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Ecological connectivity and wildlife passages on roads: a reflection for México

Conectividad ecológica y pasos para fauna en carreteras: una reflexión para México

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The construction of wildlife passages is a globally growing trend, supported by adequate legal frameworks and practical experiences that have assessed their effectiveness and efficiency to reduce roadkills; particularly for mammals. In México, however, this field is still incipient, with a few wildlife passages implemented and a non-existent legal framework, only regulated through authorization resolutions of environmental impact assessments related to road construction projects. Fauna passages play an important role in biodiversity conservation and recovery of landscape connectivity; however, studies are still required worldwide to assess the relevance of these passages on wildlife populations and communities conservation through time and space. This paper summarizes current considerations in terms of connectivity and fragmentation, and their relationship with wildlife passages construction on roads, as a strategy to mitigate wildlife impacts, encouraging the reader to reflect on the current status of these topics in México and the importance of implementing them through a legal framework as part of the commitments of México toward the global conservation of biodiversity.

Key words: Artificial corridor; biological corridor; fragmentation of ecosystems.

La construcción de pasos para fauna silvestre es una tendencia creciente en el mundo, fundamentada en marcos jurídicos adecuados y experiencias prácticas que han dado como resultado la valoración de su eficacia y eficiencia en reducir el atropello, particularmente de mamíferos. No obstante, en México el tema es aún incipiente, con pocos ejemplos ejecutados y un marco legal específico inexistente; quedando su ejecución obligada a través de los resolutivos de autorización en impacto ambiental de los proyectos de infraestructura carretera. El papel que los pasos para fauna tienen en la conservación de la biodiversidad y recuperación de la conectividad en el paisaje es de gran relevancia; sin embargo, hacen falta a nivel mundial, planificar estudios que permitan cuantificar su relevancia en la conservación de comunidades y poblaciones de especies en el tiempo y espacio antes y después de su construcción. Esta nota resume algunas de las consideraciones actuales en materia de conectividad y fragmentación, y su relación con la construcción de pasos para fauna silvestre en la infraestructura vial como una forma de mitigar el daño ejercido, invitando a la reflexión sobre el estado que guarda México con respecto a estos temas y la importancia de retomarlos en la práctica y a través de un marco legal, como parte de los compromisos que México ha adquirido en materia de conservación de la biodiversidad a nivel mundial.

Palabras clave: Corredores artificiales; corredores biológicos; fragmentación de ecosistemas.

Conserving ecosystems connectivity to protect the natural and cultural diversity of México is a commitment to present and future generations (Sarukhán 2017). Ecosystems have supported the livelihood of human populations since the early stages of history, providing goods and services (Balvanera *et al.* 2009) that are essential for the development of human societies (MEA 2005). Biodiversity represents a supporting ecosystem service, as it participates in processes such as pollination, seed dispersal, climate regulation, carbon sequestration, and pest control (Orijel *et al.* 2008).

In terms of ecosystem connectivity, the transformation and fragmentation of ecosystems resulting from the construction of road infrastructure represent a stress factor that splits and alters the ecological functions, leading to biodiversity loss (Mendoza-Sánchez and Marcos-Palomares 2016). The conservation and recovery of ecological connectivity allows to reverse fragmentation effects and, additionally, fight the threats of climate change through the recovery of ecosystem functions (Sarukhán 2017). In this context, it is evident that road projects need to be design under a comprehensive territorial planning proposal that meets the communication and mobility requirements of society without threatening the conservation of biodiversity and ecosystem services (Tsunokawa and Hoban 1997; Seiler 2001; Daigle 2010).

Nowadays, strategies such as the conservation and recovery of ecological corridors and the construction of artificial corridors perpendicular to road works, known as

wildlife passages, are feasible options to preserve ecological connectivity and reduce the adverse effects of ecosystem fragmentation; they provide a continuous habitat that represents a safe passage for animals as they move through the landscape (Conservation Corridor 2020). This document reviews the situation in México regarding the implementation of diverse strategies for the conservation and recovery of landscape connectivity, as a way to mitigate ecosystem fragmentation caused by roads, particularly considering the construction of fauna passages as a measure to recover connectivity.

