		
	Tokay gecko *Gekko gecko*	D, P		2	1	4	12	LC	LC
	Nutaphand's red-eyed gecko, *Gekko nutaphandi*[#]	D			1	2	3	LC	VU
	Gekko, *Gekko* sp.	D		2			2		
Aves (2)									
Muscicapidae	Asian brown flycatcher, *Muscicapa dauurica*	P					1	LC	LC
Pycnonotidae	Sooty-headed bulbul, *Pycnonotus aurigaster*	D			1		1	LC	LC
Mammal (4)									
Sciuromorpha	Burmese striped tree squirrel, *Tamiops mcclellandii*	D				1	1	LC	LC

	Grey-bellied squirrel, *Callosciurus caniceps**	P					1	LC	LC
Muridae	Rat, *Rattus* sp.	D			1		1		
Vespertilionidae	Wall-roosting mouse-eared bat, *Myotis muricola**	P					1	LC	LC
	Total		**1**	**66**	**19**	**32**	**170**		

Note: *: The data come from reports within the campus, outside the surveyed routes; #: Endemic species of Western Thailand; IUCN Red List and Thailand Red Data List: Vulnerable (VU), Least Concern (LC), Data Deficient (DD); Method of collection: D: Direct survey, P: Public report