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Altitudinal range extension of Long-tailed Singing Mouse, *Scotinomys xerampelinus* (Bangs, 1902) (Rodentia, Cricetidae), in Chirripó National Park, Costa Rica

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Abstract

Scotinomys xerampelinus has a restricted distribution in the Cordilleras Central and Talamanca of Costa Rica and western Panama, at an elevational range between 2100 and 3400 m. We report individuals observed at Cerro Chirripó, Costa Rica at 3820 m, which extends upwards the known elevational range by 420 m. The altitudinal range extension may indicate either incomplete surveys in the study area or an upslope shift due to increasing temperatures from climate change, a phenomenon that has forced several Costa Rican vertebrate species to transition to higher elevations.

Keywords

Cloud forest, montane rain forest, Neotropics, Páramo, rodents, small mammals

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Introduction

Biodiversity is distributed globally based on systematic patterns of spatial variation (Pianka 1989). In general, species richness tends to be correlated with latitude and elevation gradients, with the latter occurring across smaller spatial scales (Hillebrand 2004; McCain 2007; but see Wen et al. 2021). Several hypotheses have tried to explain these associations based on, for example, the effects of availability of energy or temperature on population dynamics coupled with the time available for the process of diversification to occur (Allen et al. 2002; Dyer et al. 2020). The complex interrelatedness of climate on trends in biodiversity has been recognized as important in altitudinal distributions (Brown 2001). Considering the changing global climate, it is urgent to understand how temperature changes affect all types of biological systems, from individuals to whole ecosystems

(Kontopoulos et al. 2020). At the same time, distributional changes of animal and plant species is a matter of great concern for biodiversity conservation (Mora and López 2014).

Costa Rica is a small country (51100 km^2) and covers only 0.034% of the land surface of the Earth. However, with over 250 mammal species, this country contains approximately 5% of the world's known mammal species (SINAC 2014). In the last two decades, knowledge of Costa Rican mammals has notably increased (Rodríguez-Herrera et al. 2014; Villalobos-Chaves et al. 2016; Mora et al. 2020), although much remains unknown. One of the least known groups in the country is rodents, and frequently even distributional limits of species are unknown (Rodríguez-Herrera et al. 2014). Only a few publications constitute the basis for knowledge of rodents and other mammals in Costa Rica. The pioneer publications by Frantzius (1869), Alfaro (1897), and Goodwin (1946) are among the most notable (Rodríguez-Herrera et al. 2005). At the beginning of the 1960s, the distributions of numerous species remained poorly known, notwithstanding the expansive application to Central America by Ryan (1963) of Dice's concept of biotic provinces (McPherson 1985). McPherson (1971a, 1971b, 1985) contributed greatly to the knowledge of the distribution ranges and ecological relationships of rodents in Costa Rica. The list of mammals of Costa Rica including new records and new information on distributional ranges of some species was later updated by subsequent authors (Wilson 1983; Mora 2000; Wilson et al. 2002; Rodriguez-Herrera et al. 2002, 2014). The most complete list of rodents of Costa Rica was published several years later (Villalobos-Chaves et al. 2016), and one additional rodent species, *Ichthyomys tweedii* Anthony, 1921, has been recently added (Ramírez-Fernández et al. 2020). However, all these publications include limited information and are concerned merely with presence/absence data; knowledge on the distributions of most rodents in Costa Rica is incomplete, and numerous gaps remain in the spatial distribution of most of small rodent species in the country.

Long-tailed Singing Mouse, *Scotinomys xerampelinus* (Bangs, 1902), is a cricetid rodent (Musser and Carleton 2005) which inhabits high elevations in the Cordilleras Central and Talamanca of southern Costa Rica and western Panamá between 2100 and 3400 m elevation (Naylor and Roach 2016). It is restricted to forests, meadows, and grasslands in two life zones in the high mountains: the montane rainforest and the páramo (Hooper and Carleton 1976). The páramo is a Neotropical high-mountain ecological association above the timberline consisting of ground cover by shrubs and grasses (Kappelle and Horn 2016). These two life zones are perennially wind-swept, cool, and draped in clouds or rain (Hooper and Carleton 1976). *Scotinomys xerampelinus* typically prefers areas having dense vegetative cover with mossy trunks, rocks, and dense fern cover (Bradley 2017). It is terrestrial and travels in runways under logs and among rocks (Hooper 1972). It is entirely diurnal and appears to eat only insects (Bradley 2017), mainly larval beetles which are probably located by smell (Reid 2009).