Current context on ecosystem fragmentation. Ecosystem fragmentation is on the rise, mainly the one caused by the lack of land use control and strategic planning for the use of natural systems. In México, urban development, livestock increase and agriculture practices are drivers of this issue. Additionally, in the early 20th century, the creation of transport infrastructure exacerbated this problem, initially comprising railway networks only, and later, with the increase in highways, roads, and country roads (López-Feldman 2012; INEGI 2017). The construction of roads represents an economic and anthropic symbol of progress that enables mobility and the logistical capacity to plan and improve our life quality. However, life quality also depends on ecosystem services and these, in turn, on the connection and balance of its components (MEA 2005).

Road infrastructure represents significant movement barriers for mammals, resulting in increasingly smaller, isolated populations with greater difficulty for obtaining food, water, or mating sites to conserve genetic diversity, species continuity, and ecosystem integrity (Arroyave *et al.* 2006). Additionally, the construction of road infrastructure has increased the risk of wildlife roadkills and is currently considered one of the leading causes of mammals mortality, as well as other fauna inhabiting the road neighboring area. This issue has been of great concern since the 1970s in various parts of the world, and efforts have been focused on developing solutions for safe wildlife crossing (Mendoza-Sánchez and Marcos-Palomares 2016).

There are few studies in México investigating alternatives to prevent the impacts to fauna caused by road infrastructure construction, and those that have been conducted resulted from environmental impact assessments of road projects. Also, there is no clear quantification of roadkills on various roads in the country, nor records of accidents resulting from collisions or drivers wildlife dodges. There are initiatives such as the Observatory of Mobility and Fauna Mortality on Roads of México (*Observatorio de Movilidad y Mortalidad de Fauna en Carreteras de México*), supported by the Mexican Institute of Transport (*Instituto Mexicano del Transporte;* IMT, in Spanish) with the collaboration of citizens and centers of the Secretariat of Communications and Transport (SCT, in Spanish). The objective of the observatory is to build a database through WATCH MX, a platform created for the monitoring of fauna that crosses roads in México to develop mitigation strategies and prevent accidents or collisions between vehicles and wildlife; the earliest results of this initiative were published by Mendoza-Sanchez and Palomares (2016). The project is promising and can support research studies to help mitigate, compensate, or avoid damage to wildlife, but it requires further support to remain functional and promote the use of the WATCH MX platform by different sectors and users who contribute by reporting wildlife-vehicle incidents on roads in the country.

Connectivity and wildlife passages on roads. The concept of biological or ecological connectivity is complex but in general terms include the way in which organisms can move among particular natural landscape elements or the number of connections between habitat fragments relative to the maximum number of potential connections or interrelations of key processes within and between ecosystems in multiple scales (Fisher and Lindenmayer 2007). The maintenance and construction of ecological corridors represent an effective strategy worldwide to increase such connectivity in landscapes or ecosystems.

The International Union for Conservation of Nature (IUCN) defines a biological or ecological corridor as "A clearly defined geographical space that is governed and managed over the long term to maintain or restore effective ecological connectivity" (Hilty 2020). According to their functionality, there are different types of ecological corridors. In the case of roads, wildlife passages are currently considered artificial corridors that enhance connectivity and are highly important to reduce the damage caused by road infrastructure (Panthera 2020).

Although wildlife passages were initially built in the 1970s in other countries (Clevenger 2007), they are a relatively new subject in México and still lack a specific legal framework. Although there are studies supporting that these structures can increase ecosystem connectivity (Bissonette and Adair 2008), the connectivity mentioned within the Mexican legal framework mainly refers to natural or large corridors whose objective is conservation, particularly of protected natural areas (SEMARNAT *et al.* 2017). However, no reference is made to wildlife crossings as related to the connectivity of ecosystems and the conservation of mammals and other species, hence the importance of including it within the legal framework. As human capacity to create technology generally involves ecological impacts, it can also represent the key to face environmental challenges, including the fragmentation of landscapes and ecosystems through knowledge and technology development (Maass and Equihua 2015). The incorporation of wildlife passages to the legislation may foster sustainable practices in México, as long as they are built at strategic sites and under an integrated management approach of landscapes and ecosystems, besides being preventive rather than corrective (Iuell 2003; Bissonette and Adair 2008; Correa *et al.* 2016; SCT 2021).

