THERYA NOTES 2022, Vol. 3 : 82-86 DOI: 10.12933/therya_notes-22-75 ISSN 2954-3614

Comparison of road-killed mammals on roads of different types of jurisdictions and traffic volume in Veracruz, México

Comparación de mamíferos atropellados en vías de diferentes tipos de jurisdicción y flujo vehicular en Veracruz, México

Lucero Ruíz-Ramírez[1], Alberto González-Gallina[2], Víctor Soto[1], Coral Jazvel Pacheco-Figueroa[3], and Juan Manuel Pech-Canché[1]*

[1]Facultad de Ciencias Biológicas y Agropecuarias región Poza Rica - Tuxpan, Universidad Veracruzana. Km 7.5 Carretera Tuxpan - Tampico, Col. Universitaria, C. P. 92860. Tuxpan, Veracruz, México. E-mail: lurz.07.01@gmail.com (LR-R); islaveracruz@gmail.com (VS); jmpech@uv.mx (JMP-C).

[2]Instituto de Ecología A. C. Carretera Antigua a Coatepec No. 351, El Haya. Xalapa, Veracruz, México. E-mail: fodopo@hotmail.com (AG-G).

[3]División Académica de Ciencias Biológicas, Universidad Juárez Autónoma de Tabasco. Km 0.5 carretera Villahermosa - Cárdenas, Entronque a Bosques de Saloya, C. P. 86150. Villahermosa, Tabasco, México. E-mail: pachecoral@yahoo.com.mx (CJP-F).

*Corresponding author

Road projects are key for human development but also pose a risk to wildlife. The objective of this work was to determine the number of mammal road-kills on 3 types of roads according to their jurisdiction and traffic volume in the northern part of the state of Veracruz, México. Two roads were selected according to their jurisdiction (federal, state, and municipal) considering 2 types of traffic volume (high and low). Road-killed wild mammals were recorded through systematic sampling. The inventory was enriched with non-systematic records. Non-parametric tests were used to analyze the differences in mammal roadkills between types of roads and traffic volume. We found 49 road-killed individuals of 4 mammal species and 1 genus not identified to species, in addition to 3 species from incidental records. The species with the highest number of roadkills was *Didelphis marsupialis*. There were no significant differences in the rates of collisions between types of roads, but we found a significantly higher number of records related to high traffic volume. The non-systematic records allowed to enrich the inventory of road-killed species in the area. Two of the mammal species recorded are listed under a risk category. The biological characteristics of the species influence the extent of the impact of roads on them; traffic volume is a key driver of the impact of roads on wildlife. Non-systematic records can contribute to improving roadkill inventories and provide better tools for assessing the effects of roads on wildlife.

Key words: Environmental impact; mammals; road ecology; Veracruz.

Los proyectos viales son un elemento importante de desarrollo humano, pero a la vez representan un riesgo para la fauna silvestre, por lo que el objetivo del trabajo fue determinar el número de mamíferos atropellados en tres tipos de caminos en función de su jurisdicción y flujo vehicular en el norte del estado de Veracruz, México. Se seleccionaron dos caminos por tipo de jurisdicción (federal, estatal y municipal) en dos tipos de flujo vehicular, alto y bajo, registrando de manera sistemática todos los mamíferos silvestres atropellados y enriqueciendo el inventario con registros no sistemáticos. Se emplearon pruebas no paramétricas para analizar las diferencias en los atropellamientos de mamíferos en función del tipo de camino y flujo. Se registraron 49 individuos atropellados pertenecientes a 4 especies y 1 género de mamíferos sin determinar a nivel específico, además de 3 especies por registros incidentales, donde *Didelphis marsupialis* representa la especie más atropellada. No se encontraron diferencias significativas en las tasas de atropellamientos en función del tipo de camino, pero sí con relación al flujo vehicular, con mayores registros durante el flujo alto. Los registros no sistemáticos permitieron enriquecer el inventario de especies atropelladas en la zona, además de incluir el registro de 2 especies de mamíferos bajo alguna categoría de protección. Las características biológicas de las especies condicionan su grado de afectación por las carreteras; la afluencia vehicular es un factor importante que determina el impacto de las carreteras sobre la fauna silvestre. Los registros no sistemáticos pueden ayudar a mejorar los inventarios y brindar mejores herramientas para evaluar el efecto de las carreteras sobre la fauna silvestre.

