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Revised distribution, phenotypic variation, and conservation status of *Liolaemus fittkaui* (Squamata: Liolaemidae), a lizard endemic to the Andes of Central Bolivia

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Abstract

Revised distribution, phenotypic variation and conservation status of *Liolaemus fittkaui* (Squamata: Liolaemidae), a lizard endemic to the Andes of Central Bolivia. The rare, endemic Bolivian lizard, *Liolaemus fittkaui,* was considered extinct at the locality of the paratypes. The species currently is catalogued as Vulnerable. The plausibility of the putative paratype locality is discussed, as it relates to the reported extinction event. Observations presented here evidence that the distribution of *L. fittkaui* is broader than has been reported, extending nearly 100 km along the highlands of the Cordillera de Tiraque (provinces of Chapare, Tiraque, and Carrasco). The species maintains populations in areas where its habitat is well conserved, some of them within the limits of the Carrasco National Park. This new information, following the IUCN criteria, indicates that the category of Vulnerable is adequate for the conservation status of *L. fittkaui*. Other records from Arque Province belong to *L. variegatus* and a species in the *L. montanus* series. Variation in ventral color pattern of males is described. Contrary to the whitish venter described originally, males seem to be polymorphic, having white, yellow, red, and intermediate combinations. The distribution of *L. fittkaui* and its ventral color morphs reflect a spatially fragmented range in which intraspecific evolution could result in marked genetic structure. The persistence of *L. fittkaui* and other endemisms confined to Andean highlands seems to depend on the preservation of puna grasslands, an ecosystem usually under-represented in conservation efforts.

Keywords: alpine grasslands, habitat, *Liolaemus montanus* series, polymorphism, wet puna.

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Resumen

Revisión de la distribución, variación fenotípica y estado de conservación de *Liolaemus fittkaui* (Squamata: Liolaemidae), una lagartija endémica de los Andes de Bolivia Central. La rara lagartija *Liolaemus fittkaui,* endémica de Bolivia, fue considerada extinta en la localidad de los paratipos. Actualmente la especie está catalogada como Vulnerable. La credibilidad de la supuesta localidad de los paratipos es discutida, así como el evento de extinción reportado. Las observaciones presentadas aquí, ponen de manifiesto que la distribución de *L.fittkaui* es más amplia de lo que se conocía, extendiéndose cerca de 100 km a lo largo de las zonas altas de la Cordillera de Tiraque (provincias de Chapare, Tiraque, y Carrasco). La especie conserva poblaciones en zonas donde su hábitat está bien conservado; algunas de ellas dentro de los límites del Parque Nacional Carrasco. Esta nueva información, de acuerdo a los criterios de la UICN, indica que la categoría de Vulnerable es adecuada para el estado de conservación de *L. fittkaui*. Otros registros de la Provincia de Arque corresponden a *L. variegatus* y una especie de la serie de *L. montanus*. Se describe la variación en el patrón de coloración ventral de los machos. Respecto al vientre originalmente descrito como blancuzco, los machos parecen ser polimórficos, presentando blanco, amarillo, rojo y combinaciones intermedias. La distribución de *L. fittkaui* y sus morfos de coloración ventral, refleja una extensión espacialmente fragmentada en la que la evolución intraespecífica podría resultar en una marcada estructura genética. La persistencia de *L. fittkaui* y otros endemismos confinados a las zonas altas andinas parece depender de la preservación de los pajonales de la puna, un ecosistema usualmente poco representado en los esfuerzos de conservación.

Palabras clave: hábitat, herbazales alpinos, polimorfismo, puna húmeda, serie de *Liolaemus montanus.*

Resumo

Revisão da distribuição geográfica, variação fenotípica e estado de conservação de *Liolaemus fittkaui* (Squamata: Liolaemidae), um lagarto endêmico dos Andes da Bolívia Central. O lagarto raro e endêmico da Bolívia *Liolaemus fittkaui* foi considerado extinto na localidade dos parátipos. Atualmente a espécie está classificada como Vulnerável. Discutimos a credibilidade da suposta localidade dos paratipos, assim como o evento de extinção relatado. As observações apresentadas evidenciam que a distribuição de *L. fittkaui* é mais ampla do que havia sido relatada, estendendo-se quase 100 km ao longo das regiões altas da Cordilheira de Tiraque (Províncias de Chapare, Tiraque e Carrasco). A espécie mantém populações em áreas em que seu habitat está bem-preservado, algumas delas encontradas dentro dos limites do Parque Nacional Carrasco. Essa nova informação seguindo os critérios da IUCN, indica que a categoria Vulnerável é adequada para o estado de conservação de *L. fittkaui*. Outros registros da província Arque pertencem a *Liolaemus variegatus* e a uma espécie da série de *L. montanus.* Descrevemos a variação do padrão de coloração ventral dos machos; diferentemente do ventre esbranquiçado originalmente descrito, os machos parecem ser polimórficos, apresentando coloração branca, amarela, vermelha e combinações intermediárias. A distribuição de *L. fittkaui* e de suas formas de coloração ventral reflete uma distribuição espacialmente fragmentada na qual a evolução intraespecífica poderia resultar em uma estrutura genética marcada. A persistência de *L. fittkaui* e de outros endemismos confinados às regiões altas andinas parece depender da preservação dos campos da puna, um ecossistema geralmente sub-representado nos esforços de conservação.

