



Atelopus carbonerensis Rivero, 1974: A Long-awaited Rediscovery through Citizen Science

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In 1974, Juan Rivero, a Puerto Rican herpetologist living in Venezuela, described a new subspecies of *Atelopus oxyrhynechus* as *A. o. carbonerensis*, from the region around La Carbonera, Mérida State, in the Venezuelan Andes (Rivero 1974); it was later elevated to species level by La Marca (1983). The bright yellow coloration of *A. carbonerensis* is conspicuous among Andean amphibians, probably serving as a warning color due to the presence of tetrodotoxin in the skin (Mebs and Schmidt 1989). The exceptional longevity in the wild (La Marca 1984) is likely facilitated by this antipredatory mechanism. Various researchers (Rivero 1974; Dole and Durant 1974; Durant and Dole 1974; La Marca 1983) described the extraordinary abundance of the species, suggesting that at least a hundred animals could be collected in a short period of time and uncountable numbers were road-killed in the past. Durant and Dole (1974) marked and released 750 individuals in 2,500 m² at the San Eusebio Forest (close to La Carbonera). According to La Marca and Lötters (1997) *A. carbonerensis* is the most represented species in Venezuelan herpetological collections, with more than 400 specimens known. These authors also provided information on when they last noticed survival of the species, i.e., in January 1995 near the type locality. But the very last sighting of the species was reported by Torres and Barrio-Amorós (2001) of an animal photographed by Carlos Gaviria on 13 August 1998 at the surroundings of Páramo El Tambor (8.683, -71.200). Since then, no more reports of the species have been made. La Marca and Reinthaler (1991), Barrio-Amorós (2003) and Lampo et al. (2006) provided well-established reasons for the decline of such species. The known range of this species is restricted and includes the surroundings of the type locality, La Carbonera, San Eusebio, and páramo El Tambor, from 2,000 to 2,800 m asl (Barrio-Amorós 2004; La Marca 2022) (Fig. 1). *Atelopus carbonerensis* is currently listed as Critically Endangered by the IUCN Red List (La Marca 2022) and several authors have recently indi-

cated that the species may be extinct (Barrio-Amorós et al. 2019; Lötters et al. 2019).

From 2000 to 2010, Fundación AndígenA, a Mérida-based NGO (<https://www.andigena.org/proyectos/atelopus/>), developed its Proyecto *Atelopus*, with one of its major objectives being the search for lost species of *Atelopus* in the central Cordillera de Mérida. Its main interest was *Atelopus carbonerensis*, and a vigorous campaign was carried out in the area of its distribution range, from La Carbonera to La Azulita (Barrio-Amorós 2005). In 2004, a workshop for academics, national park rangers, and the general public was held at the INPARQUES—Instituto Nacional de Parques Nacionales—headquarters, and a poster funded by donors was presented for free throughout the area (at schools, local stores, public buildings, etc.) (Fig. 2; Barrio-Amorós 2005). Based on this

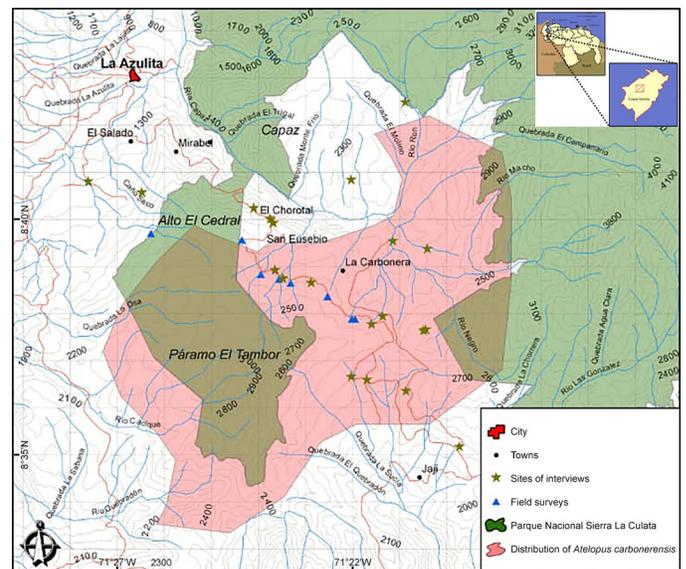


Fig. 1. The known distribution of *Atelopus carbonerensis*. Map developed by Erick Romero for the Project in 2007. The pink polygon denotes the distribution of the species and the green polygon corresponds to La Culata National Park.