Palabras clave: Ecología vial; impacto ambiental; mamíferos; Veracruz.

Road projects are an important element of human development as they represent economic and social benefits by improving the life quality of inhabitants. However, the construction and opening of roads have adverse effects on the environment, including loss and habitat fragmentation, pollution, deforestation, dispersal of exotic species, impaired animal behavior, creation of barriers for populations, limited access to resources, and wildlife mortality from collisions; the ultimate consequence is a significant decline of biodiversity (Trombulak and Frisell 2000; Jaeger *et al.* 2005; Arroyave *et al.* 2006; Colchero *et al.* 2011).

The probability of death by collision is related to road characteristics, such as traffic volume and road width (De la Ossa and Galván 2015), as well as to behavioral modifications in the local species, either because wild animals are attracted by roads, avoid them, or need to cross them.

For instance, roads are a source of food for some mammals and birds, especially scavengers. Reptiles such as snakes and lizards, which need to regulate their body temperature by absorbing heat from the environment, approach roads both during daytime and nighttime hours due to the heat absorbed by the pavement, thereby increasing the probability of roadkill events (Arroyave *et al.* 2006; Rojas 2010; Eloy-Seijas *et al.* 2011).

México is a megadiverse country as it is home to great biodiversity of multiple taxa. It ranks second globally in reptile species richness, third in mammals, fifth in amphibians, and eighth in birds (Llorente-Bousquets and Ocegueda 2008). At the same time, it has an extensive road network of approximately 780,509 km in length, including 174,779 km (22 %) of paved roads (federal, state, and municipal), 78,385 km (10 %) of urban roads and connections, and 527,345 km (68 %) of unpaved roads (INEGI 2020).

Veracruz is one of the 3 states with the greatest biodiversity in México; it ranks third in species richness of amphibians (Parra-Olea *et al*. 2014) and reptiles (Flores-Villela and García-Vázquez 2014), second in birds (Navarro-Sigüenza *et al.* 2014), and third in mammals (Sánchez-Cordero *et al.* 2014). Nevertheless, most of the current knowledge about wildlife has focused on the central and southern areas of the state, particularly the Los Tuxtlas region, an important biosphere reserve at the state level (Gaona *et al.* 2003).

One of the earliest studies on wildlife roadkills in Veracruz was conducted in Los Tuxtlas. During 24 sampling periods of 5 days each, 8 km of paved road were traveled over 2 years, recording 468 carcasses of 73 species; reptiles were the most affected group (Morales-Mávil *et al.* 1997). Another survey was performed on the Amozoc-Cantona-Perote highway. During 34 days of sampling, 14 km of highway were traveled in 2 environments (xeric shrubland and grasslands), recording 58 road-killed species of vertebrates; mammals were the most affected group with 82.87 % of the total roadkills, followed by birds (9.64 %) and reptiles (7.8 %; González-Gallina *et al.* 2013).

Therefore, and due to the lack of assessments of road impact on wildlife in northern Veracruz, the objectives of this work were to assess potential differences in the number of road-killed mammals between 3 types of roads according to their jurisdiction (federal, state, and municipal), and between 2 levels of traffic volume (high and low), and to identify the species listed in a risk category in the Mexican regulations (SEMARNAT 2010).

The study area is located in northern Veracruz and comprises the municipalities of Tuxpan, Tihuatlán, and Álamo. The fieldwork was conducted along a 35 km-stretch of 2 federal highways, a 20 km-stretch of 2 state highways, and a 4 km-stretch of 2 municipal highways.

