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First records of road-killed mammals in the state of Sinaloa, México

Primeros registros de atropellamiento de mamíferos en el estado de Sinaloa, México

Yamel Rubio-Rocha[1,2], Soila Gaxiola-Camacho[1,3]*, María Morales-García[2], Brayan Artigas-Gutiérrez[2], Alfredo Sánchez-Ríos[4], Fabiola Carvajal-Sauceda[4], and Gerardo Espinoza-Evans[4]

[1]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Sinaloa. Boulevard San Ángel s/n, Fraccionamiento San Benito, Predio Las Coloradas, C. P. 80260. Culiacán, Sinaloa, México. E-mail: yamel@uas.edu.mx (YR-R); soilagaxiola@uas.edu.mx (SG-C).

[2]Facultad de Biología, Universidad Autónoma de Sinaloa. Calzada de las Américas s/n, Ciudad Universitaria, C. P. 80013. Culiacán, Sinaloa, México. E-mail: cruz_morales243@gmail.com (MM-G); brayan.artigas07@gmail.com (BA-G).

[3]Centro de Investigación en Una Salud, Sustentabilidad y Bienestar Animal. Blvd. San Ángel 3886, C. P. 80260. Culiacán, Sinaloa, México.

[4]Fundación Sinaloense para la Conservación de la Biodiversidad, A. C. Tales de Mileto 1684, C. P. 80010. Culiacán, Sinaloa, México. E-mail: biolog99@hotmail.com (AS-R); yolandac584@gmail.com (FC-S); espinozaevans566@gmail.com (GE-E).

*Corresponding author

The present research was conducted given the lack of data on the impact of motor vehicle traffic on wild animal populations. The present study aimed to assess the number of mammal road kills in Sinaloa, México. Roadkill records were obtained through field trips along roads, the NaturaLista web page, and citizen reports. Eleven mammal species were identified, importantly including some species listed in a conservation status, such as the jaguar (*Panthera onca*), ocelot (*Leopardus pardalis*), and badger (*Taxidea taxus*). Forty-five collision events were recorded on roads running across the south-central region of the state, from February 2019 to June 2021. The species with most records were the coati (*Nasua narica*), opossum (*Didelphis virginiana*), and lynx (*Lynx rufus*). This work is the first to record mammal mortality due to road collisions with vehicles and highlights the need to allocate greater resources to this line of research, which arises from the importance of wildlife conservation and the safety of road users.

Key words: Carnivores; collisions; mortality; road ecology; wildlife.

La ausencia de datos sobre el impacto que genera el tráfico vehicular en las poblaciones de animales silvestres motivó la presente investigación, que tuvo como objetivo conocer el número de muertes por atropellamiento de mamíferos en las carreteras de Sinaloa, México. Los registros de las colisiones se obtuvieron a través de transectos libres en carreteras, registros de la red social Naturalista y reportes ciudadanos. Se identificaron 11 especies de mamíferos, resaltando algunos en estado de conservación como el jaguar (*Panthera onca*), el ocelote (*Leopardus pardalis*) y el tlalcoyote (*Taxidea taxus*). Se obtuvieron 45 registros de colisiones en las carreteras de la región centro-sur del estado dentro del periodo de febrero de 2019 a junio de 2021. Las especies con más accidentes registrados fueron el coatí (*Nasua narica*), el tlacuache (*Didelphis virginiana*) y el lince (*Lynx rufus*). Este trabajo documenta por primera vez la mortalidad de mamíferos como resultado de las colisiones con el tráfico vehicular y resalta la necesidad de dirigir mayores recursos en esta línea de investigación que emerge ante la necesidad de conservar la fauna silvestre y la integridad de los usuarios de las carreteras.

Palabras clave: Carnívoros; colisiones; ecología de carreteras; fauna silvestre; mortalidad.

The coexistence between humans and wildlife has been recorded throughout history in caverns and rocks (Santos and Viñas 2005). Mammals have been of interest to humans due to their beauty and the services they provide as food sources, means of transportation, and companionship. This relationship has currently led to risk situations for wildlife inhabiting and moving through anthropic areas such as highways, roads, towns, and cities (Gottdenker *et al.* 2001; Filius *et al.* 2020).

