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Road-killed leucistic opossum (*Didelphis virginiana* Kerr 1792) in the municipality of Lázaro Cardenas, Quintana Roo, México

Tlacuache de virginia (*Didelphis virginiana* Kerr 1792) con leucismo, atropellado en Lázaro Cárdenas, Quintana Roo, México

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Hypopigmentation, including albinism, leucism, piebaldism, and flavism, has been reported across all vertebrate groups. In the case of opossums of the genus *Didelphis*, hypopigmentation has been documented in the United States, Mexico, Colombia, Panama, and Brazil. We conducted a photo-trapping monitoring associated with the Nuevo Xcan–Playa del Carmen highway (July 2016–July 2017) crossing structures, together with opportunistic roadkill surveys as an additional source of information for the project. On March 11, 2017, at 15:44 h, between the towns of Agua Azul and Juárez (20°50'18.36" N / 87°19'30.75"W) in the municipality of Lázaro Cárdenas, Quintana Roo, Mexico, we found a road-killed adult male opossum (*Didelphis virginiana*) with leucistic coloration. This record adds to the other hypopigmented opossums reported for the Yucatan Peninsula in Mexico. Survival of hypopigmented individuals may be related to the whitish karstic soil (sascab in Maya), which could make their coloration less deleterious than in more contrasting environments. Chromatic disorders such as leucism are rare in wild populations and are often considered deleterious. However, depending on the environmental context, they may not entail significant disadvantages.

Key words: Chromatic disorder; highway; hypopigmentation; leucism; Yucatán Peninsula.

La deficiencia de melanina conocida como hipopigmentación puede causar desórdenes cromáticos como albinismo, leucismo, piebaldismo e hipomelanismo, todos reportados en los distintos grupos de vertebrados. En el caso de tlacuaches del género *Didelphis*, la hipopigmentación ha sido reportada en EUA, México, Colombia, Panamá y Brasil. Se llevo a cabo un monitoreo de mamíferos silvestres mediante la técnica de foto-trampeo (Julio 2016 a Julio 2017) y monitoreo carretero no sistemático para evaluar el uso de estructuras de paso de fauna y atropellamiento asociado a la autopista Nuevo Xcan-Playa del Carmen. Un macho adulto de tlacuache de virginia (*Didelphis virginiana*) con leucismo fue encontrado el 11 de marzo de 2017 a las 15:44 hr, atropellado entre los poblados de Agua Azul y Juárez (20° 50' 18.36" N / 87° 19' 30.75" W), municipio de Lázaro Cárdenas, Quintana Roo, México. Este registro se agrega a otros desórdenes cromáticos reportados en tlacuaches para la Península de Yucatán en México. La sobrevivencia de animales hipopigmentados puede estar vinculada a las condiciones del suelo kárstico (sascab en maya), que es de color blanquecino, por lo que les resulta menos deletéreo que en otros entornos más contrastantes. Los desórdenes cromáticos como el leucismo son algo poco común en las poblaciones silvestres y pueden representar algo deletéreo o no, dependiendo del contexto en el que ocurran.

Palabra clave: Carretera; Desorden cromático; hipopigmentación; leucismo; Península de Yucatán.

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Mammalian coloration is far from a trivial trait. To date, camouflage appears to be the primary explanation for overall coloration, whereas localized patches of colored fur are generally associated with intraspecific signaling (Caro 2005). Background matching may account for the white pelage, while black-and-white combinations are often associated with aposematism and conspecific signaling. Contrasting coloration can play a significant role in crypsis, mainly through mechanisms such as pattern blending and disruptive coloration, among other functions (Caro 2009). Additionally, Gloger's ecogeographical rule associates darker coloration with more humid environments. As Delhey (2019) points out, the two most plausible mechanisms underlying this pattern are camouflage and protection against parasites or pathogens, with the latter potentially involving pleiotropic effects on the immune system.