The stretches of federal highways were a) the México–Tuxpan 130D highway, from the Río Pantepec section to the connection with the Tampico–Poza Rica 180 highway, consisting of 4 paved lanes surrounded by grasslands, secondary vegetation, and areas near paddocks, and b) the Tampico–Poza Rica 127 highway, from Tihuatlán to Alamo, comprising 2 paved lanes surrounded by secondary vegetation, paddocks, and some populated areas.

The state highways were: a) the México 106 Highway, from Alamo to Manantial, consisting of 2 paved lanes bordered by paddocks with water bodies, orange tree plantations, and populated areas, and b) the Tuxpan–Tamiahua highway, comprising 2 paved lanes bordered by grasslands, paddocks, groves, and water bodies.

The municipal roads studied were: a) the road to La Barra Norte from the Lázaro Cárdenas Boulevard in Tuxpan, located 1 km from the coast and consisting of 2 narrow lanes with paved but sandy sections, adjacent to grasslands, halophytic vegetation, secondary vegetation, and sparsely populated areas and, b) the API Tuxpan–Santiago de la Peña road, comprising 2 paved and sandy lanes traveled by heavy trucks, adjacent to landscapes including halophytic vegetation, mangroves, and a nearby water body.

To assess the effect of traffic volume on roadkills, tours were made in 2019 on each type of road in periods of 2 different traffic volume levels: high, during the Easter (April) and summer (July) holiday periods; low, during March and June. To calculate the traffic volume, 3 equidistant observation points in each section were considered on all sampling dates; the vehicles traveling through the observation point in both directions were quantified for 1 minute using a digital counter. In each period of high / low traffic volume, 2 tours were conducted over the course of 2 weeks each month on the 3 types of roads, for a total of 48 tours.

Road tours were conducted systematically in both directions (one every day of the week), between 11:00 and 18:00 hr, to take advantage of daylight and prevent accidents, at an average driving speed of 40 km / hr. Two observers participated in each tour. When a carcass was spotted, preventive signs were placed on the road, the collision event was recorded, and the corpse was removed from the road to avoid duplication of records. Mammal specimens were identified using specialized literature and field guides (Aranda 2012; Reid 2009). At the collision sites, the data gathered included date and time, road type, and whether the corpse was found on a curve or straight stretch; the coordinates were read with a GPS (Garmin Etrex 10). To supplement the inventory of road-killed species in the area, road-killed animals spotted during random encounters were also recorded; these non-systematic records were considered valid if they corresponded to the same road and sampling period studied and provided a photograph of the specimen was included along with its approximate location.

The relationship between the roadkill rate (number of road-killed individuals divided by the total number of kilometers traveled), type of road, and traffic volume was assessed using a Kruskal-Wallis test (Zar 2014). The relationship between the species richness of road-killed mam-

mals and the average traffic volume for each road type was explored through a Spearman correlation test (Zar 2014). These analyses were selected due to the non-parametric distribution of the data.

Systematic sampling led to the identification of 4 species (*Didelphis marsupialis, D. virginiana, Dasypus novemcinctus,* and *Sciurus aureogaster*) and 1 unidentified mammal species (*Didelphis* sp.), in addition to 4 domestic cats (*Felis catus*) and 9 dogs (*Canis lupus familiaris*) that were excluded from the analyses. Opossum (*Didelphis marsupialis*) was the most affected species (Figure 1).

Regarding the type of road, no significant relationship was found with the roadkill rate ($K = 2$; $P = 0.36$). However, significant differences were found between traffic volume and roadkill rates ($K = 5.91$; $P = 0.01$), which were higher for high traffic volume. A positive and significant correlation was also found between species richness and mean traffic volume by road type ($S = 2.53$; $P = 0.007$; $rho = 0.92$; Figure 2).

The non-systematic sampling resulted in 12 validated records involving 5 mammal species, including 3 species not recorded in the systematic sampling: raccoon (*Procyon lotor*), jaguarundi (*Herpailurus yagouaroundi*), and anteater (*Tamandua mexicana*). It is worth highlighting that the latter 2 species are protected by the Mexican Official Norm (NOM-059-SEMANART-2010; SEMARNAT 2010), listed as threatened and endangered of extinction, respectively.