Roads are indicators of socioeconomic development; they give rise to opportunities for productive activities and improve the communication between people and communities (Bañón and Beviá 2000). However, their construction and operation involve permanent adverse effects on ecosystems, including habitat fragmentation and destruction, and reduction of forest areas and natural biological corridors. This results in lesser dispersal capacity of wildlife individuals, thus threatening local populations (Dirzo *et al.* 2014; Suazo-Ortuño *et al.* 2018; Dean *et al.* 2019). The most conspicuous impacts include collisions between vehicles and wildlife, known as roadkill events (Gottdenker *et al.* 2001), which usually result in the death of animals when they attempt to cross the roads and are hit by vehicles. Road infrastructure also acts as a barrier for certain spe-

cies and impairs the mobility and connectivity among wild populations, thus affecting their genetic diversity (Arroyave *et al.* 2006; Holderregger and Di Giulio 2010).

The impact of roads on wildlife has been documented for some regions of México. The vertebrates with the highest frequency of deaths by collision are mammals, followed by birds and reptiles (González-Gallina *et al.* 2013; Pacheco *et al.* 2016; Cupul-Magaña 2019; Canales-Delgadillo *et al.* 2020). Roadkill events can influence the decline of local populations (Puc-Sánchez *et al.* 2013), which is of particular concern considering the ongoing mass extinction of wildlife (Ceballos *et al.* 2015). The impact of vehicle traffic on animals in the state of Sinaloa, México, is currently unknown, although there are important records for some endangered or threatened mammal species (Rubio-Rocha *et al.* 2010), such as wild cats that are forced to cross roads as part of their natural displacement patterns. This research represents the first effort to quantify and report the impact of road traffic on wildlife in Sinaloa and documents the mortality of various groups of mammals due to collisions.

The state of Sinaloa is located in northwestern México, between coordinates 22° 31′ and 26° 56′ N, and 105° 24′ and 109° 27′ W. It comprises an area of 57,365.4 km^2 organized in 18 municipalities distributed from the Pacific coast to the Sierra Madre Occidental mountain range, according to data from the National Institute of Statistics and Geography (INEGI, in Spanish; INEGI 2017). The prevailing climate is warm sub-humid and semi-dry in 48 % of the territory, arid in 10 %, and temperate in only 2 %, with mean annual temperature and precipitation of 25 °C and 769 mm, respectively. Dry forests are the dominant vegetation type, and there are important extensions of medium-height tropical forests, pine-oak forests, and xeric shrubland (INEGI 2013).

The study area comprised nine municipalities located in the south-central region, from Culiacán city to Escuinapa city (Figure 1); these municipalities have state and municipal paved roads measuring approximately 6.5–7 m in width. These highways are crossed in some sections by the México 015 and the Maxipista México 015 D federal highways, whose paved cross-section is approximately 7 m wide, but can reach up to 17 m wide in some sections. State and federal highways have drainage zones at some points, which broaden the paved width by up to 1.5 m (IMT 2006). Records were gathered from February 2019 to June 2021 using three approaches. 1) Evidence found along free transects traveled by car whenever possible, during tours along the road infrastructure of the south-central region of Sinaloa, with the assistance of three persons. During 31 sampling days, a total distance of 4,328 km was traveled, 90 % on the two federal highways and the remaining 10 % along five state and four municipal roads. The average distance traveled per trip was 139.6 km; monitoring was conducted during daylight, usually between 11:00 and 18:00 hr, at an average driving speed of 80 km/hr. When a roadkill was spotted, data were gathered, including the road name or code, location (km #) and coordinates of the collision site, species and sex of the