Chromatic disorders in mammals result from either excess (hyperpigmentation or melanism) or a deficiency (hypopigmentation) of melanin (Abreu *et al.* 2013). Hypopigmentation disorders include albinism, leucism, piebaldism, and hypomelanism (such as flavism, erythrism, and rufism). Albinism is an inherited condition characterized

by a complete lack of melanin due to the absence of enzyme tyrosinase. Leucism is a condition characterized by a total or partial loss of pigmentation throughout the body, resulting in a white, whitish, or yellowish appearance. This condition is caused by a recessive gene that inhibits melanin synthesis, although it rarely affects hairless areas, such as the nose, feet, and other exposed skin, and it never alters the pigmentation of the iris (Miller, 2005). As a result, the eyes and/or extremities may retain their original coloration (Fertl and Rosel 2002; Miller 2005; Acevedo and Aguayo 2008). Piebaldism is characterized by localized areas of depigmentation resulting from the absence of melanocytes in affected skin and hair follicles, typically caused by mutations in several genes (Lamoreux *et al.* 2010). Hypomelanism results in hair varying shades of red or yellow, while eye coloration remains unchanged. This condition is linked to the synthesis of pheomelanin and may be caused by mutations that affect melanin biosynthesis, pigment granule trafficking, or membrane sorting (Lucati and López-Baucells, 2017).

These conditions are generally considered rare in wild populations (Abreu *et al.* 2013), as they are often associated with various pathologies, including visual (Pérez-Carpinell *et al*. 1992; Grant *et al*. 2001; Garipis and Hoffmann 2003) and immunological defects (Carretero *et al*. 2009; Summers 2009). Hypopigmentation may increase an individual's conspicuousness, thereby raising susceptibility to predation (Krecsák 2008). Conversely, in some cases, it may reduce predation risk if predators exhibit neophobia, or fear novel stimuli (Mappes *et al*. 2005)

Hypopigmentation conditions have been documented across all major vertebrate groups in the Neotropics (Abreu *et al*. 2013), including fish (e.g., Wakida-Kusunoki *et al.* 2022; Paschoal *et al*. 2024), amphibians (e.g., Sanabria *et al.* 2010; Valdez-Villavicencio and Peralta-García 2014), reptiles (e.g., Silva *et al*. 2010; de Noronha *et al*. 2013; Sosa-Cornejo *et al*. 2022), birds (e.g., Ayala-Pérez *et al.* 2013; Reséndiz-Cruz and Caballero-Jiménez 2016; Palacios-Vázquez 2016; Salgado-Flores and Rodríguez-Ruiz 2022), and mammals (e.g., López-González 2011; Camargo *et al.* 2014; Arriaga-Flores *et al.* 2016; Lucati and López-Baucells 2017; Ramos-Luna *et al.* 2022). In Mexico, several cases have been reported in bats (see Uieda 2000), including albinism in the common vampire bat (*Desmodus rotundus*, Uieda 2001; Ramírez *et al.* 2010), piebaldism in the common fruit bat (*Artibeus jamaicensis*, Sánchez-Hernández *et al*. 2010), and leucism in Waterhouse's leaf-nosed bat (*Macrotus waterhousii*), the free-tailed bat (*Tadarida brasiliensis*), the common fruit bat (*A. jamaicensis*, Sánchez-Hernández *et al.* 2012), and the ghost-faced bat (*Mormoops megalophylla*, Hernández-Aguilar and Santos-Moreno 2018). Other documented cases in carnivores include the coyote (*Canis latrans*, López-González 2011) and the neotropical otter (*Lontra longicaudis annectens*, Arriaga-Flores *et al*. 2016), as well as in primates such as howler monkeys (Ramos-Luna *et al*. 2022) and marine mammals like dolphins (Ortega-Ortiz *et al*. 2022), to name a few.

In opossums (order Didelphimorphia), hypopig-0mentation has been reported in Brazil (*Didelphis marsupialis*, Abreu *et al*. 2013), Colombia (*D. marsupialis*, Hoyos et al. 2020), Panama (*Caluromys derbianus*, Fuentes *et al*. 2024), and Mexico. In Mexico, cases have only been documented on the Yucatán Peninsula, including an albino *D. virginiana* (Cuxim-Koyoc *et al*. 2020) and a case of flavism (characterized by cinnamon-colored fur in *Didelphis* sp.; Tenorio-Rodríguez *et al*. 2024). This is particularly notable given that opossums (genus *Didelphis*, Linnaeus, 1758) are widespread and relatively common across Mexico, occurring in nearly all states except for the Baja California Peninsula and some arid regions bordering the United States and the Central Plateau (Ceballos *et al*. 2002; Gardner and Sunquist 2003). On the Yucatán Peninsula, *Didelphis* is represented by two sympatric species, *D. marsupialis* and *D. virginiana*, with populations of *D. virginiana* appearing to dominate the northern region over *D. marsupialis* (Jones *et al*. 1974; Ruiz-Piña and Cruz-Reyes 2002).