Based on the results obtained in the present study, mammals are among the most affected groups by wildlife roadkills. This pattern is consistent with the reported by several studies globally (Puc-Sánchez *et al.* 2013). However, it may be influenced by the methodology used (roads traveled at constant speed), the environmental characteristics of the study area (few water bodies), and the sampling periods based on traffic volume instead of climate season. Other works conducted in Veracruz with different methodology (walking tours) and climatic and environmental conditions (Morales-Mávil *et al.* 1997) reported different results, finding amphibians as the second most affected group. Recent studies have described that in Latin America, amphibians have the highest average roadkill rate (0.2 ind / km / year; Pinto *et al.* 2020). Therefore, we suggest conducting further studies on this topic in the study area to confirm the actual effect of roads on different groups of vertebrates.

Opossums, particularly *D. marsupialis*, were the most affected mammals, not only for recording the largest number of road-killed individuals but also because these were recorded in almost all types of roads and traffic volume levels. This may be associated with their reproductive season, which ranges from January / February to June / July, when young and inexperienced individuals are more abundant and might be attracted by food lying on the roads or at roadsides. This factor, alongside their generalist habits, great displacement capacity, and defense response when threatened (paralyzing), makes them more vulnerable to roadkills (McManus 1974; Puc-Sánchez *et al.* 2013).

The results reported in this study, namely the higher roadkill rates in periods of higher traffic volume and the correlation between species richness and traffic volume according to the type of roads, demonstrate that traffic is

