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Documentation of a road-killed spectral bat (*Vampyrum spectrum*) and first report of the species in Tabasco, México

Documentación de un murciélago espectral (*Vampyrum spectrum*) atropellado en carretera y primer reporte de la especie en Tabasco, México

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Roads are human infrastructures with adverse effects on wildlife; in the case of mammals, bats are rarely mentioned as road-killed animals. This work describes the record of a road-killed spectral bat (*Vampyrum spectrum*) on the El Bellote–Santa Cruz section of the 180 highway in Paraiso, Tabasco, México, the first report of the species in the state. The spectral bat is the largest bat species in the Americas, considered locally rare. The finding was recorded in 2015 during a wildlife mortality sampling tour. The specimen was collected and deposited in the National Mammals Collection of Universidad Nacional Autónoma de México. The corpse of a bird (Tyrannidae) was also found during the sampling trip. This is the first documented record of a road-killed spectral bat. The unique flight characteristics of the spectral bat, such as flying near obstacles and at ground level, make it vulnerable to vehicles and collisions. Mitigation measures should be applied to reduce the risk of collision for this species in particular and all bats in general.

Key words: Bats; mammals; road ecology; roadkill.

Las carreteras son infraestructuras humanas con efectos negativos para la fauna silvestre; en el caso de los mamíferos, los murciélagos pocas veces se mencionan como víctimas de atropellos. En este trabajo, se presenta el registro de un murciélago espectral (*Vampyrum spectrum*) atropellado en la carretera 180 del Tramo El Bellote-Santa Cruz, Paraíso, Tabasco, México, representando el primer reporte de esta especie en el estado. El murciélago espectral es el más grande del Continente Americano, el cual es considerado como una especie localmente rara. El hallazgo ocurrió en 2015 durante un recorrido de un muestreo de mortandad de fauna silvestre. El ejemplar fue recolectado e incorporado a la Colección Nacional de Mamíferos de la Universidad Nacional Autónoma de México. Al momento de la colecta se encontró también el cuerpo de un ave (Tyrannidae). El presente registro corresponde al primero de atropellamiento de murciélago espectral del que se tenga documentación. Las características particulares de vuelo del murciélago espectral de volar cerca de obstáculos y a ras del suelo, lo hace vulnerable a los vehículos y a las colisiones. Es necesario tomar medidas de mitigación que disminuyan los riesgos de colisión para esta especie y murciélagos en general.

Palabras clave: Atropello; ecología de carreteras; mamíferos; murciélagos.

Roads are the type of anthropic infrastructure with the most adverse effects on wildlife, mainly from collisions with vehicles and the impact of roads on habitat loss, fragmentation, and alteration (van der Ree *et al.* 2011; van der Ree *et al.* 2015; Schwartz *et al.* 2020; Benítez *et al.* 2021). Roadkills account for 6.25 % of vertebrate mortality (Hill *et al.* 2019), with large mammals as the most recorded and vulnerable taxa, followed by birds, amphibians, and reptiles (Rytwinski and Fahrig 2012; Silva *et al.* 2021).

Mammals are a group of great concern because of their vulnerability to local extinction due to roadkills (Grilo *et al.* 2021) and the human and economic costs of these accidents (Ascensão *et al.* 2021). The impact of roads on wild mammals has been focused mainly on ungulates, large carnivores, and small non-flying mammals (Novaes *et al.* 2018; Pinto *et al.* 2020).

Bats are rarely detected in roadkill studies compared to birds and amphibians (Berthinussen and Altringham 2012; Medinas *et al.* 2019; de Figueiredo Ramalho *et al.* 2021a; de Figueiredo Ramalho *et al.* 2021b). This group of mammals is vulnerable to roadkills due to the barrier effect limiting their displacement from one site to another.

Despite its low detectability and scarce documentation, they are assumed to be at high risk of collision with motor vehicles given their flight habits by preferring to forage in the linear elements of the landscape (Bennett and Zurcher 2013; Claireau *et al.* 2021). They go unnoticed due to their small size, their ability to hide out among the vegetation, rapid decomposition of the corpse, and predation by scavengers (Russell *et al.* 2009; Teixeira *et al.* 2013; Altringham and Kerth 2016; Delgado *et al.* 2019). Since bats are less frequently detected than most vertebrates in road studies, collisions with vehicles might be an important cause of bat mortality (Lesiński *et al.* 2011).