Populations of *D. virginiana* in the Peninsula may correspond to the subspecies *D. v. yucatanensis* (Gardner 1973; MacManus 1974), which is reportedly smaller than *D. v. californica*, although both subspecies share the same coloration pattern (Gardner 1973): dichromatic, with a common dark phase characterized by black legs, feet, and ears; extensive black pigmentation on the tail; dark body coloration extending forward over the top of the head forming a wedge between the eyes; darker sides of the head and neck; and a prominent ocular stripe extending from in front of the eye to a pale spot at the base of the ear, distinctly outlining the white cheek area. If local populations are small, isolated, and subject to inbreeding, we might expect an increased frequency of developmental abnormalities, including coloration disorders (MacManus 1974).

Here, we presented the first documented case of leucism in *Didelphis virginiana* and the third recorded case of hypopigmentation for this species in the Yucatán Peninsula.

We conducted a photo-trapping survey targeting medium- to large-sized mammals associated with the wildlife crossing structures (pipes, box culverts, and wildlife underpasses) along the Nuevo Xcan–Playa del Carmen Highway, located in the municipalities of Solidaridad and Lázaro Cárdenas, Quintana Roo, Mexico. The region is predominantly flat, with an elevation ranging from 5 to 10 meters above sea level. The climate is warm and sub-humid, with annual mean temperatures ranging from 26°C to 33°C, and an average annual precipitation of approximately 1,300 mm, concentrated primarily between June and October (INEGI 2017). The natural vegetation in the area consists of subperennial evergreen forest at various stages of succession (Rzedowski 2006).

We set up 28 monitoring stations that continuously operated from July 2016 to July 2017. Cameras were placed approximately 50cm above the ground in the middle section inside the crossing structure, perpendicular to