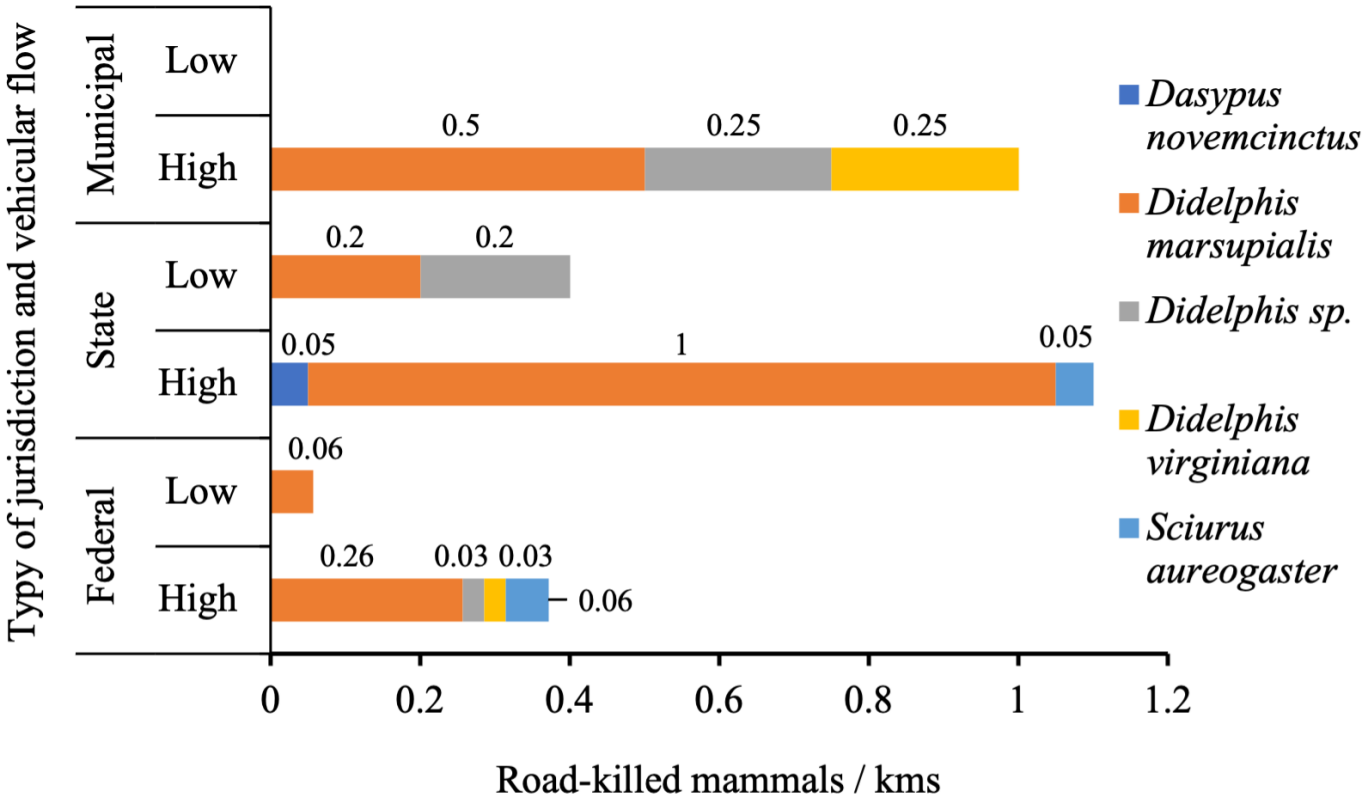

Figure 1. Diagram showing the number of road-killed mammal individuals per kilometer traveled and by type of road and traffic volume on roads in northern Veracruz, México.

