

New occurrences and habitat description of southern Ecuador endemic frog *Atelopus exiguus* (Anura: Bufonidae) from a conservation hotspot in the high Andes

Nuevas ocurrencias y descripción del hábitat de la rana endémica del sur de Ecuador *Atelopus exiguus* (Anura: Bufonidae) en un punto crítico de conservación en los altos Andes

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Abstract

Atelopus species are classified as a priority taxon for monitoring and conservation, of these *A. exiguus* is endemic to southern Ecuador and is classified as critically endangered, however, within its known geographic range, little attention has been given to identifying new localities particularly across the páramo ecosystem (> 3500 m a.s.l.). Therefore, in the páramo landscape of Macizo del Cajas Biosphere Reserve, a conservation hotspot, we intensively searched for *A. exiguus* across 15 localities (elevation range: 3550 – 3800 m a.s.l.). In one year of monitoring (2020 – 2021), we recorded four individuals of *A. exiguus* (two were tadpoles) in two localities. The localities are characterized by a higher proportion of páramo grassland in association with shrubby páramo as well as cushion páramo; this riparian habitat is related to relatively good water quality (according to Andean Biotic Index), relatively low water temperatures and relatively low water flow. Our findings, accompanied by a detailed monitoring protocol, suggest habitat requirements for *A. exiguus*. Further intensive surveys beyond the limits of protected areas of Azuay province, especially across the páramos, is emerging as an urgent step to improve conservation decisions.

Resumen

Las especies del género *Atelopus* están clasificadas como un taxón prioritario para su monitoreo y conservación, de ellas *A. exiguus* es endémica del sur de Ecuador y está clasificada como en peligro crítico de extinción. Sin embargo, dentro de su área de distribución geográfica conocida, poca atención se ha prestado en identificar nuevas localidades, especialmente en el ecosistema del páramo (> 3500 m de altitud). Por lo tanto, en el paisaje de páramo de la Reserva de la Biosfera Macizo del Cajas, un punto caliente de conservación, buscamos intensamente la especie en 15 localidades (rango de elevación: 3550 – 3800 m de altitud). En un año de monitoreo (2020 – 2021), registramos cuatro individuos de *A. exiguus* (dos fueron renacuajos) en dos localidades. Las localidades se caracterizan por una mayor proporción de pastizales de páramo en asociación con páramo arbustivo, así como páramo de almohadilla; este hábitat ribereño está relacionado con una calidad de agua relativamente buena (según el Índice Biótico Andino), temperaturas de agua relativamente bajas, así como un flujo de agua relativamente bajo. Nuestros hallazgos, acompañados de un protocolo de monitoreo detallado, sugieren los requerimientos de hábitat para *A. exiguus*. La realización de más estudios intensivos más allá de los límites de las áreas protegidas de la provincia de Azuay, especialmente a través de los páramos, se considera como urgente para mejorar las decisiones de conservación.

Keywords

Macizo del Cajas; monitoring; endangered frogs; páramo ecosystem; water quality; conservation.

Palabras clave

Macizo del Cajas; monitoreo; ranas amenazadas; ecosistema de páramo; calidad del agua; conservación.

Introduction

The human modifications of ecosystems increasingly confine the biodiversity to landscapes with a mosaic of altered habitats (Foley et al. 2005). Particularly, in zones with high levels of species richness, endemism and concentrations of threatened species, biodiversity is more sensitive to human-induced changes to natural habitats (Sala et al. 2000). For instance, endemic frogs, such as species of *Atelopus* (endemic to the Neotropical region) have been greater predicted extinction risk as a consequence of global climatic change as well as disease such as the pathogenic chytrid fungus (Pounds et al. 2006, Roach et al. 2020, Urgiles et al. 2021). *Atelopus exiguus* is a critically endangered endemic (Ortega-Andrade et al. 2021) found in both páramo grassland and montane forest in only a few highland localities (elevation range: 3000 – 4000 m a.s.l.) of the Macizo del Cajas Biosphere Reserve (MCB) in the western Andean cordillera of Azuay province, southern Ecuador (Ron et al. 2018). The type locality of *A. exiguus* is Zurucuchu valley (2°50'34.8" S, 79°8'45.6" W; 3150 m a.s.l.) located in the Cajas National Park (CNP); additional localities have been reported beyond to the limits of another protected area south of CNP, Quimsacocha National Recreation Area (ARQ), near to Tres Lagunas (3°2'29.58" S, 79°12'56.41" W, 3760 m a.s.l.) and Zhurucay (3°4'55.20" S, 79°13'59.63" W, 3675 m a.s.l.) for example (Ron et al. 2018, Coloma et al. 2000). Within respect to the known geographic range, little attention has been given to identifying new localities in addition to the historical records – e.g., Mazán Reserve, CNP (Maldonado 2010), given that *Atelopus* species are a priority taxon to monitor and conserve (Roach et al. 2020). Therefore, it is crucial to publish new occurrences along with detailed habitat descriptions of *A. exiguus* to update knowledge and to identify localities of interest for conservation.