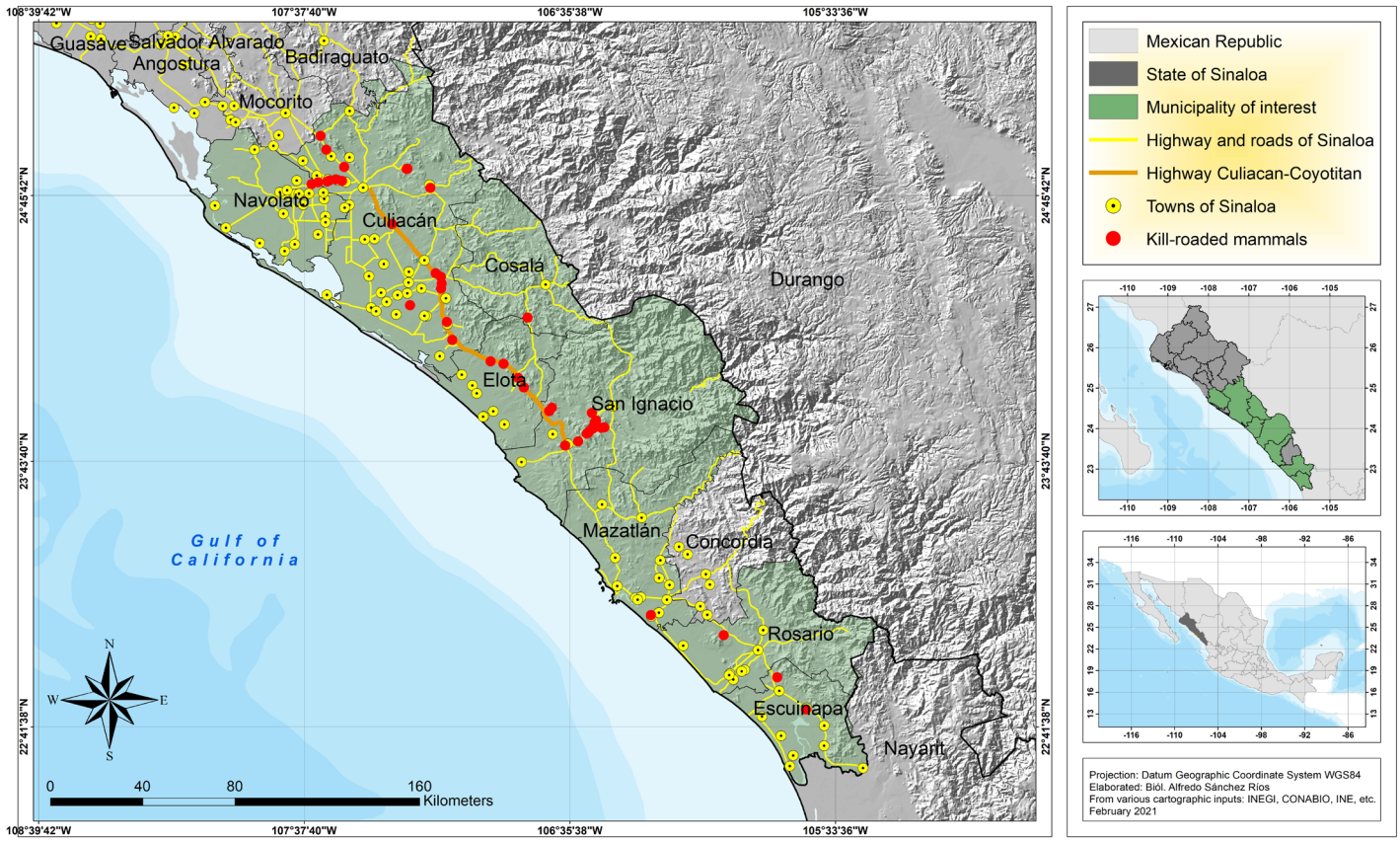

Figure 1. Study area and location of sites with reports of wild mammals roadkills on roads of Sinaloa, México, from 2019 to 2021.

mammal individual, photograph of the specimen, and habitat type. Species were identified at the collision site using field guides (Reid 1997). 2) Roadkill records gathered by users of the "Road Ecology of the state of Sinaloa" project website and posted at the NaturaLista web page. 3) Contributions of road users who photographed or lifted corpses and sent them to the facilities of the Fundación Sinaloense para la Conservación de la Biodiversidad A. C., reporting this to the Procuraduría Federal de Protección al Ambiente en Sinaloa. All records were added into a database.

A total of 45 mammal roadkills were recorded on the Sinaloa roads studied: 25 during road trips, 18 recorded on the NaturaLista web page, and 2 documented by road users (Table 1). Of these, 51.1 % of the collision events occurred on five state and four municipal highways, 44.4 % on the México 015 and 015D federal highways, and 4.4 % on dirt roads. The Culiacán-Coyotitan section of the México 015 federal highway, with a length of 145 km, showed the highest number of roadkills, with 14 records (Figure 1). The information reported herein corresponds to 8 of the 9 municipalities located in the south-central region of Sinaloa. The section of the México 015 federal highway connecting the municipalities of Culiacán, Elota, and San Ignacio showed the highest percentage of roadkills.

Eleven mammal species belonging to four orders were identified. The best-represented order was Carnivora, with 5 families: Felidae, Canidae, Mustelidae, Mephitidae, and Procyonidae. The orders Cingulata, Lagomorpha, and Didelphimorphia were each represented by 1 family with one species (Table 1). Carnivores were the group with the highest number of mammals roadkills (82 %); the families with the highest number of records were Procyonidae (n = 18), Felidae (n = 10), and Didelphidae (n = 9). The species most frequently involved in roadkills were the coati (*Nasua narica*), followed by opossum (*Didelphis virgiana*) and lynx (*Lynx rufus*). Seventy-three percent of the records occurred in 2 municipalities: Culiacán and San Ignacio. Figure 2 illustrates 8 of the road-killed species.