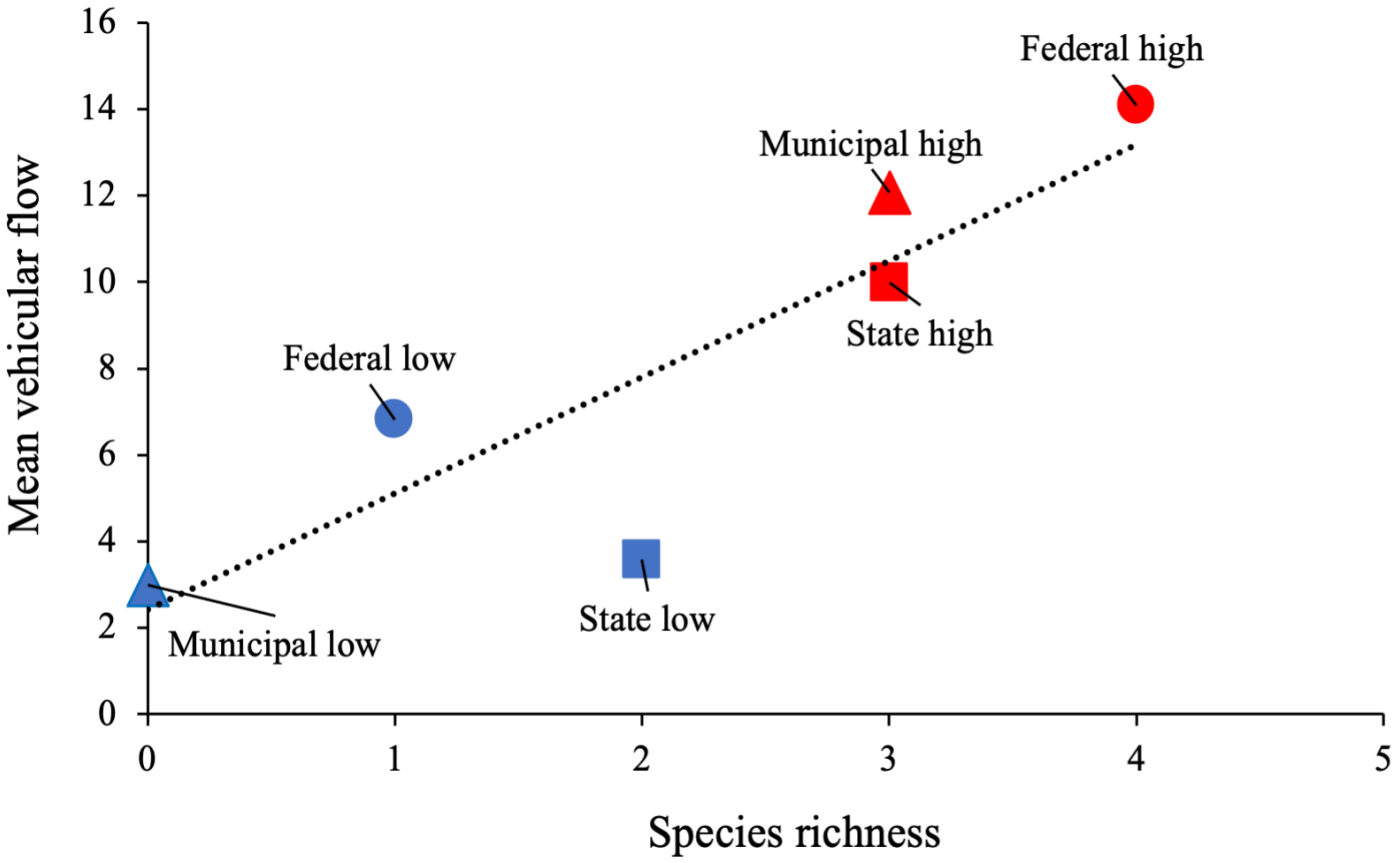

Figure 2. Relationship between richness of mammal road-killed species and mean traffic volume and type of road on roads in northern Veracruz, México.

a key factor in wildlife roadkills. Therefore, it is important to develop a permanent conservation program to reduce the environmental impact of roads, which should include, at least (SCT 2020): proper road signs to make users aware of the presence of wildlife, particularly during the seasons of high traffic volume, when the highest roadkill rates were found; drainage works retrofitted in areas near water bodies to allow water flow and the displacement of slow-moving aquatic fauna (*e.g.*, amphibians); seasonal passages for migratory invertebrates because high mortality of the crab *Gecarcinus lateralis* was observed in one of the sites studied (road to La Barra Norte) during a sampling period coinciding with its breeding season (July; Capistrán-Barradas *et al.* 2003); and reforestation of areas parallel to the roads affected by Hurricane Grace in August 2021.

Non-systematic records added 2 species of protected mammals: jaguarundi and anteater. This demonstrates the importance of this type of records, many of them reported by citizens, which can reduce biases in systematic studies, mainly when digital platforms are used to share information (Di Cecco *et al.* 2021), in addition to helping improve the assessment of the real impact of roads on biodiversity.

Acknowledgements

The first author wishes to thank the Consejo Nacional de Ciencia y Tecnología (CONACyT, in Spanish) for the grant to undertake her postgraduate studies with the Speciality in Environmental Management and Impact. The third author thanks CONACyT for the Postdoctoral fellowship in the Master of Environmental Sciences. The authors thank I. Morales and C. Pérez for their assistance in the identification of some of the species, and to all the persons who provided fieldwork assistance. Thanks also to the editors of this special fascicle and the external reviewers. M. E. Sánchez-Salazar translated the manuscript into English.

Literature cited

Aranda, M. 2012. Manual para el rastreo de mamíferos silvestres de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México City, México.

Arroyave, M., *et al.* 2006. Impactos de las carreteras sobre la fauna silvestre y sus principales medidas de manejo. Revista de la Escuela de Ingeniería de Antioquía 5:46-50.

Capistrán-Barradas, A., O. Defeo, and P. Moreno-Casasola. 2003. Density and population structure of the red land crab *Gecarcinus lateralis* in a tropical semideciduous forest in Veracruz, Mexico. Interciencia 28:323-327.

Colchero, F., *et al.* 2011. Jaguars on the move: modeling movement to mitigate fragmentation from road expansion in the Mayan Forest. Animal Conservation 14:158-166.

De la Ossa, J., and S. Galván. 2015. Registro de mortalidad de fauna silvestre por colisión vehicular en la carretera Toluviejo – Ciénaga La Caimanera, Sucre, Colombia. Biota Colombiana 16:67-77.