The selection of the best route among several alternatives should prevent affecting ecologically relevant areas.

For instance, in conserved areas, a single type of wildlife passage out of the eight described as a mitigation measure in the Manual for the Design of Road Wildlife Passages (*Manual de Diseño de Pasos para Fauna Silvestre en Carreteras*; SCT 2021) may be insufficient to provide the permeability required by different species in a given habitat (Rytwinski *et al.* 2016) since these structures should be built according to their biological and ecological needs. Thus, it is worth to emphasize that the best wildlife crossing is the one that does not need to be built, *i.e.*, when the road or railway has been designed in order to avoid ecosystem fragmentation.

On the other hand, even though other countries have implemented fauna passages, each case has its own experiences and requires particular alternatives, considering the needs of the area in terms of its fauna and ecosystems (Rytwinski *et al.* 2015) and the political and social contexts. An example is the wildlife passages built in the temperate region of the United States and Canada, where the presence of large mammals and their displacement in herds requires the construction of large wildlife passages over the roads and the fencing of the entire right of way. These measures reduce wildlife-vehicle collisions and the high costs of driver compensation and insurance payments (the primary motivation for constructing these crossings). In São Paulo, Brazil, collisions between vehicles and wildlife have produced annual costs to society of USD 25,144,794.00 (Abra *et al.* 2019). In this sense, the cost-benefit balance justifies the profitability of the construction (Lee *et al.* 2013; Ascensão *et al.* 2021). However, in countries with diverse tropical fauna, usually small-sized and abundant, as is the case of México, the construction of large structures as passages, with long distances between them, would not solve the fragmentation issues. The ecological characteristics of the animals living in these regions require a greater density of passages with shorter distances between them in order to allow the animals to move across the roads, which differs from requirements for wildlife in North America. These features reduce construction costs, even allowing to include structures for multiple species (Sijtsma *et al.* 2020). Additionally, it is feasible to consider the use of road structures as passages, like drainage works that can be adapted for a dual use: water flow and wildlife passage (SCT 2021).

An important aspect in the construction of wildlife passages is the implementation of actions to protect the habitat of wildlife species, that is, to connect these structures with the surrounding ecosystems, thereby maintaining connectivity and ecosystem services at the same time. Some studies report that purchasing agricultural land for ecological restoration is more effective and efficient for species conservation and connectivity than constructing large crossings as the only mitigation measure (Queiroz *et al.* 2014).

It is important to note that vehicle collisions with medium-sized or small fauna usually causes no damage to cars, unless the driver attempts to dodge it, which can result in a serious car accident; therefore, it is difficult to perform collisions cost analyses with small animals to justify for the construction costs of wildlife passages under these circumstances. This makes it necessary to assess the construction costs of wildlife crossings based on a cascade of issues and adverse effects that result from the loss of biodiversity; therefore, construction of such wildlife passes should be perceived as part of the ecosystem support services that provide long-term benefits for the quality of human life. To this date the economic quantification of this type of ecosystem services benefits is a scarcely developed parameter (Sijtsma *et al.* 2020), given the complexity and abstraction involved (Bartkowski *et al.* 2015).

Importance of the legal framework and its application through public policies aimed at promoting ecological connectivity and fauna passages. Globally, the implementation of legislation and public policies at the spatial and temporal levels is related to the idiosyncrasy, culture, development, and economy of each region. According to 147 documents about the regulatory framework of countries in Europe, North America, and Latin America in terms of connectivity, fragmentation, and wildlife conservation, there is a marked difference in the application of environmental policies between the governments of developed and developing countries. One of the most advanced regions in environmental regulations and with broad experience in preserving their ecosystems and fauna is the European Union. The protection of fauna, flora, landscapes, and ecosystems is a comprehensive part of its political agenda, and the actions to support its natural heritage have acquired increasing importance over the past 30 years.