The spectral bat (*Vampyrum spectrum*) is the largest bat species in the Americas, with a wingspan from 101 to 110 cm and a weight of approximately 180 gr (Navarro and Wilson 1982; Gardner 2008). It belongs to the family Phyllostomidae and is an apex predator with a wide home range and small scattered populations (Timm *et al.* 1989; Ceballos and Oliva 2005). This species inhabits caves or tree cavities and lives as solitary individuals or in family groups of about 5 members (Solari *et al.* 2019).

The spectral bat has a wide distribution in the Neotropical region, from Veracruz in México to Brazil, Perú, and Bolivia (Hall 1981; Medellín *et al.* 2008; Solari *et al.* 2019). This species has been found in tropical forests and secondary and riparian vegetation (Vehrencamp *et al.* 1977; Solari *et al.* 2019), and recorded in elevations from 4 m to 1,600 m (Timm *et al.* 1989; LaVal and Rodríguez 2002).

Vampyrum spectrum is a carnivorous bat (Gual-Suárez and Medellín 2021) that consumes rodents, other bats, probably insects, and birds of 20 gr to 150 gr. Up to 18 bird species have been identified in their diet, mainly trogons (Trogonidae), columbids (Columbidae), motmots (Momotidae), cuckoos (Cuculidae), wrens (Troglodytidae), and icterids (Icteridae; Timm *et al.* 1989; Reid 2006; Reid *et al.* 2010). *Vampyrum spectrum* is considered locally rare (Reid 2006). In México, it is classified as endangered (SEMARNAT 2010), while the International Union for Conservation of Nature listed it as Near Threatened (IUCN 2021). The main threats to their populations are fragmentation, habitat loss (Solari 2018), and anthropic destruction of their shelters due to negative perceptions influenced by myths and ignorance (Gómez-Nísino 2006).

This note reports for the first time one specimen of *V. spectrum* inhabiting the Tabasco plain that was road-killed from a collision with a vehicle on a road in the Paraiso municipality.

This information was obtained during the Wildlife Mortality Project in the Tabasco Plain conducted by researchers of the Universidad Juárez Autónoma de Tabasco (UJAT). The objective of this project was to identify critical sites of wildlife collisions and to define mitigation measures in the Tabasco Plain.

The prevailing climate in the study area is warm humid, with annual precipitation ranging from 1,500 to 2,000 mm and annual mean temperatures above 26 °C, with maximum values between 30 °C and 34 °C in May and minimum between 20 °C and 22 °C in January (Hernández-Santana *et al.* 2008). Dominant winds flow from E to NE at an average speed of 4 to 6 m/s (Hernández-Santana *et al.* 2008). There are three clearly defined seasons in a year: dry, rainy, and winter rainy seasons (Moguel and Molina-Enríquez 2000). The dominant habitats are mangrove forests, wetlands, cultivated pastures, and water bodies (INEGI 2016).

The prevailing land use at the collision site is permanent rainfed agriculture (INEGI 2016). The study section is a paved state road consisting of two C-type lanes with an average crown width of 18 m. The speed limit is 80 km/h, and the mean traffic volume is 103 vehicles per day, of which 83.6 % are cars. The Annual Mean Daily Traffic (TDPA, in Spanish) was 3,489 vehicles in the year of the road-kill event (SCT 2016).

The corpse was photographed, collected, and brought to the Landscape Ecology and Global Change Laboratory of the Biological Sciences Division at UJAT for identification. Afterward, it was frozen and sent to the National Mammal Collection (CNMA, in Spanish) of the Institute of Biology at Universidad Nacional Autónoma de México (UNAM), where its identification was confirmed. The specimen was conventionally prepared (skin and skeleton) and listed with the corresponding coordinates. The following measurements were recorded in millimeters (mm): total length (LT), tail length (LC); rear right leg length (LPDT); and right ear length (LOD). Additionally, the total weight was reported.

The sites where this species has been documented in México were gathered from a survey in the literature, the Global Biodiversity Information Facility (GBIF 2021), and the NaturaLista platform (2021). The data obtained was visualized on a map of the region.