Di Cecco, G. J., *et al*. 2021. Observing the Observers: How Participants Contribute Data to iNaturalist and Implications for Biodiversity Science. BioScience 71:1179-1188.

Eloy-Seijas, A., A. Araujo-Quintero, and N. Velázquez. 2011. Mortalidad de vertebrados en la carretera Guanare-Guanarito, Estado Portuguesa, Venezuela. Revista de Biología Tropical 61:1619-1636.

Flores-Villela, O., and U. O. García-Vázquez. 2014. Biodiversidad de reptiles en México. Revista Mexicana de Biodiversidad 85:S467-S475.

Gaona, S., A. González-Christen, and R. López-Wilchis. 2003. Síntesis del conocimiento de los mamíferos silvestres del Estado de Veracruz, México. Revista de la Sociedad Mexicana de Historia Natural, 3ª época 1:91-124.

González-Gallina, A., *et al*. 2013. The small, the forgotten and the dead: highway impact on vertebrates and its implications for mitigation strategies. Biodiversity and Conservation 22:325-342.

Instituto Nacional de Estadística y Geografía (INEGI). 2020. Red Nacional de Caminos (RNC). https://www.gob.mx/imt/acciones-y-programas/red-nacional-de-caminos. Accessed September 1, 2021.

Jaeger, J. A. G., *et al*. 2005. Predicting when animal populations are at risk from roads: an interactive model of road avoidance behavior. Ecological Modelling 185:329-348.

Llorente-Bousquets, J., and S. Ocegueda. 2008. Estado del conocimiento de la biota. Pp. 283-322 *in* Capital natural de México, vol. I: Conocimiento actual de la biodiversidad (Soberón, J., G. Halffter, and J. Llorente-Bousquets, eds.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México City, México.

McManus, J. J. 1974. *Didelphis virginiana*. Mammalian Species 40:1-6.

Morales-Mávil, J. E., *et al*. 1997. Mortalidad de vertebrados silvestres en una carretera asfaltada de la región de Los Tuxtlas, Veracruz, México. La Ciencia y el Hombre 27:7-23.

Navarro-Sigüenza, A. G., *et al*. 2014. Biodiversidad de aves en México. Revista Mexicana de Biodiversidad 85:S476-S495.

Parra-Olea, G., *et al*. 2014. Biodiversidad de anfibios en México. Revista Mexicana de Biodiversidad 85:S460-S466.

Pinto, F. A. S., A. P. Clevenger, and C. Grilo. 2020. Effects of roads on terrestrial vertebrate species in Latin America. Environmental Impact Assessment Review 81:106337.

Puc-Sánchez, J. I., *et al*. 2013. Las carreteras como una fuente de mortalidad de fauna silvestre en México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Biodiversitas 11:12-16.

Reid, F. A. 2009. A field guide to the mammals of Central America and southeast Mexico. Oxford University Press. New York, U.S.A.

Rojas, E. 2010. Atropello de vertebrados en una carretera secundaria en Costa Rica. Cuadernos de investigación UNED 3:81-84.

Sánchez-Cordero, V., *et al*. 2014. Biodiversidad de Chordata (Mammalia) en México. Revista Mexicana de Biodiversidad 85:S496-S504.

Secretaría de Comunicaciones y Transportes (SCT). 2020. Manual de diseño de pasos para fauna silvestre en carreteras. Dirección General de Servicios Técnicos. México. https://www.sct.gob.mx/fileadmin/DireccionesGrales/DGST/Manuales/Manual_de_Fauna/ManualPasosparaFauna.pdf. Accessed June 1, 2021.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental - Especies nativas de México de flora y fauna silvestres - Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo. Diario Oficial de la Federación. 30 de diciembre de 2010.

Trombulak, S., and C. Frisell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Zar, J. H. 2014. Statistical Analysis. 5th Ed. Pearson Education Limited. New Jersey, U.S.A.

Associated editor: Juan de Dios Valdez-Leal
Submitted: September 13, 2021; Reviewed: March 10, 2022.
Accepted: April 8, 2022; Published on line: May 5, 2022.