



## Altitudinal range extension of the nine-banded armadillo, *Dasypos novemcinctus* (Linnaeus, 1758) (Mammalia, Xenarthra), in Irazú Volcano National Park, Costa Rica

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**Abstract** The nine-banded armadillo (*Dasypos novemcinctus*) is a widely distributed species throughout North and South America, however its distribution has been restricted by latitude and altitude due to cold temperatures. The maximum reported altitude for the nine-banded armadillo is between 2000–3000 m asl; hence, new records at high elevations might suggest range shifts. Here we report video evidence of a nine-banded armadillo at 3400 m asl near the summit of the Irazú volcano in Costa Rica, which extends upwards the previously known elevation range by 300 m. We speculate this altitudinal range extension is indicative of regime shifts of ecosystems due to climate variability in response to rising temperatures, such as previously reported for several species.

**Keywords:** cloud forest, distribution, Neotropics, páramo, small mammals, xenarthrans

**Extensión altitudinal del área de distribución del armadillo de nueve bandas, *Dasypos novemcinctus* (Linnaeus, 1758) (Mammalia, Xenarthra), en el Parque Nacional Volcán Irazú, Costa Rica**

**Resumen** El armadillo de nueve bandas (*Dasypos novemcinctus*) es una especie ampliamente distribuida por Norteamérica y Sudamérica, aunque su distribución se ha visto restringida por la latitud y la altitud debido a las bajas temperaturas. La altitud máxima registrada del armadillo de nueve bandas es de 2000–3000 msnm, por lo que nuevos registros a grandes altitudes podrían sugerir modificaciones en su rango. Aquí reportamos evidencia en video de un armadillo de nueve bandas a 3400 msnm, cerca de la cima del volcán Irazú en Costa Rica. Este registro extiende el rango de elevación previamente conocido en 300 m. Especulamos que esta extensión del rango altitudinal es indicativa de cambios en el régimen de los ecosistemas debido a la variabilidad climática en respuesta al aumento de las temperaturas, tal como se reportó previamente para varias especies.

**Palabras clave:** bosque nuboso, distribución, Neotrópico, páramo, pequeños mamíferos, xenartros

### INTRODUCTION

The nine-banded armadillo (*Dasypos novemcinctus*) is a common species throughout North and South America. It has a wide range from the southern United States to as far south as northern Argentina (Humphrey, 1974; McBee & Baker, 1982; Gardner, 2008; Abba & Vizcaíno, 2011; Loughry & McDonough, 2013). The nine-banded armadillo

is the only xenarthran species that is undergoing significant northward range expansion (Aguiar & Fonseca, 2008). Over the last 150 years, the species historically resided in the warmer southern coastal area of the United States (Audubon & Bachman, 1849; Humphrey, 1974; McBee & Baker, 1982; Taulman & Robbins, 1996; Aguiar & Fonseca, 2008; Eichler & Gaudin, 2011). However, recently the