Three species listed in NOM-059-SEMARNAT-2010 (SEMARNAT 2019) were identified in this study; the ocelot (*Leopardus pardalis*) and jaguar (*Panthera onca*), classified as endangered species, and the badger (*Taxidea taxus*), listed as a threatened species. Specimens of these species were found in the Culiacán-Coyotitan section; the ocelot was recorded by a local inhabitant and the jaguar and badger, by the working group.

During this research, it was observed that the number of vehicles, high speed, and lack of roadside barriers are part of the threats and risks faced by mammals when crossing roads (González-Gallina *et al.* 2013; Puc-Sánchez *et al.* 2013; Pacheco *et al.* 2016; Filius *et al.* 2020). The maximum speed limit in federal and state highways is between 60 and 80 km/hr; however, this limit is frequently exceeded. According to the Secretariat of Communications and Transport (SCT, in Spanish), the average travel speed is about 100 km/hr (SCT 2018), which increases the risk of wildlife roadkills. The México 015 federal highway communicates important population centers that demand services from the main urban areas, Culiacán and Mazatlán cities, located at both ends of the road section studied. On average, 4,647 vehicles travel along these roads every day, of which 76 % are cars and the rest, motor carriers and trailer trucks (SCT 2017; SCT 2018). The trade and transport industries are the leading road users at the regional level (INEGI 2016); transport of passengers, freights, and various products to regional and international destinations takes place permanently throughout the year.

The Culiacán municipality, located at the center of the state, has a growing road and real-estate infrastructure, in addition to agricultural and forestry activities, which together account for 68 % of the deforestation compared to the rest of productive and service activities (INEGI 2016). The mean annual rate of vegetation cover loss in Sinaloa is one of the highest in the country (0.41 %), considering that the national average ranges between 0.35 % and 0.40 % (Monjardín-Armenta *et al.* 2017). This situation is likely

Table 1. Number of mammals struck on roads in Sinaloa, México, and conservation status. *NOM: Mexican Official Norm NOM-059-SEMARNAT-2010. P: extinction risk; A: threatened (SEMARNAT 2019). ** IUCN: Red list of threatened species of the International Union for Conservation of Nature. VU: vulnerable; LC: least concern (IUCN 2021). M: Number of records obtained by monitoring. N: Number of records obtained from the NaturaLista web page. A: Number of records from road users.

Family	Species	Common name	* NOM	** IUCN	M	N	A	Total records
Canidae	*Urocyon cinereoargenteus*	Gray fox		LC	3			3
Felidae	*Leopardus pardalis*	Ocelot	P	LC			1	1
Felidae	*Lynx rufus*	Bobcat		LC	3	5		8
Felidae	*Panthera onca*	Jaguar	P	VU			1	1
Mephitidae	*Mephitis mephitis*	Striped skunk		LC		1		1
Mustelidae	*Taxidea taxus*	American badger	A	LC	1			1
Procyonidae	*Nasua narica*	White-nosed coatí		LC	12	1		13
Procyonidae	*Procyon lotor*	Raccoon		LC	2	3		5
Dasypodidae	*Dasypus novemcinctus*	Nine-banded armadillo		LC	1	1		2
Dildelphidae	*Didelphis virginiana*	Virginia opossum		LC	2	7		9
Leporidae	*Lepus alleni*	Antelope jackrabbit		LC	1			1
Total					25	18	2	45

affecting the distribution, abundance, and interactions of mammals (Krebs 2014). Habitat fragmentation increases the edge and barrier effects and consequently, the risk of animals being struck while crossing roads in search of food (Fahrig 2003; Dirzo *et al.* 2014; Suazo-Ortuño *et al.* 2018; Abra *et al.* 2021). Nevertheless, it cannot be affirmed that the roads studied have the highest risk of wildlife roadkills in Sinaloa, but they are the scenario of road-killed animals as recorded by the working group and participants of the NaturaLista project (Naturalista 2021).