Palavras-chave: campos alpinos, habitat, polimorfismo, puna úmida, série de *Liolaemus montanus.*

Introduction

The Andes are one of the most biodiverse and threatened regions of the world (Myers *et al.* 2000), hosting high amounts of endemic plant and animal species (García-Moreno and Fjeldså 2000, Young *et al.* 2002, Hughes and Eastwood 2006). The higher species richness and sparse human population in lowland and mid-elevation Neotropical ecosystems have drawn the attention of conservationists, whereas the Andean highlands have received less attention. Bolivia is one of the lesser-known countries from a biodiversity standpoint, and consequently, the effects of anthropogenic disturbance on biodiversity are less documented. For thousands of years, agricultural anthropogenic activities (mostly crops and pastures) have dramatically modified the Bolivian Andean ecosystems (Ribera Arismedi 1992). Andean highland plant communities are remarkably degraded (Kessler 2002, Gareca *et al.* 2010). As a consequence, many vertebrates are considered endangered, and others have been totally or partially extirpated from these ecosystems (Ergueta and Morales 1996, Aguirre *et al.* 2009).

At the same time, little is known about the distribution and natural history of organisms within the Andean region of Bolivia (Tarifa *et al.* 2007). Undoubtedly there are new taxa to be found and described, including plants, invertebrates, and even vertebrates (De la Riva 2007). Moreover, many Andean species are endemic to particular mountain ranges, isolated by the complex topography of the area (Swenson *et al.* 2012, Anthelme *et al.* 2014).

Many Andean endemics are primarily known from their original descriptions. One of such species is the Bolivian lizard *Liolaemus fittkaui* Laurent, 1986. The holotype (ZSM 17/1983) was collected by Benno Marcus (1905, Bayern, Germany–1976, Cochabamba, Bolivia) without a date and with the imprecise locality of "Región de Cochabamba" (Laurent 1986). The four paratypes (UMMZ 68143, 172931; Laurent, 1986) together with nine specimens (UMMZ 224325–28, 172932–33; FML 16121–2; and MVZ 36458) (G. Schneider and C. Spencer, pers. comm.) were collected by F. B. Steinbach at "Tiraque, Depto. de Cochabamba", in April 1927 (Laurent 1986).

Owing to the scarce knowledge of this species, the conservation status of *Liolaemus fittkaui* was not evaluated in the first reviews of Bolivian vertebrates (Pacheco and Aparicio 1996, Aparicio 2003). It was declared as Critically Endangered by Embert (2007), because of its rarity and putative absence from protected areas. For years, searches for *L. fittkaui* in the environs of the village of Tiraque (3370 m a.s.l.) were conducted without success. The worldwide lizard extinction analysis by Sinervo *et al.* (2001) included this absence datum (as "*Liolaemus fitzkauii* [*sic*]" in Table S7A of that publication).

The distribution of *Liolaemus fittkaui* has been a mystery for years. To our knowledge, the first precise geographic records for *L. fittkaui* in the Cordillera de Tiraque were made in 2007, in wet puna grasslands above Koari-Quewiñacocha Lake, 4110 m a.s.l., Tiraque Province (locality 5 in Figure 1B), 13 km to the East of the village of the same name (T. Camacho-Badani & O. Quinteros-Muñoz, pers. comm.; Aguayo *et al.* 2008). Because of this finding, *L. fittkaui* appeared as Vulnerable in the most recent review of conservation status of Bolivian reptiles (Aguayo *et al.* 2009).

Apart from this deficient information, none of the aforementioned conservation evaluations for the species included other previous records. In August 2000, T. Tarifa and E. Yensen collected and identified as *Liolaemus fittkaui* five lizards (CBF 2247–51) in Pusuq'huni (3700 m a.s.l.), Cerro Queñua Sandora, Arque Province, Cochabamba Department (question mark in Figure 1A) (Tarifa *et al.* 2007). This locality would increase the known range of *L. fittkaui* more than 80 km WSW of Tiraque. Specimens CBF 2247 and 2250 (but not the other three) were identified as *L. fittkaui* for morphological comparisons in the description of *L. porosus* (Abdala *et al.* 2013).