In North America, each country has its own regulations and programs to preserve and manage wildlife species and ecosystems. To protect biodiversity affected by the vigorous development of the region, the Canada/México/United States Trilateral Committee for Wildlife and Ecosystem Conservation and Management was established in 1995. Its goals focus on promoting a comprehensive approach to the conservation and sustainable use of biological resources, contributing to the maintenance of the ecological integrity of its ecoregions, and the conservation of biodiversity.

Additionally, México has signed a significant number of international, bilateral, and multilateral environmental treaties and agreements, providing the bases for developing our environmental legislation. The commitments adopted by México by joining these treaties have led, at different times, to the issuance of new laws addressing different areas of human activities, as well as a series of amendments to the existing regulations, from the Constitution to the regulatory provisions of secondary laws.

Finally, it is important to note that, although the Mexican environmental legal system addresses the proper protection of flora and fauna, it is not necessarily managed holistically. This is the consequence of the lack of linkage between the different planning and management instruments, and ineffective implementation in terms of governance and conservation economics.

Today, there are few environmental regulations and enforcement instruments in matters of ecological connectivity and fauna passages in the Mexican environmental legislation. Although México has worked in subjects related to connectivity and biological corridors for over two decades, integrating the definitions and associated regulations in the General Law of Ecological Balance and Environmental Protection (LGEEPA, in Spanish) is still pending. The LGEEPA does mention the "landscape" concept from an aesthetic standpoint as part of the establishment of Natural Protected Areas (article 47 bis, Fracc. II, section e); however, it includes neither a comprehensive vision of landscape as an environmental entity, nor the relationship with connectivity, biological corridors, ecosystems, and conservation of flora and fauna. The only federal law that defines biological corridors and refers to ecological connectivity is the General Law on Climate Change, issued on 6 June 2012. The General Wildlife Law (LGVS, in Spanish), issued in 2000 and with its latest amendment published in 2020 (SEMARNAT 2021), was the first of its kind to address the establishment of biological corridors within the framework of Management Units for Wildlife Conservation (UMAs, in Spanish); however, no legal policies were developed for the protection and conservation of biological corridors addressing the displacement of mammals or other wildlife species.

México is committed to preserving ecosystems and their connectivity by 2030 in response to the international agreements signed regarding a Sustainable Development, particularly in relation to biodiversity conservation, as part of the Aichi targets on the Strategic Plan for Biodiversity 2011-2020, through the document "National Vision for Integrated Landscape Management and Connectivity", intended to build a national policy of integrated landscape management and connectivity under a coordinated approach (SEMARNAT 2017). However, no regulatory framework in the legal system is still available that mandates the construction of artificial corridors (herein referred to as wildlife passages on roads and railways) as a measure to foster connectivity and reduce fragmentation caused by such infrastructure.

Location, design, construction, and monitoring initiatives such as those presented in the Manual for the Design of Road Wildlife Passages (SCT 2021) are essential to standardize monitoring activities and eventually define the efficiency and effectiveness of the different types and sizes of passages, as well as the economic profitability of the construction in terms of conservation and recovery of ecological connectivity. There have been some legislative initiatives promoting the regulation of these topics in road construction. An example is the one addressed by Deputy G. E. Ralis Cumplido in 2018: "That amends article 2 and adds article 25 Bis to the Law of Roads, Bridges, and Federal Motor Transportation in 2018" and "With an agreement, by which the SCT is encouraged to issue, with the support of SEMARNAT, the Mexican Official Standard (NOM, in Spanish) that sets forth the technical specifications to build wildlife passages on federal roads and highways". Another is the initiative of 25 March 2021, where the Chamber of Deputies unanimously approved the "Addition of article 22 Bis to the Law of Roads, Bridges, and Federal Motor Transportation, which establishes that for the construction of new roads and highways, as well as in the modernization of the existing ones, the Secretariat of Communications and Transport, seeking the protection and conservation of ecosystems, shall include the implementation of fauna crossings in its design and conservation plan". The latter was forwarded to the United Commissions on Communications and Transport and Legislative Studies of the Senate on 6 April 2021 and is currently pending approval in the Senate. In both instances, the agreements that establish mandatory technical guidelines for implementing the construction of fauna passages from the planning stage of roads, as a necessary measure to reduce fragmentation and foster connectivity in landscape and ecosystems, have not yet permeated the Mexican legislation.