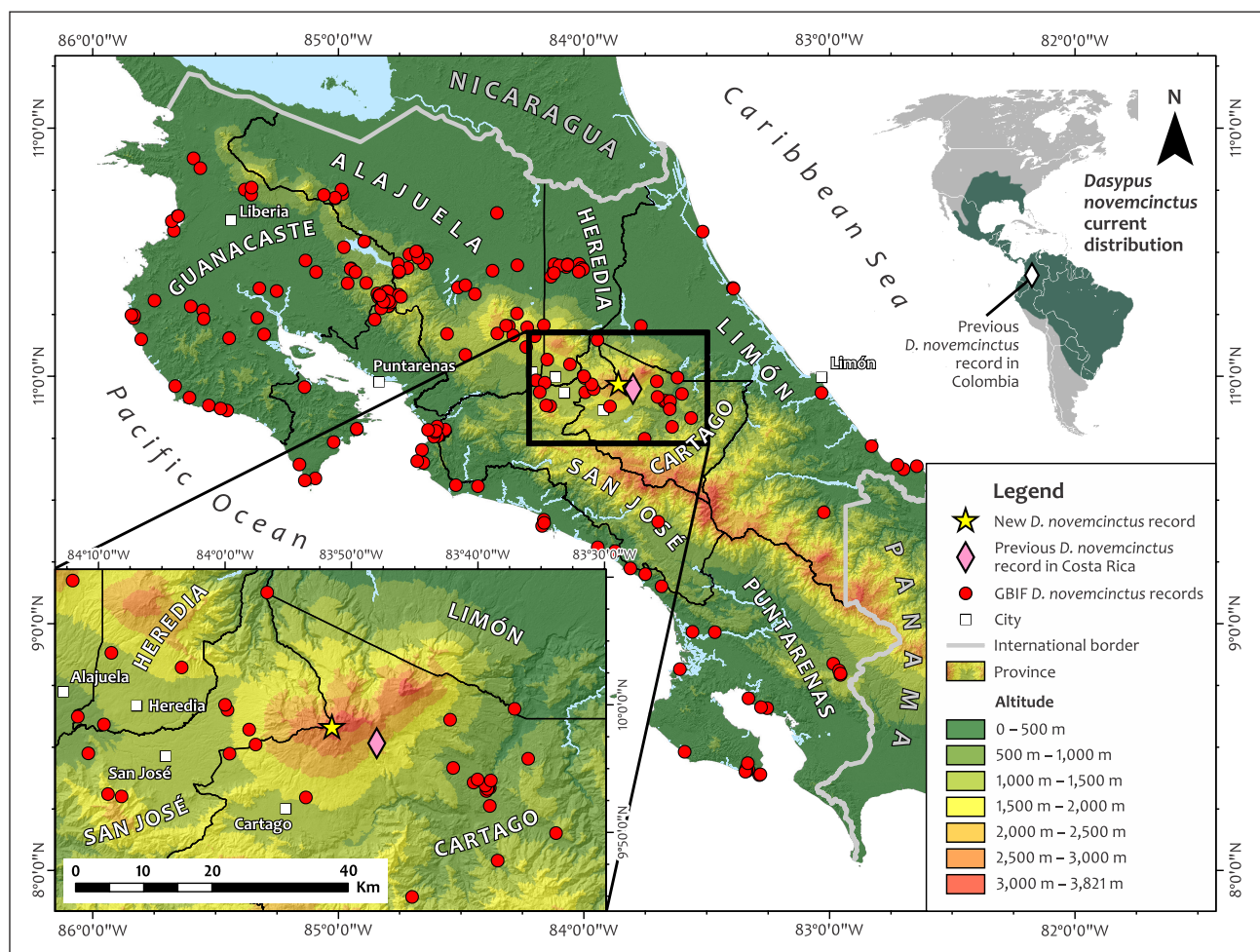
latitudinal range of the nine-banded armadillo has expanded from the southern coastal areas (western Texas, Louisiana, Alabama, Georgia, Mississippi, and Florida) to the central eastern states that include Illinois, Nebraska, Tennessee, New Mexico, Kansas, Missouri, Indiana, and South Carolina (Taulman & Robbins, 2014). On the other hand, their southward expansion has been limited due to competition with other armadillo species and harsher environments (Feijó *et al.*, 2020).

Among the xenarthrans, the nine-banded armadillo is an opportunist invader—an insectivore that inhabits disturbed habitats, secondary forests, scrubland, and human disturbed environments (Carrillo *et al.*, 1999; Loughry *et al.*, 2013, 2014). The nine-banded armadillo's reproductive plasticity and ability to colonize adjacent disturbed habitats makes it a successful invader of new environments (Eichler & Gaudin, 2011; Loughry *et al.*, 2013). Previous evidence suggests climate change could cause rapid shifts in species distributions (Pounds & Crump, 1994; Gillings *et al.*, 2015). Thus, rising temperatures may push a species to higher

altitudes in response to climate change, and species could colonize new habitats previously limited due to cold temperatures.

Costa Rica is a small country in Central America that covers only a small fraction of the land surface of the Earth, however it embraces approximately 5% of the world's known mammal species (SINAC, 2014). Moreover, knowledge of Costa Rican mammals is constantly being updated (Rodríguez-Herrera *et al.*, 2014; Ramírez-Fernández *et al.*, 2023). In spite of such updates, much still remains unknown, including the ecology and importance of xenarthrans. Knowledge of the nine-banded armadillo throughout Costa Rica is scarce and has been limited to their presence/absence and basic life history traits (Vaughan & Shoenfelder, 1999; Timock & Vaughan, 2002).

Nine-banded armadillos normally range up to 2000 m asl (Loughry *et al.*, 2014). The highest record was at 3100 m asl in Colombia (Alberico *et al.*, 2000; Rojas-Díaz, 2017; GBIF, 2023). Here we report a nine-banded armadillo at Irazú Volcano National Park in Costa Rica at 3400 m asl (**Fig. 1, 2**).



**FIGURE 1.** Records of the nine-banded armadillo (*Dasypos novemcinctus*) in Costa Rica and its overall distribution in North and South America (GBIF, 2023; Loughry *et al.*, 2014). The previous highest record from Colombia is shown, as well as the new one at 3400 m asl from Costa Rica.



**FIGURE 2.** Video evidence of nine-banded armadillo (*Dasypus novemcinctus*) from a camera trap placed at 3400 m asl in the Irazú Volcano National Park.

## MATERIALS AND METHODS

Our data were collected as part of a wider project aimed at monitoring coyotes (*Canis latrans*) in two study areas in Costa Rica: Guanacaste Conservation Area and the Central Conservation Area. One of the main objectives of the project was to monitor the fauna surrounding the Irazú and Turrialba Volcanoes in a 16 km<sup>2</sup> grid with 10 camera traps for a one-year period. The camera traps were set to record three picture bursts with one-minute intervals. An additional camera trap was placed at the summit of the Irazú Volcano to record in video mode, with the aim of monitoring the coyotes' social behavior.