Material and methods

Within the current known geographic range of *A. exiguus*, particularly in the páramo habitats (> 3500 m a.s.l.) of MCB (Fig. 1), southern Ecuador, we performed intensive surveys for the species across 15 localities (elevation range: 3550 – 3800 m a.s.l.) between September 2020 and August 2021. The localities are within the core area of MCB (2°55'25" S, 79°21'57" W), including páramos inside of ARQ and its buffer páramo-areas (within a radius of ~10 km). The localities were selected based on similarities in habitat to areas where past records in the study area were found (Fig. 1). In each locality, we installed a transect along the banks of streams and small rivers. Each transect was 150 m in length and 50 m in width (total area = 7500 m²). We monitored all substrates, including moving rocks and logs inside the water body as well as searches in bunch-grass species of *Chalamagristis* (páramo grassland habitat), cushion plants such as *Plantago rigida* and *Oreobous ecuadorensis* (cushion páramo) and shrubs plants such as *Monticalia*, *Hypericum* and *Valeriana* species (shrubby páramo) as principal riparian vegetation. Each locality was surveyed once per month for a minimum of three hours, always during the day due

to the species' diurnal habits (9:00 – 17:00 h). All surveys were performed by at least two observers. All individuals recorded were identified and photographed *in situ*. No individuals were collected (not authorized by the Ecuadorian deputy of environment). For species identification, we used the descriptions of Coloma et al. (2000) and Ron et al. (2018). Individuals were recognized as *A. exiguus* by their relatively small size, dark brown dorsum and flanks with yellowish-green spots, black irises, poorly developed palmar tubercles, and snout pointed from above; while the tadpoles were recognized by the elongate-ovoid body, the greatest width at the posterior part of body, body slightly constricted at eye level, robust caudal musculature, and translucent marks posterior to eyes (Fig. 1). In addition, we performed aquatic macroinvertebrate surveys to estimate the biological water quality [Andean Biotic Index [ABI] Rios-Touma et al. 2014) and therefore habitat requirements of the species. We followed the macroinvertebrate monitoring protocol developed for the study area (for more details see Jiménez et al. [2021]).

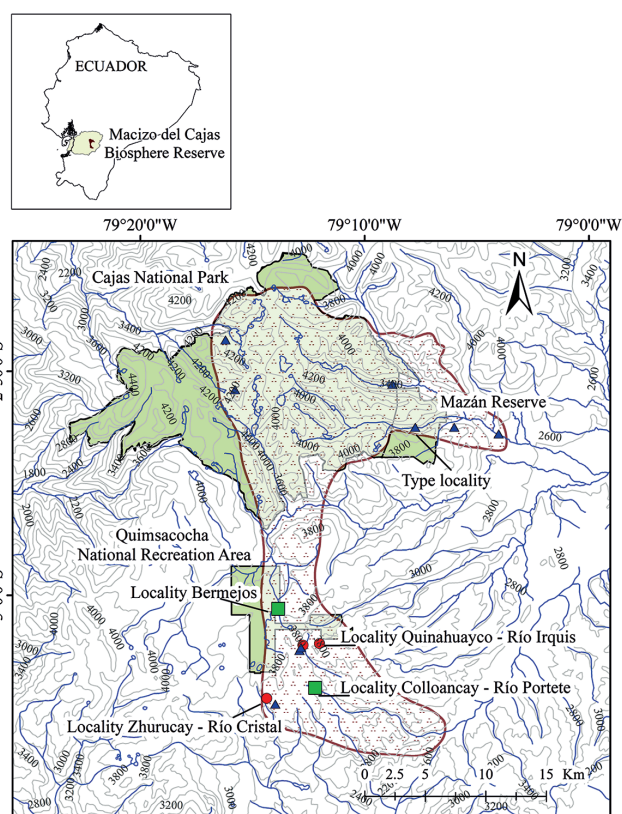


Figure 1. Map of the study area and location of the new and previous occurrences of *Atelopus exiguus* across the páramo ecosystem of southern Andes of Ecuador (Azuay province). The filled-green squares are the new records from this study. The filled-red circles are unpublished previous occurrences, deposited in the data base of Universidad del Azuay by J.C. Sánchez-Nivicela & G. Samaniego (2009–2010). The filled-blue triangles are the occurrences documented by Ron et al., (2018). The brown polygon with dots is the geographic range of *A. exiguus* (UICN 2018).

