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Drainage culverts as a measure to avoid mammal roadkills in Costa Rica: the case of *Dasyprocta punctata*

Estructuras de drenaje como medida para evitar la mortalidad por atropello de mamíferos en Costa Rica: el caso de *Dasyprocta punctata*

Michelle Monge-Velázquez[1]*, and Joel C. Sáenz[1]

[1]Instituto en Conservación y Manejo de Vida Silvestre, Universidad Nacional, 1350-3000. Heredia, Costa Rica. E-mail: mich.monge11@gmail.com (MM-V); jsaenz@una.cr (JCS).
*Corresponding author

Wildlife passages are structures that connect habitats, populations and reduce wildlife mortality. In places with no road mitigation, wildlife can resort to using underground structures called drainage culverts to prevent direct road-crossing. To determine which mammal species generally benefit from these structures, we placed camera traps in 6 drainage culverts and compare the number of road-killed species by vehicle tours along a 30 km segment of the North Inter-American Highway in Costa Rica. We detected 14 mammal species using drainage culverts as wildlife passages. The Central American agouti (*Dasyprocta punctata*) showed the highest number of records. The absence of *D. punctata* roadkill records and the high culvert use rates suggests that these structures may be effective in roadkill mitigation for this species, allowing them to cross safely from one forest patch to another.

Key words: Animal behaviour; Central American agouti; Pan-American Highway; road ecology; wildlife passages.

Los pasos de fauna son estructuras que conectan hábitats, poblaciones y reducen la mortalidad de la vida silvestre. En sitios donde no hay mitigación vial, la fauna puede recurrir a estructuras de drenaje subterráneas llamadas alcantarillas, para evitar el cruce directo por la carretera. Para determinar de manera general qué especies de mamíferos se ven beneficiadas por estas estructuras, colocamos cámaras trampa en 6 alcantarillas y comparamos cuantificando las especies de mamíferos que mueren atropelladas mediante recorridos en vehículo a lo largo de 30 km de la carretera Interamericana Norte en Costa Rica. Detectamos 14 especies de mamíferos utilizando las alcantarillas como pasos de fauna, siendo el agutí centroamericano (*Dasyprocta punctata*) la especie con mayor número de registros. La ausencia de registros de atropello de *D. punctata* y la alta tasa de uso de alcantarillas sugiere que estas estructuras pueden ser efectivas en la mitigación de atropellamiento para esta especie y son un medio para cruzar de un bloque boscoso a otro.

Palabras clave: Carretera Panamericana; comportamiento animal; ecología de carreteras; guatusa centroamericana; pasos de fauna.

Roads running through national parks have multiple effects on wildlife, with mortality due to road collisions being the most researched impact (Andrews 1990; Bennett 1999). The construction of wildlife passages, including underpasses, overpasses, and oversized drains, is one of the most popular measures to reduce animal-vehicle collisions (mitigation) and connect habitats fragmented by roads (Beckmann *et al.* 2010).

Some studies have determined that the effectiveness of this type of mitigation varies depending on the size of the structure, the building material, and the location of the construction (Forman *et al.* 2003; Langton 2015). In addition, this mitigation is not equally effective for all taxa, as species use structure designs differently (Clevenger and Waltho 2000). Most roads in Latin America lack mitigation structures (Pinto *et al.* 2020), so wildlife crossing from one side of the road to the other resorts to non-specialized structures such as drainage culverts. These culverts are short ducts built at road intersections with ravines, streams, or rivers, and are usually designed according to the expected water flow (Carmona 2013) rather than on the local wildlife species (Torres 2011). In this work, we compared the species richness of both road-killed mammals and mammals that use drainage culverts to travel across roads in a segment of the North Inter-American Highway, to determine the potential relationship between roadkill rate and use of drainage culverts.

The North Inter-American Highway is one of the two sections of the Pan-American Highway that crosses Costa Rica. The study area comprises a 30 km segment that goes from Tempisquito River (10° 48′ 56.58″ N, 85° 32′ 38.25″ W) to the Santa Cecilia crossing (11° 2′ 46.64″ N, 85° 37′ 35.30″ W). This section crosses the Guanacaste Conservation Area (ACG, in Spanish), a site comprising 163,000 ha of Protected Wildlife Area belonging to 2 national parks: Guanacaste and Santa Rosa (Janzen and Hallwachs 2016; Figure 1). Nineteen drainage culverts were observed in this segment of the Inter-American Highway crossing the ACG.

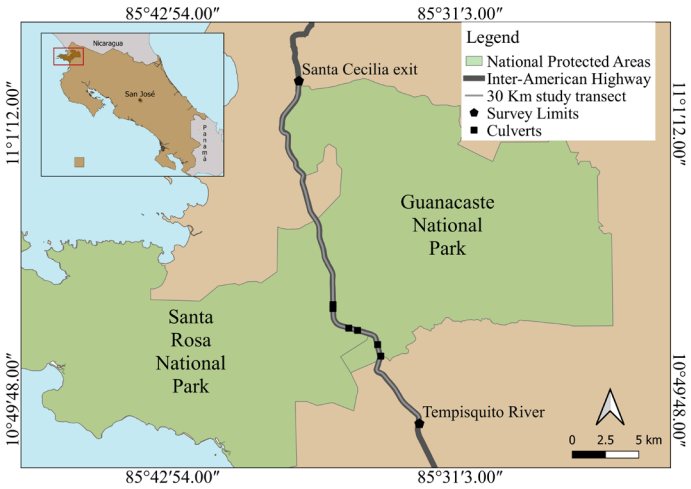

Figure 1. Study area (North Inter-American Highway) in Guanacaste, Costa Rica. The 30-kilometer segment used for road-killed mammal sampling is highlighted in grey, and black squares mark the location of culverts with a camera trap installed.