On 16 May 2015, at 6:00 hr, a male road-killed *V. spectrum* bat was observed during a monitoring trip (Figure 1). The animal was found lying on the El Bellote-Santa Cruz section of the 180 highway in Chiltepec village, Paraiso municipality, Tabasco. It was recorded during the rainy season (May to October) when precipitation exceeds 120 mm. The collision occurred on a stretch of the straight road surrounded by secondary vegetation associated with fruit trees: mango (*Magnifera indica*), banana (*Musa paradisiaca*), coconut (*Cocos nucifera*), and gliricidia (*Gliricidia sepium*).

The bat specimen was recorded under catalog data CNMA 47872, male; sampling locality 0.64 km W Aquiles Serdán, Paraíso municipality, Tabasco (18° 24' 46.89" N, 93° 0' 57.74" W), on the Chiltepec-Vicente Guerrero highway, at 1 m above sea level. The measurements of the specimen (mm) were: LT 144; LC 0; LPDT 32.0; LOD 42. total weight was 182.9 gr.

The bat specimen was collected with bird feathers in the mouth. The headless body of a bird of the family Tyrannidae was also observed (Figure 1). The head was not found near the site, so the bird was likely captured by the bat.

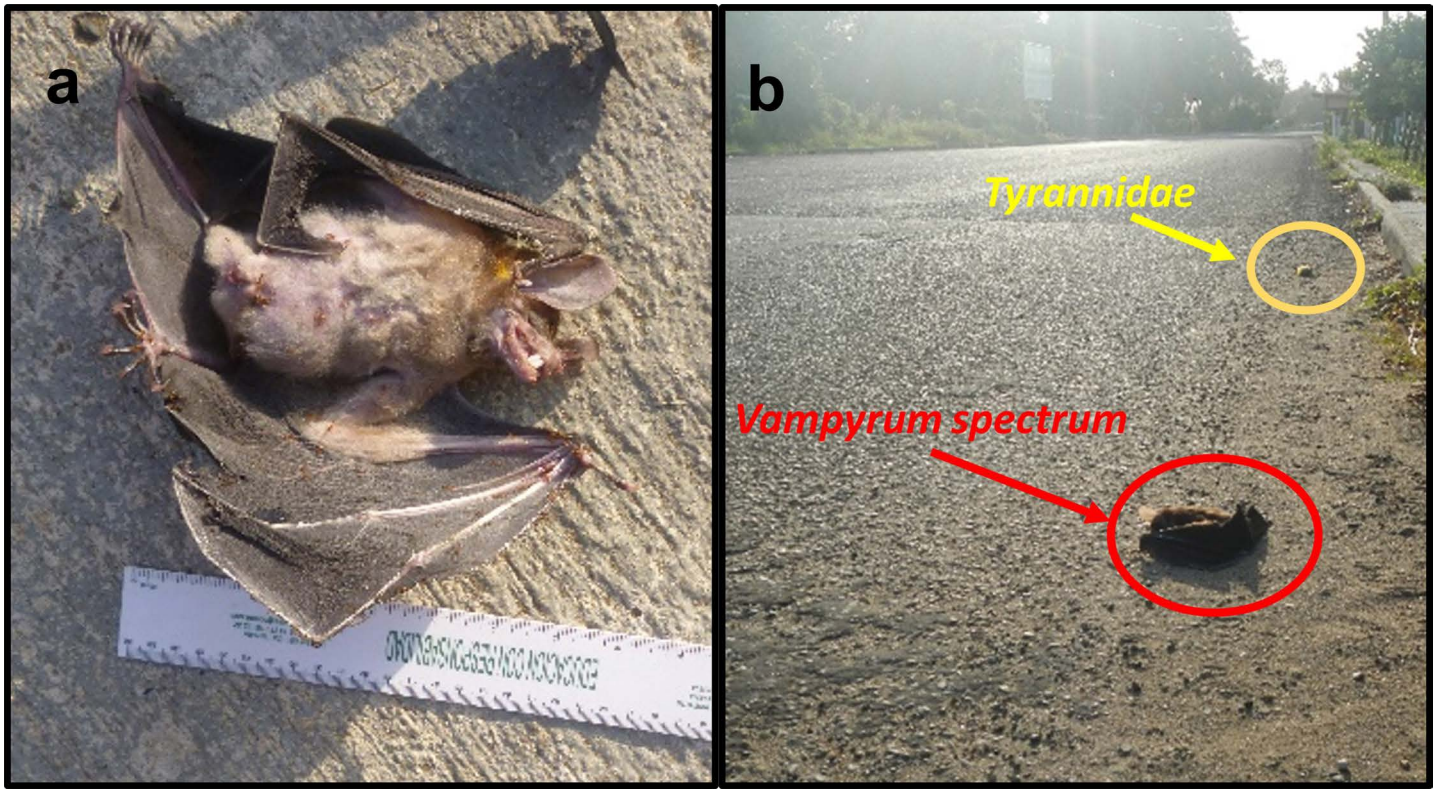

Figure 1. a) *Vampyrum spectrum* individual at the collision site. Ants are observed preying on the specimen, and b) location of the spectral bat and a bird specimen of the family Tyrannidae at a distance of approximately 2 meters, possibly preyed upon by the bat.

Only 13 previous records of *V. spectrum* were found (Figure 2): 3 in Veracruz (Goldman 1917; Navarro 1979; GBIF 2021), 2 in Oaxaca (Alfaro *et al.* 2005; Santos Moreno *et al.* 2010), 3 in Chiapas (Hernández-Mijangos *et al.* 2008; López *et al.* 1998; Peña-Cuéllar *et al.* 2012), 4 in Campeche (Hernández-Huerta *et al.* 2000; Escalona-Segura *et al.* 2002; NaturaLista 2021a, 2021b), and 1 in Quintana Roo (NaturaLista 2021c). Therefore, this is the first documented record of the species for Tabasco, which is also a roadkill report.