We detected the nine-banded armadillo opportunistically with the use of camera traps (Brown-ing©, Morgan, USA; Strike Force model) located at the summit of the Irazú Volcano. The Irazú Volcano is a National Park (IVNP) and the highest active volcano in Costa Rica (3432 m asl). It also contains the northernmost patches of the Talamancan páramo, which is only located in Costa Rica and Panama (Kappelle & Horn, 2005).

## RESULTS

The photographic record of the nine-banded armadillo was obtained on 20 August 2022 (**FIG. 1**) at 9°58'14"N, 83°51'34"W, near the summit of the Irazú Volcano (**FIG. 2**; 3400 m asl). The nine-banded armadillo can be distinguished from the northern

naked-tailed armadillo (*Cabassous centralis*), the other armadillo species that occurs in Costa Rica, by the absence of a lighter tinge on the lower margin of the carapace and the dome-shaped carapace that is characteristic for *Dasypus* spp. (Carillo *et al.*, 1999).

## DISCUSSION

The nine-banded armadillo is a common species and its continuing range extension has been well documented in the United States (Humphrey 1974; Taulman & Robbins, 1996; Loughry & McDonough, 2013; Feng & Papes, 2015; Haywood *et al.*, 2021), but reports of altitudinal range extensions have been scarce. Our new elevational record for the nine-banded armadillo may be part of a growing pattern of shifts in species distribution resulting from an increase in climatically suitable areas due to climate change (Taulman & Robbins, 2014; Feng & Papes, 2015; Imbach *et al.*, 2018; Feijó *et al.*, 2020; World Bank Group, 2021). Global warming has presumably facilitated the northern expansion of the nine-banded armadillo in the U.S. from its historic range (Feijó *et al.*, 2020). Coupled with the behavioral and phenotypic plasticity of nine-banded armadillos, climate change has likely promoted colonization of new territories, such as those found at higher latitudes and elevations. With regard to altitude, it is possible that additional records of the nine-banded armadillo at high elevations have been missed because of low levels of monitoring at such sites.

For example, there have been multiple sightings of the nine-banded armadillo in the surrounding areas of the Irazú Volcano, such as the previous local altitude record for this species listed in the Global Biodiversity Information Facility (GBIF), which corresponds to an individual that was sighted at approximately 2600 masl (Carrillo *et al.*, 1999). During our study, we recorded nine-banded armadillos in several other camera traps deployed in close proximity to the new record: one near the main crater at ~3300 masl, and two around the foothills of the volcano at ~3000 masl. These multiple sightings of the nine-banded armadillos indicate that the species is thriving at much higher altitudes than previously reported.

Our record is the first of the nine-banded armadillo at 3400 masl. It is also the first observation of this species in high alpine ecosystems, such as the Talamancan páramo (Carrillo *et al.*, 1999). The altitudinal record is consistent with the life-history traits of the species as a generalist that inhabits many vegetation types in different conditions. Nine-banded armadillos are common in the forests surrounding Irazú Volcano National Park below 3100 m asl. These forests are composed of a heterogeneous mix of cloud forest oak (*Quercus* spp.), several species of exotic trees, such as eucalyptus (*Eucalyptus* spp.), pine (*Pinus pseudostrobus*), and cypress (*Cupressus lusitanica*), and are primarily surrounded by cattle farms (González, 2017). Other authors have reported that the nine-banded armadillo can also thrive in secondary forests and disturbed habitats near human developed areas (McDonough *et al.*, 2000; Dotta & Verdade, 2011; Bovo *et al.*, 2018; Ferreira & Garcia, 2018). Similarly, the elevational record we report is associated with areas that are a heterogeneous mix of human disturbed areas and patches of forests (González, 2017; Ferreira & Garcia, 2018). Although we have no records yet, we predict that the Talamancan páramo has a high probability of colonization by nine-banded armadillos in the near future.

The páramo ecosystem is characterized as high alpine scrubland with low-lying vegetation that is typically found in the northern Andes mountains (Kappelle & Horn, 2005). Coupled with a similar altitudinal record in Colombia of 3100 masl, we believe our new record represents a change in the distribution of the nine-banded armadillo, and propose that its distribution is not limited to lower and mid altitudes (Alberico *et al.*, 2000; Rojas-Díaz, 2017; GBIF, 2023). We recommend increased monitoring at higher elevations to provide more robust evaluations of nine-banded armadillo distributional changes. The Talamancan páramo is a temperature sensitive ecosystem that once limited the distributions of some species; however, today the warming of the planet and other environmental changes have altered these limits for some species.

## ACKNOWLEDGEMENTS

We thank the National University of Costa Rica (UNA), Sistema Nacional de Áreas de Conservación (SINAC), and Área de Conservación Central (ACC), especially the staff of the Ranger stations at the Irazú Volcano National Park and students who collaborated in the field work.

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Received: 19 December 2023; Accepted: 20 February 2024