Males of *S. xerampelinus* are recognized by their vocalizations (Mora 2000) which they use to attract mates and to warn off other males from their territories (Pasch et al. 2013). Their songs also serve to repel a smaller, competing species, Alston's Singing Mouse, *Scotinomys teguina* (Alston, 1877) (Pasch et al. 2013). Long-tailed Singing Mouse is behaviorally dominant and excludes and abruptly replaces *S. teguina* at higher, cooler elevations (Hooper 1972; Hooper and Carleton 1976; Pasch et al. 2013). Here we report a new altitudinal record of Long-tailed Singing Mouse from the top of Chirripó mountain, Chirripó National Park, Costa Rica.

Methods

An unexpected encounter while visiting Cerro Chirripó, Parque Nacional Chirripó (PNC, Chirripó National Park in English) allowed us to photograph, measure, and release an individual *Scotinomys xerampelinus*. The PNC is located in the central section of the Cordillera de Talamanca (Veas-Ayala et al. 2018), a mountainous system with a southeast–northwest orientation that has the highest elevations in Costa Rica and separates the Caribbean plains from the lowlands of the Pacific slope (Bergoeing 2007). Cerro Chirripó is the highest summit in the country with an elevation of 3821 m (Alfaro and Gamboa 1999).

At approximately 3000 m elevation, the montane rainforest is replaced by the páramo ecosystem, which dominates the upper areas of the PNC. The páramo has an approximate extent of 6000 ha and temperatures can drop to −5 °C (Alfaro and Gamboa 1999). Páramo vegetation typically is composed of Dwarf Bamboo, *Chusquea subtessellata* Hitchcock, and there are small brooks, small, exposed boggy sites, and rock outcrops (Holz and Gradstein 2005). Marshes, meadows, expanses of bunch grass or bamboo, and thickets of shrubs, all are common in the páramo (Hooper and Carleton 1976).

We captured the mouse with a butterfly net and took measurements with calipers to the nearest 1 mm. We measured total head–body length, tail length, ear length, and foot length. We weighed the mouse with a spring scale. We compared eye sizes using photographs of the two species of *Scotinomys* occurring in Costa Rica. In addition, we reviewed records in the Global Biodiversity Information Facility (GBIF 2021), which mainly consisted of records from the Museum of Zoology of the University of Michigan (UMMZ), as well as the literature (Hooper 1972; Hooper and Carleton 1976; Reid 2009; Pasch et al. 2013; Naylor and Roach 2016; Bradley 2017).

To estimate the potential area occupied by *S. xerampelinus* in Costa Rica and Panama, we first calculated the area between 2100 and 3400 m elevation in the Cordillera de Talamanca and Irazú and Turrialba volcanoes in the Cordillera Central. These upper and lower elevational limits were based on historical records in the literature for *S. xerampelinus*. However, published elevations are only presence data and may not represent the actual elevational limits of this species. Second, we estimated the area within an elevational range of 3400–3820 m, which considers the extension of the upper elevational range in one part of the extremely limited extent of occurrence of this species (Naylor and Roach 2016). To estimate the extent of these areas of distribution, both previously known as well as our hypothesized increase vertical range, we used the topographic layers for Costa Rica (Ortíz-Malavassi 2015) and Panama (http://www.diva-gis.org/gdata). For the Costa Rican analysis, we filtered by elevation data from a vector shapefile, from 2100 to 3400 m and higher than 3400 m, and the area of each subset then estimated. For the analysis of Panamanian geographic data, we transformed a raster.vrt file into a vector shapefile. We extracted the 2100 and 3400 m contour lines, made a polygon from these limits, and then calculated the polygon's area. Both Costa Rican and Panamanian data sets were examined at the same scale to avoid errors resulting from varying scales. We used the QGIS v. 3.10.6-A (Coruña) for this geographical analysis (QGIS 2020).

Results

***Scotinomys xerampelinus* (Bangs, 1902)**
Figure 1

New record. COSTA RICA – **Limón** • Cordillera de Talamanca, Parque Nacional Chirripó, Cerro Chirripó; 09°29′04″N, 083°29′19″W; 3820 m a.s.l.; 02.VIII.2015; Jairo García Céspedes leg; highest point of the Cerro; individual measured but not collected; 1 adult, sex undetermined.

Comments. JGC measured and photographed a *S. xerampelinus* found at rocky terrain dominated by Dwarf Bamboo (Fig. 2). The mouse was at an elevation of 3820 m, the highest point of altitude in Parque Nacional Chirripó (Fig. 3). The mouse prowled around the visitors maybe waiting for food. One tourist fed it a small piece of bread that the mouse started to eat immediately. In the

Figure 1. A Long-Tailed Singing Mouse *Scotinomys xerampelinus* at Cerro Chirripó at 3820 m elevation, Parque Nacional Chirripó, Costa Rica. Photo by Jairo García Céspedes.