Roadkills allow verifying the presence of species with potential distribution in the area of collision sites, including common species, those considered rare or with a low frequency of observation, and species at risk (Krebs 2014; Abra *et al.* 2021). Roadkill records worth highlighting are those of endangered species, such as the jaguar and the ocelot; threatened species, such as the badger, and regional endemic species such as the antelope jackrabbit (*Lepus alleni*). A pregnant female raccoon (*Procyon lotor*) and young specimens of ocelot, lynx, and coati were also recorded. The jaguar cub was a male found on the road adjacent to the Meseta de Cacaxtla Flora and Fauna Protection Area, an ecological reserve demarcated by the México 015 federal highway in a 40 km stretch that goes from San Ignacio to Mazatlán, according to information from the Secretariat of the Environment and Natural Resources (SEMARNAT, in Spanish; SEMARNAT 2016). Vehicle traffic may be affecting the abundance and population structure of mammal species that move across its areas of influence, particularly in the case of rare species such as the badger (Bárcenas *et al.* 2009). This also occurs to endangered species such as felines for which roadkills have been reported throughout the country (González-Gallina and Hidalgo-Mihart 2018; Canales-Delgadillo *et al.* 2020).

According to previous reports, quantitative research addressing the impact of roads on wildlife is recent in México. Records of sporadic or fortuitous roadkills provide valuable data for recent studies on the subject. Three records of struck ocelots (González-Gallina and Hidalgo-Mihart 2018) have been found for Sinaloa. This information is valuable and reflects the need to focus efforts on the design of projects that generate systematic information on road ecology and assess the use and impact of infrastructure on wildlife (Canales-Delgadillo *et al.* 2020; Manteca-Rodríguez *et al.* 2021). The information recorded in the present study is the first effort to document wildlife roadkills occurring in the region. Academic and government organization should act coordinately to identify the sites or spots of greatest collision risk and the associated critical factors. Roadkill records can support the development of mitigation strategies to prevent wildlife deaths and injuries from collisions, which contribute to the loss of wildlife individuals and populations (Cáceres *et al.* 2010; Pacheco *et al.* 2016; Manteca-Rodríguez *et al.* 2021; Salom-Pérez *et al.* 2021). It is necessary to produce information to identify the critical wildlife crossing hotspots in the region to support road infrastructure design, construction, and management. It is equally important to provide resources for key aspects, such as proper signaling related to wildlife crossings that inform and raise awareness among road drivers to avoid hitting wild animals, which will contribute to wildlife conservation and the safety of road users.

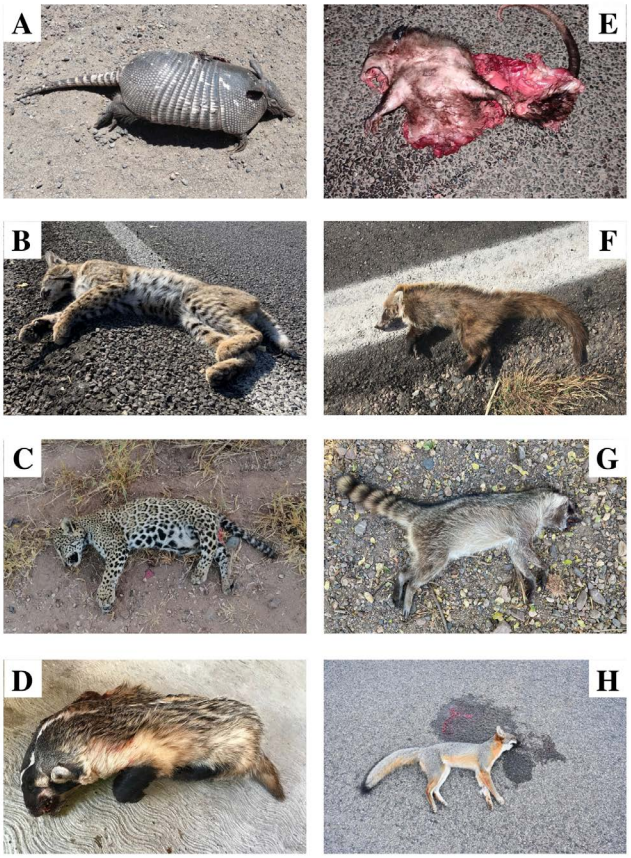

Figure 2. Mammals hit on roads of the south-central region of Sinaloa, México. A) *Dasypus novemcinctus* (Photograph by C. Anguamea), B) *Lynx rufus* (Photograph by B. Artigas), C) *Panthera onca* (Photograph by A. Loaiza), D) *Taxidea taxus* (Photograph by Y. Rubio), E) *Didelphis virginiana* (Photograph by C. Anguamea), F) *Nasua narica* (Photograph by Y. Rubio), G) *Procyon lotor* (Photograph by D. Alvarado), H) *Urocyon cinereoargenteus* (Photograph by Y. Rubio).

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