Results

In one year of monitoring, we only recorded *A. exiguus* in two localities (Fig. 1). In total, we recorded four individuals (Fig. 2). On 11 June 2020, in the locality of

Bermejos (3°00'32.16" S, 79°13'51.25" W; 3724 m a.s.l.), we recorded a frog (Fig 2A-C) as well as one tadpole (Fig 2E-F); the individuals were found between rocks, partially cover by the water flow, near to the bank of a stream which is part of headwaters of Bermejos hydrological system. In the same locality, on 20 November 2020, we photographed a frog (Fig 2D), the individual was recorded ~10 m from the banks of the stream in cushion páramo. Finally, on 1 December 2020, in Colloancay (3°04'03.77" S, 79°12'12.33" W; 3572 m a.s.l.), we recorded a tadpole (Fig 2G-H) in the muddy-rocky bottom of the stream that is part of the headwaters of Portete hydrological system. All tadpoles were found opportunistically during the macroinvertebrate surveys.

The locality of Bermejos is characterized as a habitat dominated by páramo grassland (50%) in association with shrubby páramo (20%) as well as cushion páramo

in lower proportion (5%), the remaining 25% represents the water body; water flow was seasonal throughout the year (min [Nov.] = $0.1 \text{ m}^3 \text{ s}^{-1}$, max [Abr.] = $2.2 \text{ m}^3 \text{ s}^{-1}$, average = $0.9 \text{ m}^3 \text{ s}^{-1}$) with relatively small temperature variation (min [Nov.] = 9.8°C , max [Dec.] = 12.7°C , average = 11.5°C) and water quality, at the moment of the record was estimated to be between medium (ABI [June] = 57) and very good (ABI [Nov.] = 98). The locality of Colloancay is a wetland dominated by páramo grassland (55%) with a lower proportion of shrubby páramo (20%) as well as cushion páramo (5%), the final 20% represents the water body; water flow was lower throughout the year but more consistent (min [Oct.] = $0.1 \text{ m}^3 \text{ s}^{-1}$, max [Abr.] = $0.9 \text{ m}^3 \text{ s}^{-1}$, average = $0.4 \text{ m}^3 \text{ s}^{-1}$), also with little variation in the temperature (min [Nov.] = 11.5°C , max [Jun.] = 13.1°C , average = 12.5°C) and the water quality at the moment of the record was good (ABI [Dec.] = 65).