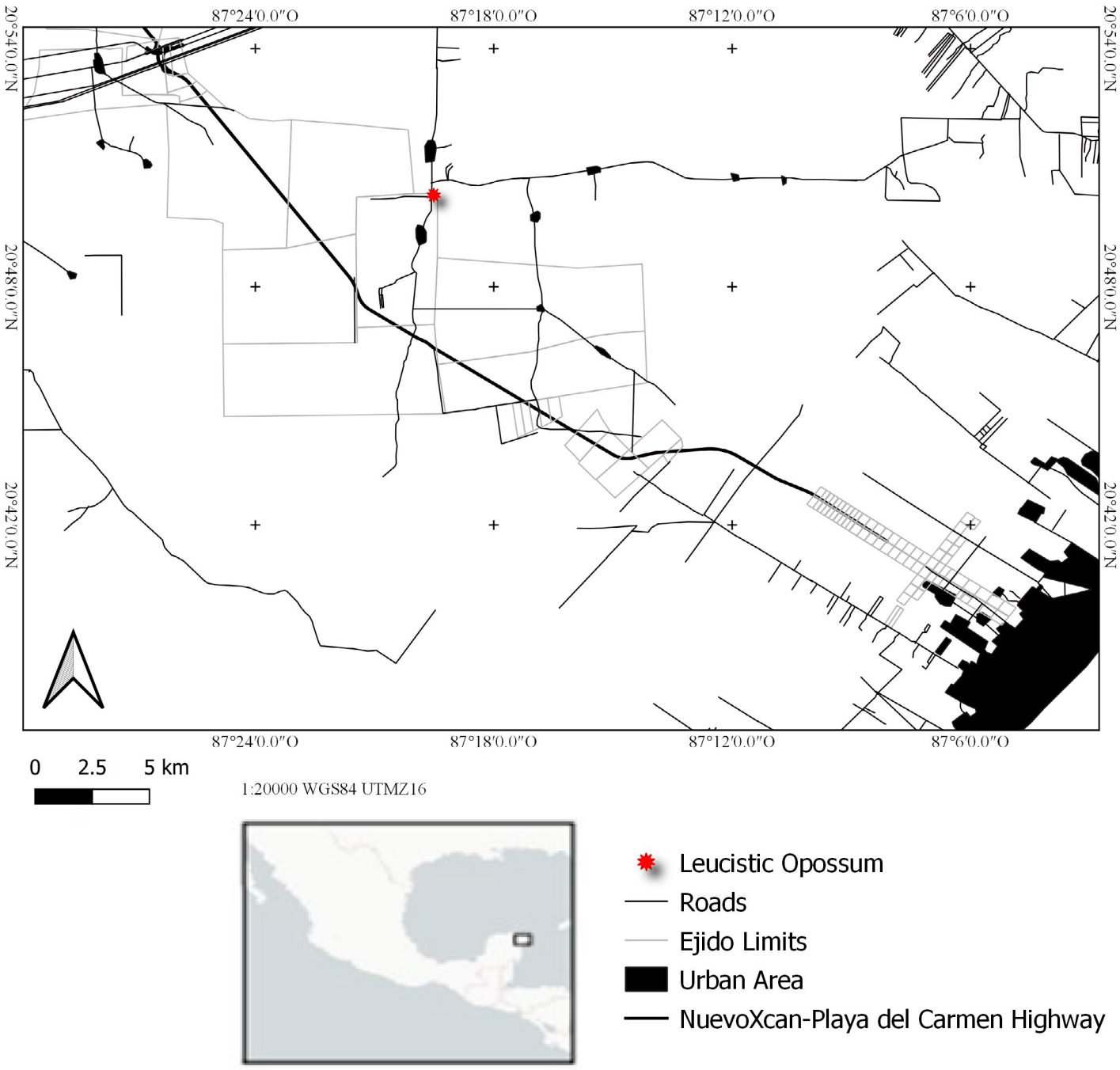

Figure 1. Location of the roadkilled leucistic opossum (*Didelphis virginiana*) in the municipality of Lázaro Cárdenas State of Quintana Roo, México.

the entrance aimed at photographing all passing animals (González-Gallina *et al.* 2018). We considered a camera night a 24-hour period during which the camera was operating. Sampling effort per station was obtained by counting the days the camera was active subtracting days when the camera was not functioning and total sampling effort as the added number of camera nights for each station (Ramesh and Downs 2015).

As part of the project, we also recorded opportunistic observations of road-killed animals encountered while traveling between photo-trapping stations by vehicle. When the condition of the carcasses permitted, individuals were identified to species level using specialized field guides (Reid 2009). To differentiate *Didelphis virginiana* from *D. marsupialis*, we relied on diagnostic features such as cheek coloration, whisker color on the muzzle and cheeks, tail length, and the proportion of the tail covered in dark pigmentation. For each observation, we recorded the GPS location and took reference photographs. In the case of photo-trapping data, individuals of the genus *Didelphis* (*D. marsupialis* and *D. virginiana*) were grouped into a single category, as distinguishing between the two species was not feasible in most photographs.