Although bats are a well-studied group in Tabasco (Sánchez and Romero 1995; García-Morales *et al.* 2014; Hidalgo-Mihart *et al.* 2016), the presence of *V. spectrum* had not been previously reported in the literature. According to Solari *et al.* (2019), its distribution in México comprises southern Veracruz, Oaxaca, Chiapas, and the southern Yucatán Península, so this record adds Tabasco to its distribution range.

Bats are among the rarest organisms reported in roadkill studies (de Figueiredo Ramalho and Aguiar 2020; de Figueiredo Ramalho *et al.* 2021a; Vargas-Contreras *et al.* 2021), but an underestimation is plausible due to the poor detectability of these individuals. Furthermore, specific studies have reported that roads cause significant adverse effects on this group, particularly on insectivorous bats (Berthinussen and Altringham 2012; Medinas *et al.* 2019). The families most commonly recorded are Vespertilionidae and Phyllostomidae (de Figueiredo Ramalho and Aguiar 2020; Novaes *et al.* 2018).

In México, bat records in road ecology studies are scarce (González-Gallina and Badillo 2013; González-Gallina *et al.* 2013; Pacheco-Figueroa *et al.* 2021; Vargas-Contreras *et al.* 2021), probably because of the sampling techniques applied. As mentioned by Vargas-Contreras *et al.* (2021), corpses lying on the road are difficult to spot since the speed of the vehicle forces bats out of the road area and into the vegetation. Therefore, this is likely the first record of a road-killed *V. spectrum* (González-Gallina and Badillo 2013; González-Gallina *et al.* 2013; Ceron *et al.* 2017; Cervantes-Huerta *et al.* 2017; de Figueiredo Ramalho and Aguiar 2020; de Figueiredo Ramalho *et al.* 2021a).

Furthermore, the flight strategy influences the risk of collision (Vargas-Contreras *et al.* 2021). Species flying at less than 10 m high, such as members of the family Phyllostomidae, face a higher risk of vehicle collisions (de Figueiredo Ramalho and Aguiar 2020); this family includes the spectral bat, the largest in the Neotropics. The spectral bat uses smell to locate its prey (Veherencamp *et al.* 1977) and flies slowly, near obstacles, and at ground level (Khan 2015), making it particularly vulnerable to vehicles and collisions. Spectral bats are likely to move across roads continuously, being frequently hit by vehicles, but road surveys are not efficient enough to record them.