These structures vary in shape, building material, length, and number of entrances at each passage, and are used by multiple wildlife species (Torres 2011; Figure 2).

To identify the richness of species that use these structures, we placed one camera trap (SG570V; Scoutguard, Santa Clara, California) in 6 of the 19 underground culverts on the same road segment (Figure 1). Cameras were placed in culverts with low probability of flooding and theft, from November 2020 to September 2021. They were set to capture 2 photographs and a 5-second video when motion was detected through an infrared sensor, and remained operational 24 hours a day. An event was considered independent when the photograph or video had been captured 30 minutes apart from the next (O'Brien *et al.* 2003). The capture rate per species was calculated as the number of captures divided by the number of sampling days, multiplied by 100. To quantify the richness of road-killed species, we traveled the 30 km segment of the road in a vehicle with two observers at 25 km / hr. When a road-killed animal was spotted, we stopped the car to identify the species using field guides (Langen *et al.* 2007; Reid 2009) and recorded the event coordinates with a Garmin GPSMAP 64 (GPS). This procedure was performed for 3 consecutive days per month, from 19:30 to 22:00 hr and from 5:00 to 7:30 hr.

We captured 183 photographs of 14 mammal species using culverts as wildlife passages over 309 trap days. The species with the highest number of records (54 %) was the Central American agouti (*Dasyprocta punctata*), followed by the southern or black-eared opossum (*Didelphis marsupialis*), with 12 % of captures. On the other hand, we found 28 road-killed individuals of 14 mammal species, none of them belonging to *D. punctata* (Table 1).

Although the North Inter-American Highway lacks drainage culverts tailored to the local fauna, the absence of *D. punctata* roadkill records and the high culvert use rates suggest that these structures may be effective in roadkill mitigation for this species and allows crossing from one forest patch to another. This report is important since roads act as barriers for small and medium-sized mammals such as the Central American agouti, also affecting seed dispersal and forest regeneration (Lambert *et al.* 2014). Maintaining this connectivity is crucial as *D. punctata* is one of the main means of seed dispersal for many trees within its distribution range (Smythe 1978; Hallwachs 1986).

These results are consistent with those reported by Torres (2011), who also notes that the time of the day when these culverts are used by *D. punctata* is associated with the noise level on the road. Being a species with shy behavior (Smythe 1978), the agouti is expected to avoid roads due to traffic noise. According to the 2015 yearbook of traffic information (MOPT 2015), the North Inter-American Highway has an average daily traffic of 2,361 to 4,998 vehicles, which corresponds to a high-risk traffic level for wildlife (Clevenger *et al.* 2003).

Table 1. Number of photographs captured by camera traps placed in 6 drainage culverts and number of roadkill records in a 30-kilometer segment of the North Inter-American Highway, Costa Rica.

Species	Culvert use rate (% of captures)	Capture rate (No. of captures /No. of sampling days × 100)	Number of roadkill records
Dicotyles crassus	0.54	0.32	0
Odocoileus virginianus	1.09	0.32	0
Puma concolor	1.09	0.32	0
Nasua narica	1.09	0.64	1
Tapirella bairdii	1.09	0.64	1
Dasypus novemcinctus	2.18	1.29	1
Heteromys sp.	2.18	1.29	10
Cuniculus paca	2.73	1.61	0
Conepatus semistriatus	3.27	1.94	2
Leopardus pardalis	4.37	2.58	2
Saccopteryx sp.	4.37	2.58	3
Eira barbara	10.92	6.47	0
Didelphis marsupialis	12.02	7.11	8
Dasyprocta punctata	54.09	32.03	0

Figure 2. Culverts or drainage structures built on the 30-kilometer segment of the North Inter-American Highway. These structures are built according to the rivers and streams running across roads, rather than to animals that may cross the road.

Although culverts may play a mitigating role for *D. punctata*, building and adapting proper drainage in the underground sewer system is required. It has been reported that some species do not cross if the terrain is flooded or uneven (Jochimsen *et al.* 2004), as in the case of the structures in the study site. In addition, other taxonomic groups with high mortality rates, such as the cane toad (*Rhinella horribilis*) and other amphibian species not included in this note, are unable to detect the presence of nearby culverts to walk towards it (Bouchard *et al.* 2009; Cunnington *et al.* 2014). Hence, building and adapting culverts with accessory structures such as barrier fencing (2 – 2.5 m high wire mesh fences running parallel to the road; Littlewood *et al.* 2020) are essential to benefit other fauna species.

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