On March 11, 2017, at 15:44 h, we documented a road-

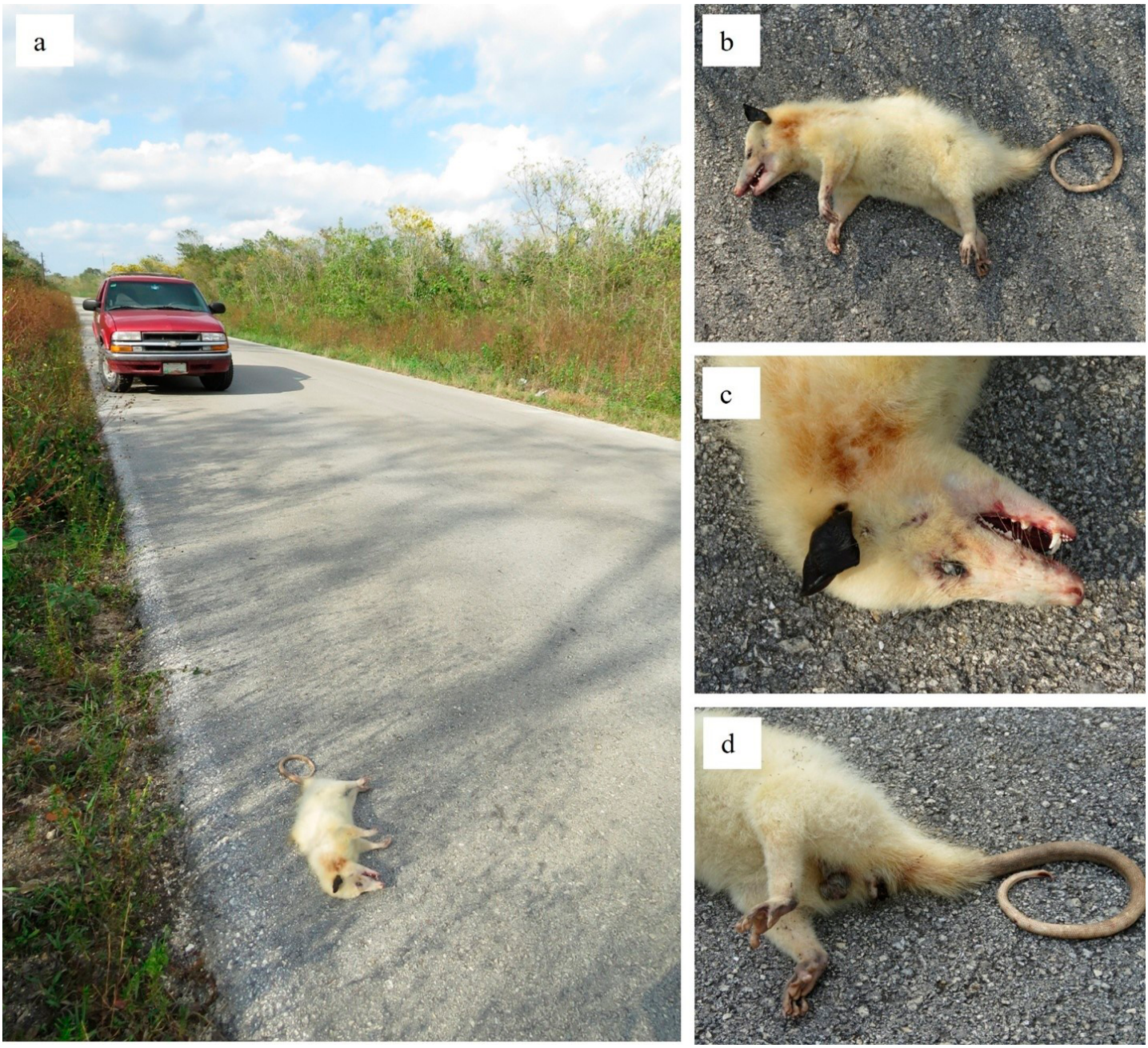

Figure 2. a) Photograph of the leucistic male opossum (*Didelphis virginiana*) that was found road-killed between the towns of Agua Azul and Juárez, in the municipality of Lázaro Cárdenas, Quintana Roo. The surrounding vegetation consisted of secondary growth from subperennial evergreen forest. Close-up images include b) the entire body, c) the head, which allows for observation of the uniformly colored whiskers and dark ears—traits indicative of an adult—and d) the tail, which exhibits a more significant proportion of dark coloration than white and is shorter than the body length, a diagnostic feature distinguishing *D. virginiana* from *D. marsupialis*. The presence of testicles confirms that the specimen is male.

killed adult male opossum (*Didelphis virginiana*) with leucistic coloration along the highway connecting the Mérida–Cancún freeway with the town of Juárez, between the villages of Agua Azul and Juárez (20°50′18.36″ N / 87°19′30.75″ W) (Figure 1). While traveling this route, we encountered the specimen and examined it for diagnostic characteristics to distinguish between *Didelphis* species. These included uniformly white whiskers and a tail shorter than the body length, with the dark portion of the tail longer than the white portion—though in this individual, the contrast was less conspicuous (Figure 2)—allowing for identification as *D. virginiana*. The specimen appeared relatively fresh and based on the degree of rigor mortis and overall condition, we estimated that it had likely died during the night of March 10 because of a vehicle collision. This was the only individual exhibiting abnormal coloration that we encountered during our entire photo-trapping survey in the area.