Fig. 2. Poster depicting *Atelopus carbonerensis* distributed by Fundación AndígenA. Art by Roger Manrique.

poster, another toad in the same genus, *A. mucubajensis*, was reported by interested and concerned people (Barrio-Amorós 2004), but that individual is still considered the last of its kind (Lampo et al. 2007). Despite this effort, no further individuals of *A. mucubajensis* (Barrio-Amorós 2009) or *A. carbonerensis* were ever found. Interviews with local *campesinos* always provided some hope, as one or another of them was always certain they had seen the species “recently.” Although AndígenA’s Proyecto *Atelopus* came to an end in 2010, many contacts made during the campaigns became permanent friends and collaborators, and the interest in finding the lost species never disappeared.

Citizen science increases the impact and reach of research projects by including the general public to participate in data collection or reporting by allowing any curious or interested person to join in. This way, researchers gain extra eyes, ears and hands to collect the data required (Pokock et al. 2018; Lee et al. 2021).

On 23 August 2014, a single individual of *A. carbonerensis* was seen in the surroundings of Páramo El Tambor by one of the former guides of the Project, Fernando Dugarte (Fig.

3A). That species is the only one in the genus known from that general area. Its bright yellow color readily distinguishes it from any other species of anuran in the area. Recognizing immediately the value of the observation, he sent the photo to CBA for further identification. This already meant that the species had survived at least until that year, 16 years after the previous one seen (Torres and Barrio-Amorós 2001). In addition, Fernando found a couple of *A. carbonerensis* in amplexus in the same location on 7 December 2021 (Fig. 3B), indicating that the species is still surviving at this Páramo until today. Finding one amplexing pair is a positive sign as it is possible that the couple is reproducing, although there are no further details. The exact location is not given to secure the species survival.

Further efforts must be undertaken to detect additional specimens/populations. The search for tadpoles in watercourses and vocalizations of calling males, in addition to visual encounter survey of juvenile and adults, could increase the chances of new encounters (Lötters et al. 2019).

The next step is to start another information campaign and establish a project monitoring the species, but without extracting animals for ex-situ breeding until it is clear how many remain in the wild. Extraction for breeding does not assure the species’ survival, whereas they managed to survive to this very day in their own habitat. On the other hand, the fact that some specimens have been seen recently does not mean that the survival of the species is guaranteed even in the short term (see the case of *Atelopus mucubajensis*; Barrio-Amorós 2009). Furthermore, global warming, pollution, habitat loss, and emergent diseases are responsible for the population decline of *Atelopus carbonerensis* (Lampo et al. 2006, La Marca 2022). Other important problems can arise even given good reproductive success in captivity, as in the case of *Atelopus limosus* in Panama, in which a release of captive-bred individuals is no guarantee of success (Estrada et al. 2022). Skin-associated microbial communities differ between captive and wild indi-



Fig. 3. Three surviving *Atelopus carbonerensis* at Páramo El Tambor, Mérida, Venezuela: A single individual photographed on 23 August 2014 (left) and a pair in amplexus photographed on 7 December 2021 (right). Photographs by Fernando Dugarte.

viduals and released animals need at least a month to adapt to a new habitat. Survival in semi-captivity should be studied prior to any release. Another case is *Atelopus zeteki* which is currently extinct in the wild, but has an increasing captive population (DellaTogna et al. 2014). However, no reported attempt to return to the wild was ever made.

Furthermore, Voyles et al. (2018) suggest that the amphibian community in general is displaying signs of recovery, including some species presumed to have been in critical decline due to the outbreak of chytrid fungus. Increased host resistance may be responsible for this recovery, but is not confirmed. Any effort for *ex situ* husbandry of highly endangered species should strictly follow the guidelines of the IUCN (Linhoff et al. 2021).

Given that *Atelopus carbonerensis* has survived to this day without intervention, the most viable action would be to offer proper education and advice to the private property owners where the animals were found; this would protect the area and allow the monitoring of the species, assessing its health status, genetic diversity, population size, and other demographic parameters, previous to deciding on capturing extant individuals for an *ex-situ* project.

Acknowledgements

Involving the general public in specific research, in this case, the search of one of the rarest and most threatened amphibians in the world, was one of the main interests of Fundación AndígenA. Thanks to the many local inhabitants, the search endured and after losing all expectations, had an unexpected end in the rediscovery of this species. Particular mention to the family Dugarte, Fernando and Ancelmo, two of the local guides who accompanied us in many surveys. Fernando also had the good luck to see and photograph the species both in 2014 and 2021. The late Jorge Bravo (RIP) owner of Estancia La Bravera helped our research extensively during 2000–2010 through an agreement, and would be very proud to know the Harlequin Toad never was extinct. We thank Erick Romero for his company during the project and his help making Fig. 1. Lastly, we could not make anything without the financial support and donation of field equipment provided from the Cleveland Zoological Society, Cleveland Metroparks Zoo, the IUCN/SSC Declining Amphibian Population Task Force, and IDEA WILD.

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