Although the implementation of wildlife passages in road infrastructure is a growing trend worldwide, México currently lacks regulations and public policies in this regard. Therefore, initiatives should be put forward to develop the corresponding legal framework aimed at building increasingly sustainable road projects in the country. A first step taken in this direction is the development of the first Manual for the Design of Road Wildlife Passages (SCT 2021); this document is expected to serve as a guide from the project planning and decision-making stages regarding the design, types, and number of wildlife passages, to the evaluation and monitoring of their effectiveness and efficiency.

Also, additional studies should be conducted on the efficiency, effectiveness, and role of wildlife passages in the conservation and recovery of connectivity, biodiversity, and associated environmental services on which we all depend. The "wildlife passage" figure should be institutionalized in the respective regulatory bodies in a coordinated and integral manner, aiming to promote the creation of sustainable projects in México.

Literature cited

Abra, F. D., *et al*. 2019. Pay or prevent? Human safety, costs to society and legal perspectives on animal-vehicle collisions in São Paulo state, Brazil. Plos One 14:1-22.

Arroyave, M. D. P., *et al*. 2006. Impactos de las carreteras sobre la fauna silvestre y sus principales medidas de manejo. Revista EIA 5:45-57.

Ascensão, F., *et al*. 2021. Preventing wildlife roadkill can offset mitigation investments in short-medium term. Biological Conservation 253:1-9.

Bartkowski, B., N. Lienhoop, and B. Hansjürgens. 2015. Capturing the complexity of biodiversity: A critical review of economic valuation studies of biological diversity. Ecological Economics 113:1-14.

Balvanera, P., *et al*. 2009. Estado y tendencias de los servicios ecosistémicos. Pp. 185-245 *in* Capital Natural de México.

Volumen II: Estado de conservación y tendencias de cambio (Sarukhán, J., R. Dirzo, R. González, and I. March, eds.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México City, México.

Bissonette, J. A., and W. Adair. 2008. Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. Biological Conservation 141:482-488.

Clevenger, T. 2007. Highways Through Habitats: The Banff Wildlife Crossings Project. TR NEWS 249:14-17.

Conservation corridor. 2020. Connecting Science to Conservation. https://conservationcorridor.org/. Accessed November 22, 2021.

Correa, A., *et al*. 2016. Habitat connectivity in biodiversity conservation: A review of recent studies and applications. Progress in Physical Geography 40:7-37.

Daigle, P. 2010. A summary of the environmental impacts of roads, management responses, and research gaps: A literature review. Journal of Ecosystems and Management 10:65-89.

Fischer, J., and D. B. Lindenmayer. 2007. Landscape modification and habitat fragmentation: a synthesis. Global ecology and biogeography 16:265-280.

Hilty, J., *et al*. 2020. Guidelines for conserving connectivity through ecological networks and corridors. Best Practice Protected Area Guidelines Series No. 30. IUCN. Gland, Switzerland.

Instituto Nacional de Estadística y Geografía (INEGI). 2017. Conjunto de datos vectoriales de la carta de Uso del suelo y vegetación. Escala 1:250 000. Serie VI. Conjunto Nacional. Instituto Nacional de Estadística y Geografía. México City, México.

Iuell, B. 2003. Wildlife and Traffic: A European handbook for identifying conflicts and designing solutions en The XXIInd PIARC World Road Congress World Road Association-PIARC. https://www.miteco.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/cost341-handbook_tcm30-195789.pdf. Accessed September 28, 2020.