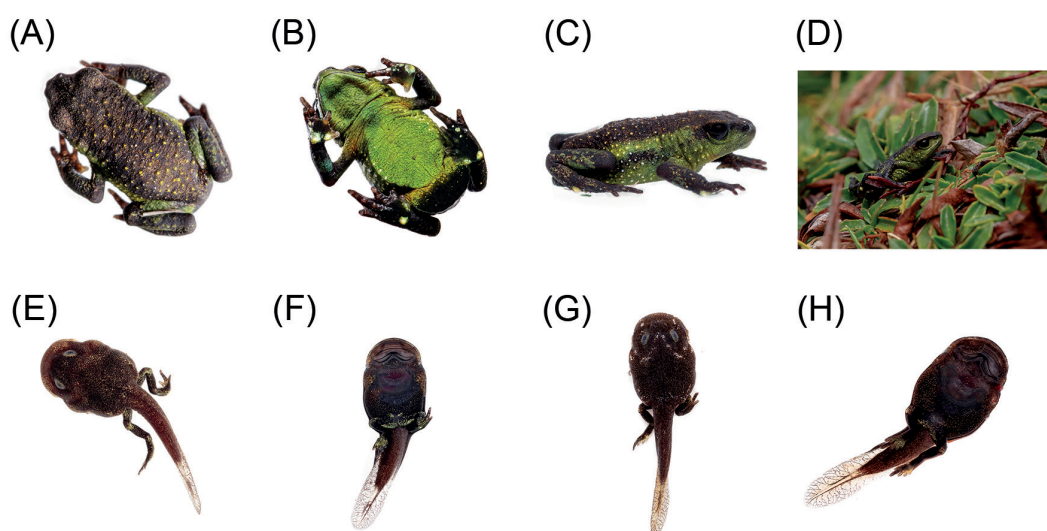


Figure 2. Individuals of *Atelopus exiguus* recorded in two localities of the páramo ecosystem of southern Andes of Ecuador (Azuay province). A-D are two individuals photographed in the locality of Bermejos. A-C (dorsal, ventral, and lateral view respectively) is an individual photographed on 11 June 2020; D is an individual photographed on 20 November 2020. E-F (dorsal and ventral view respectively) is a tadpole photographed on 11 June 2020. G-H (dorsal and ventral view respectively) is a tadpole photographed in the locality of Colloancay on 1 December 2020 (all photos: BT). For localities see Fig. 1.

Discussions

Our findings are the first record for ARQ (i.e., Bermejos) as well as indicating that there are indeed localities beyond the limits of the protected areas with suitable habitat for *A. exiguus*. More importantly, as far as we know, our results are the first approximation towards a habitat description for this species in the páramo ecosystem.

Before our study, one of the most complete monitoring efforts for *A. exiguus* came from Maldonado (2010). The study was carried out in the montane forest habitats of Mazán Reserve (3100 m a.s.l.) and recorded 14 individuals (seven adult-males, one adult-female and six sub-adults). Maldonado (2010) provided a very fine description of montane habitat, including humid pastures in association with woody shrubs as well as less proportion of tress always near to the banks (~ 2 m) of small tributaries of the Mazán river, with temperature range from 11 to 14.2°C . This study conclude that Mazán Reserve is one the most suitable habitats for *A. exiguus*.

However, despite several previous records of *A. exiguus* across the study area (Fig 1), no record is accompanied by a formal protocol or habitat descriptions. Thus, our findings demonstrate that in addition to montane forest habitats, páramo habitats are important. Particularly, riparian vegetation in the form of open and semi-open páramo (elevation range: 3500 – 3750 m) in combination with slower moving streams with relatively good water quality (according to ABI) and low temperature water is suitable habitat.

An important factor in *Atelopus* species extinctions globally is the increasing presence of a pathogenic chytrid fungus linked to global climate change (Pounds et al. 2006). The optimum growth of this pathogenic fungus is predicted in ranges from 17 to 25°C (Pounds et al. 2006). Our results indicate that the microhabitat conditions of *A. exiguus* across the study area are less favourable for the development of this fungus as the water temperatures were $< 13.1^\circ\text{C}$. However, close to Bermejos, Urgiles et al. (2021) reported the presence of chytrid fungus on

Pristimantis species. Due to the fungus' association with decreasing amphibian populations, and the predicted dramatic climatic shifts in the high Andes region with associated higher chytrid fungus prevalence (Urgiles et al. 2021), it is evident that more studies are needed. Thus, monitoring water quality and temperature is a key element to consider within further monitoring programs across montane and páramo habitats (Roach et al. 2020). Besides, the presence of individuals including tadpoles, our results may suggest that the new localities are suitable reproductive habitat. For better and more comprehensive monitoring-conservation programs, an interdisciplinary effort is required to fully understand ecological and habitat requirements for *A. exiguus*. Here, intensive surveys beyond the limits of protected areas of Azuay province, focused within the páramos, are emerging as urgent steps to improve conservation decisions for threatened species such as Andean frogs belonging to the *A. bomolochos* group such as *A. exiguus* and *A. nanay*.

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The authors declare no conflict of interest.

Rol de los autores / Authors Roles:

PA: Conceptualización, Metodología, Investigación, Recursos, Escritura-Preparación del borrador original, Supervisión, Adquisición de fondos, Administración de proyecto, Redacción-revisión y edición.

RJ: Conceptualización, Metodología, Investigación, Recursos, Escritura-Preparación del borrador original, Supervisión, Adquisición de fondos, Administración de proyecto.

DS: Conceptualización, Metodología, Investigación, Recursos, Escritura-Preparación del borrador original, Supervisión, Adquisición de fondos, Administración de proyecto.

BT: Conceptualización, Metodología, Investigación, Recursos, Escritura-Preparación del borrador original, Supervisión, Adquisición de fondos, Administración de proyecto.

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Aspectos éticos / legales; Ethics / legal:

Authors declare that they did not violate or omit ethical or legal norms in this research. All activities were conducted under the permit number MAAE-ARSFC-2021-1069 issued by Environmental and Water Ministry of Ecuador and therefore no individuals were collected. All individuals were photographed in the field.