Figure 2. Páramo habitat at Cerro Chirripó (3820 m elevation). The dominant grass looking plant is Dwarf Bamboo, *Chusquea subtessellata*. Parque Nacional Chirripó, Talamanca, Costa Rica. Photo by Jairo García Céspedes.

vicinity, some meters below the highest point of Cerro Chirripó, we observed two additional mice of the same species.

Other data records. Individuals of Long-tailed Singing Mouse have been collected or seen at numerous localities throughout its geographic range. Some extreme elevation records for this species found online at the UMMZ and other collections in the GBIF database (GBIF 2021) are from Cerro de la Muerte (Costa Rica), at 3100 m elevation (UMMZ 111773, 112258, and at least nine more records), and five localities in the Cordillera de Talamanca, including Villa Mills and Cerro Asunción (Costa Rica). There are also several localities by the Turrialba and Irazú volcanoes (Costa Rica) up to 3300 m a.s.l. (UMMZ 116836 and at least 57 more records). Eleven additional localities are from lower elevations. Pasch et al. (2013) hypothesized that the elevational range extends to 3451 m in Cerro de la Muerte, 3432 m in Volcán Irazú, and 3474 in Volcán Barú (Panama).

Identification. The mouse observed at Cerro Chirripó weighted 14 g, had a head–body length of 82 mm, a tail length of 68 mm, ear length of 16 mm, and foot length of 19 mm; these measurements agree with those of *S. xerampelinus* (Reid 2009; Villalobos-Chaves et al. 2016). This chocolate-brown mouse differs from the congeneric *S. teguina* by having a proportionally longer tail, which is about 80–85% of the head–body length; longer fur, which appears fuzzy rather than smooth; and smaller eyes (Reid 2009).

The potential area occupied by *Scotinomys xerampelinus* at elevations between 2100 and 3400 m is about 2101 km^2 in Costa Rica and 557 km^2 in Panamá, for a total of 2658 km^2. Including the new locality at 3820 m, the potential distribution area increases by 53 km^2 to 2711 km^2 (Fig. 3).

Discussion

Although *Scotinomys xerampelinus* is hypothesized to be common (Reid 2009), Naylor and Roach (2016) correctly pointed out that the extent of occurrence of this species is probably less than 10,000 km^2. Despite this restricted distribution, the species is Least Concern "in view of its presumed large and stable population, occurrence in a number of protected areas, and because it does not appear to be under threat and is unlikely to be declining at nearly the rate required to qualify for listing in a threatened category" (Naylor and Roach 2016). However, based on our elevational range analysis and on museum records, we hypothesize that the area occupied by *S. xerampelinus* could be as small as 2711 km^2 (Fig. 3). Outside of the protected areas, there are threats to this species, including habitat loss and the increase of mesocarnivores such as Coyote, *Canis latrans* (Say, 1823), Tayra *Eira barbara* (Linnaeus, 1758), and other predators. The increase in predators, which may negatively impact small mammals such as *S. xerampelinus*, is due to human-induced habitat changes (Mora and Ruedas 2018; Hody et al. 2019).