In addition to this observation, during the survey, we recorded other roadkill specimens, including two opossums (*Didelphis marsupialis*), two gray foxes (*Urocyon cinereoargenteus*), two coatis (*Nasua narica*), and one Yucatán squirrel (*Sciurus yucatanensis*).

Throughout 10,166 camera trap nights, we obtained 33 records of *Didelphis* spp. using underpass structures

to cross the highway. Of these, nine were inside wildlife-specific crossing structures, 19 utilized box culverts, and five employed concrete pipes.

Pigmentation anomalies in natural populations of Neotropical mammals have been considered rare (Abreu *et al.* 2013). To provide local context, from November 2012 to July 2013, the consultancy SEGA S.A. de C.V. conducted biological monitoring along the Nuevo Xcan–Playa del Carmen highway (Hidalgo-Mihart *et al.* 2013). This effort involved 54 camera traps across 81 photo-trapping stations, resulting in a total of 7,937 trap-nights. Opossums (*Didelphis* spp., as the species are difficult to distinguish in photographs) emerged as a dominant species, with 325 independent records. Also, González-Gallina *et al.* (2018) reported an additional 36 records of *Didelphis*. Across both monitoring efforts—361 total records—only a single case of color abnormality was detected within the genus. This single record of a pigmentation anomaly through roadkill rather than photo-trapping shows that opportunistic highway surveys can yield important complementary records (González-Gallina *et al.* 2016).

Hypopigmented animals are generally more susceptible to fitness declines compared to hyperpigmented (melanic) individuals. The occurrence of hypopigmented wild mammals appears to be more frequent in areas with high levels of human activity, where fragmented populations are more prone to environmental stress and inbreeding (Guestalla *et al.* 2021; Cotts *et al.* 2024). This pattern may reflect underlying environmental conditions in the Yucatán Peninsula, as all reported cases of hypopigmentation in *Didelphis* from Mexico originate from this region. However, in our study area, low population, isolation and inbreeding are unlikely explanations, as *Didelphis* (including both *virginiana* and *marsupialis*) was the most abundant species recorded (Hidalgo-Mihart *et al.* 2013). Still, these genetic disorders are naturally occurring (sometimes by random mutations) but rare (Abreu *et al.* 2013) as in this case this record represents 0.28 of all records.

If white pelage is better explained by background matching (Caro 2009), we propose that the light-colored karstic substrate that characterizes much of the Yucatán Peninsula (Bautista *et al.* 2015) may play a role in the survival of these hypopigmented individuals. The local soil type, known as *sascab* (meaning "white dirt" in Maya), could favor them by reducing their detectability to predators, thus mitigating the fitness costs often associated with conspicuous coloration. In this context, the cryptic advantage provided by *sascab* may reduce the non-physiological (e.g., predation-related) adverse effects of hypopigmentation observed in other environments.

This could help explain how the albino opossum reported by Cuxim-Koyoc *et al.* (2020) reached adulthood despite likely visual impairments—limitations not typically present in leucistic individuals such as the one we report here. It might also account for our observation of a leucistic female great curassow (*Crax rubra*) captured during photo trapping in the same locality (Hidalgo-Mihart *et al.* 2013).

We suspect that color patterns in mammals may be influenced by both habitat characteristics and human-induced factors (Ausband and Krohner 2022). Further research is necessary to better understand how selective pressures related to habitat, life history, developmental stage, and season contribute to the evolutionary mechanisms underlying external coloration. To advance this understanding, it is necessary to compile enough records of chromatic disorders across a wide range of species and taxonomic groups worldwide. This would allow us to begin identifying potential environmental patterns and, importantly, to determine which variables may promote the occurrence of such chromatic anomalies in wild populations.

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