Lee, T., R. Ament, and T. P. Clevenger. 2013. Trans-Canada Highway and Dead Man's Flats Underpass: Is Highway Mitigation Cost Effective? In 2013 International Conference on Ecology and Transportation (ICOET 2013) Federal Highway Administration Arizona. Department of Transportation Arizona. Game and Fish Department. USDA Forest Service North Carolina State University. Raleigh, U.S.A.

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and human well-being: wetlands and water Synthesis. World Resources Institute. Washington, D. C., U.S.A.

López-Feldman, A. J. 2012. Deforestación en México: Un análisis preliminar. Centro de Investigación y Docencia Económicas A. C. México City, México.

Maass, M., and M. Equihua. 2015. Earth stewardship, socioecosystems, the need for a transdisciplinary approach and the role of the International Long Term Ecological Research Network (ILTER). Pp. 217-233 *in* Earth Stewardship (Rozzi, R., F. StuartChapin III, J. Baird Callicott, S. T. A. Pickett, M. E. Power, J. J. Armesto, and R. H. May Jr., eds.). Springer. Cham, Switzerland.

Mendoza-Sánchez, J. F., and O. A. Marcos-Palomares. 2016. Observatorio de movilidad y mortalidad de fauna en carreteras en México. Publicación técnica, 454. Instituto Mexicano del Transporte. Querétaro, México.

Orijel, R. G., *et al*. 2008. Grupos funcionales. Capital Natural de México, I, 365-412. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México City, México.

Panthera. 2020. Plan Jaguar 2030: Plan Regional para la Conservación del felino más grande del continente y sus ecosistemas. https://static1.squarespace.com/static/5bf3393f5b409be1f882f5d4/t/5bf444b288251bf85f9456d3/1542735028351/Panthera_Jaguar2030Roadmap_ESP_Draft03.pdf. Accessed September 28, 2020.

Queiroz, C., *et al*. 2014. Farmland abandonment: threat or opportunity for biodiversity conservation? A global review. Frontiers in Ecology and the Environment 12:288-296.

Rytwinski, T., *et al*. 2015. Experimental study designs to improve the evaluation of road mitigation measures for wildlife. Journal of Environmental Management 154:48-64.

Rytwinski, T., *et al*. 2016. How effective is road mitigation at reducing road-kill? A meta-analysis. Plos One 21:1-25.

Sarukhán, J. 2017. Capital natural de México, síntesis (actualizada a 2017): evaluación del conocimiento y tendencias de cambio, perspectivas de sustentabilidad, capacidades humanas e institucionales. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México City, México.

Secretaría de Comunicaciones y Transportes (SCT). 2021. Manual De Diseño De Pasos Para Fauna Silvestre En Carreteras. Secretaria de Telecomunicaciones y Transporte. https://www.sct.gob.mx/fileadmin/DireccionesGrales/DGST/Manuales/Manual_de_Fauna/ManualPasosparaFauna.pdf. Accessed December 3, 2020.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), *et al*. 2017. Visión Nacional de Manejo Integrado del Paisaje y Conectividad. México City, México. https://www.biodiversidad.gob.mx/corredor/cobiored/images/2016/VNMIPVersionFINAL.pdf. Accessed September 28, 2021.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 2021. Ley General de Vida Silvestre. Publicada el 3 de julio de 2000 en el Diario Oficial de la Federación. Última reforma publicada el 29 de abril del 2020. https://www.dof.gob.mx/nota_detalle.php?codigo=5610325&fecha=25/01/2021. Accessed October 20, 2021.

Seiler, A. 2001. Ecological effects of roads: a review. Uppsala: Swedish University of Agricultural Sciences. Riddarhyttan, Switzerland.

Sijtsma, F. J. *et al*. 2020. Ecological impact and cost-effectiveness of wildlife crossings in a highly fragmented landscape: a multi-method approach. Landscape Ecology 35:1701-1720.

Tsunokawa, K., and C. Hoban. 1997. Roads and the environment: a handbook. The International Bank for Reconstruction and Development. Washington, D. C., U.S.A.

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