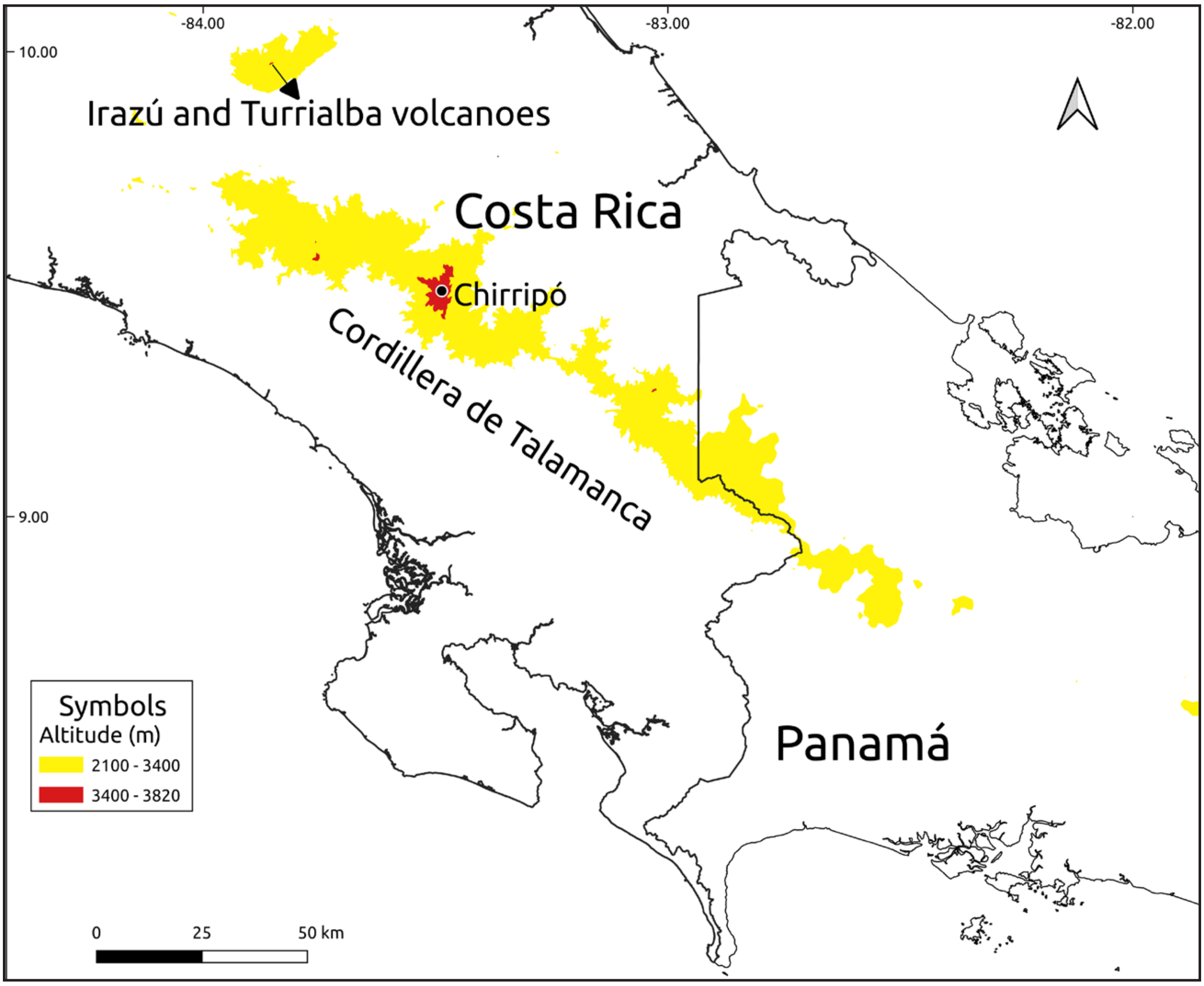

Figure 3. New altitudinal record (black dot) for the Long-tailed Singing Mouse (*Scotinomys xerampelinus*) at the top of Cerro Chirripó, Costa Rica. The yellow areas indicate lands between 2100 and 3400 m elevation, and the red areas indicate lands between 3400 and 3821 m elevation. Map by Gerardo Chaves.

Scotinomys xerampelinus previously was unknown from elevations above 3400 m (Reid 2009) and not reported from the top of Cerro Chirripó (Mora 1994; Carrillo et al. 2005; Chaverri 2008; Kappelle and Horn 2016). This could be due to a sampling bias or to an upward expansion of the species' range in recent decades. Because the fauna of Cerro Chirripó has been intensively studied (Kappelle and Horn 2016), sampling bias is an unlikely explanation for the previous lack of records from this site. The upslope shift is more likely the result, caused by increasing temperatures from climate change, which has forced several Costa Rican vertebrate species to move their distributions to higher elevations (Pounds et al. 1999). There is a general trend toward poleward and upward shifts of latitudinal and elevational boundaries of the ranges of several species (Chen et al. 2011; Rowe et al. 2015). Species inhabiting mountains may be more sensitive to climate change due to the various factors that affect community assemblages across elevational gradients (Neate-Clegg et al. 2018).

We point out the necessity for increasing systematic sampling for small mammals in the Cordillera de Talamanca, mainly at high elevations at Cerro Chirripó, Cerro Kamuk, Cerro Ventisqueros, Cerro Cuericí, Terbi, Los Crestones, Sabana de los leones, Valle de los Conejos and Fila Urán. Our new record for *S. xerampelinus* offers evidence that the new site, at 3820 elevation, currently is ecologically suitable for this species.

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Authors' Contributions

JMM identified the species and elaborated the manuscript. JGC found the specimen at the new locality and collected the data; LIL explored databases and helped on the manuscript preparation. GC conducted the geographical analysis and elaborated the map. All four authors read, edited, and approved the manuscript.

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