The impact of roads on bats remains poorly documented and with unknown effects on species that are rarely observed. Most of the available research focuses on four-lane, high-traffic roads, and large or charismatic species. Low-to-moderate traffic roads are considered to have negligible impacts. However, small roads run across landscapes all over the world, with poorly studied species incidentally found in collision events on these roads.

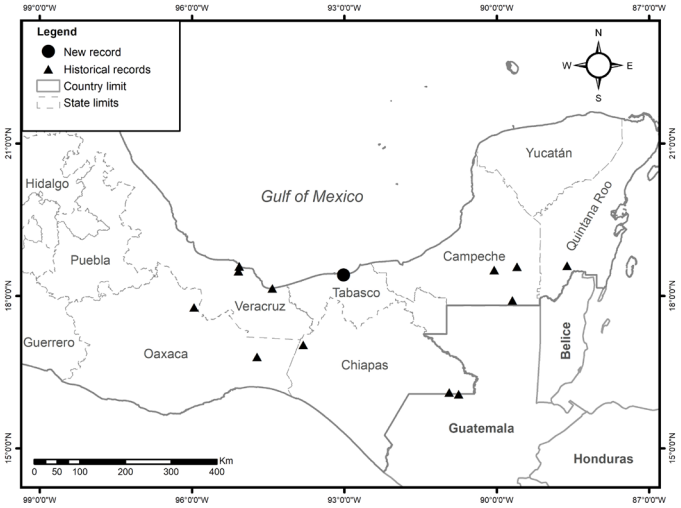

Figure 2. Historical and current records of the spectral bat (*Vampyrum spectrum*) near Paraíso, Tabasco, México.

The spectral bat is threatened by habitat loss and the negative perception of bats among people (Ceballos and Oliva 2005; Gómes-Nísimo 2006; Solari 2018). This species prefers little-disturbed habitats; however, as Vleut (2013) mentioned, it can also take advantage of secondary vegetation, as long as there are forests that provide roost sites and shelter. Bats are most frequently hit by vehicles on roads close to vegetation that offers shelter, food, and roost sites (Rusell *et al.* 2009; Roemer *et al.* 2020). The road where the killed spectral bat was found is surrounded by natural vegetation dominated by mangrove trees, providing shelter and roost sites (Timm *et al.* 1989). Besides, the tyrannid bird, which apparently was caught as prey, suggests that these bats forage in patches adjacent to the road. The road studied represents high-risk conditions for the spectral bat to get hit by vehicles.

The road section where the bat was found showed a marked increase in the TDPA from 5,768 vehicles per year in 2015 to 6,977 vehicles per year in 2016. Although these values dropped in the following years (6,002 vehicles per year in 2019; SCT 2021), the risk of collision persists because this road is part of the Modernization and Expansion Plan of the Sánchez Magallanes – Paraíso – Frontera Highway (GET 2019), which involves expansion works and increased traffic flow, particularly cargo trucks.

Since *V. spectrum* is a threatened species, it should be considered in mitigation measures to reduce the impact of roads on this species. Without proper control and measures, isolated populations of *V. spectrum* in Tabasco may suffer adverse effects without even having an estimate of their populations.

Regarding mitigation measures, green bridges allow safe passage of bats (de Figueiredo Ramalho and Aguiar 2020), but proper measures must be applied to guide bats towards these structures. Underpasses such as large bridges and culverts are considered effective measures (Claireau *et al.* 2019); however, these passages are implemented mainly in temperate climates, so there is no evidence of their effectiveness in tropical areas (Vargas-Contreras *et al.* 2021). Therefore, these measures must be applied along with a monitoring program allowing for future adaptations.

The most effective measure is the reduction of speed limits in areas with tree cover surrounding the road because these are the sites with the highest probability of vehicle-wildlife collisions. Structural modifications should be implemented by planting trees or installing fences that force bats to fly higher (Vargas-Contreras *et al.* 2021). Continuous artificial light affects the behavior of nocturnal species (MITECO 20219); therefore, if the road infrastructure requires lighting, it should be kept to a minimum (Garin *et al.* 2016).

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