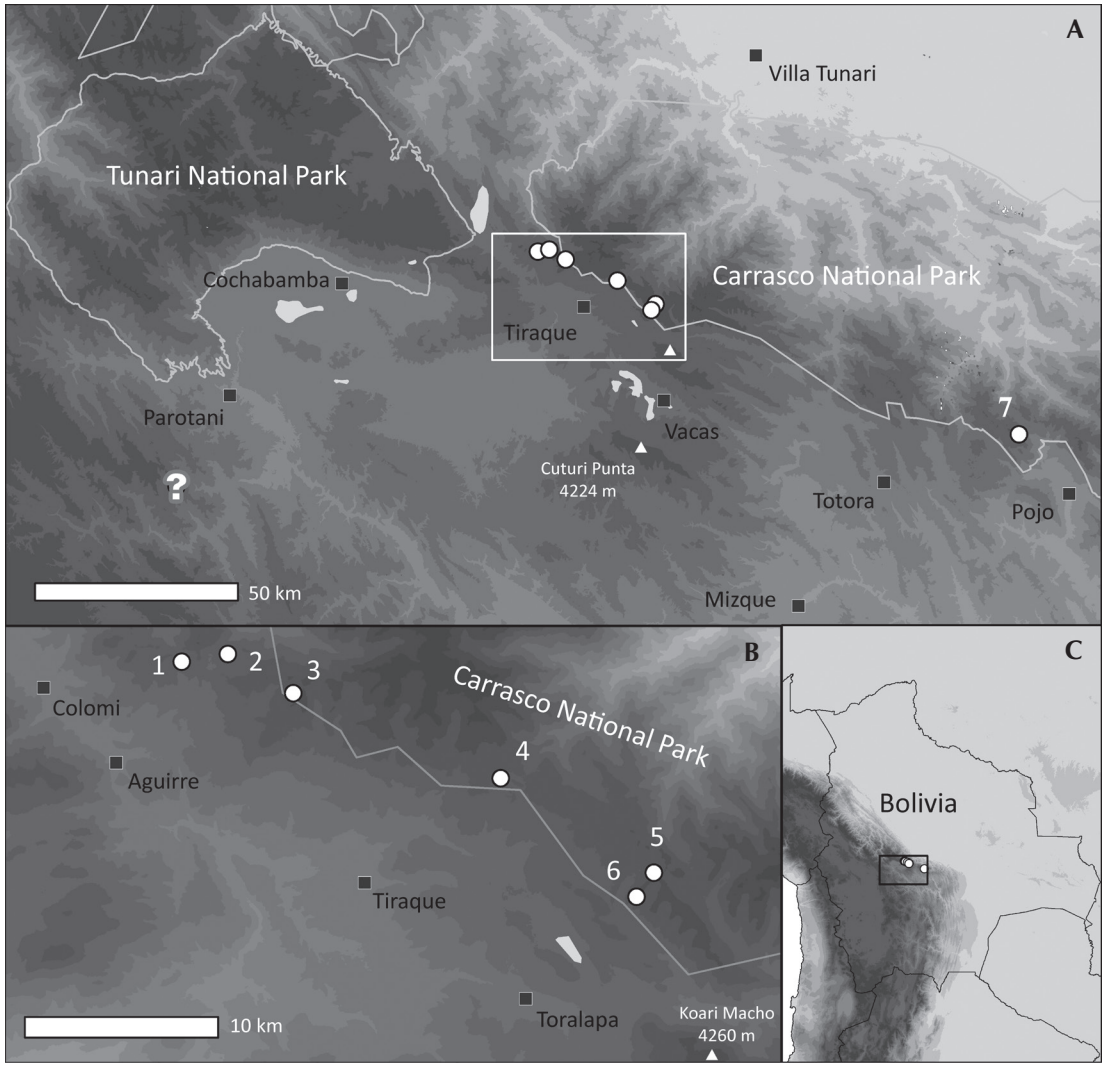

Figure 1. Maps showing the *Liolaemus fittkaui* records mentioned in the text: (**A**) mountains surrounding Cochabamba with Tunari and Carrasco National Parks; (**B**) southwestern border of the Carrasco National Park; and (**C**) area within Bolivia. Localities are: (1) Laguna de San Isidro, 3860 m a.s.l.; (2) Laguna Robada, 3870 m a.s.l.; (3) Cerro Rodeo, 4180 m a.s.l., Cotani Alto Highlands; (4) Laguna de Sallamani, 4050 m a.s.l.; (5) above Koari-Quewiñacocha, 4110 m a.s.l.; (6) above Quewiñacocha, 4105 m a.s.l.; (7) Pojo highlands, approximately 3800 m a.s.l.; and question mark, record of *Liolaemus* sp. (*L. montanus* series) and *L. variegatus* that were previously identified as *L. fittkaui* (Tarifa *et al.* 2007) in Pusuq'huni, 3700 m a.s.l., Cerro Queñua Sandora.

Given the intriguing distribution and conservation status of *Liolaemus fittkaui*, we review all the available information concerning observations and the collections, providing new findings about the distribution and biology of this endemic Bolivian species.

Materials and Methods

In November 2012 and September–December 2013 we explored several localities between 3700 and 4200 m a.s.l. in the provinces of Tiraque and Chapare, in the Cordillera de Tiraque, Department of Cochabamba. We registered every observation with a GPS and photographed the specimens. Some individuals died during short-term captivity to study their thermal ecology. These were fixed in 100% ethanol, preserved in 70% ethanol, and deposited in two collections—Colección Boliviana de Fauna (CBF), Museo Nacional de Historia Natural, La Paz, Bolivia, and Museo Nacional de Ciencias Naturales (MNCN), Madrid, Spain. The remaining individuals were released after data collection.

We compared the morphometry, scutellation, and coloration of our field observations, voucher specimens, along with those from Pusuq'huni with the diagnosis of the original description of *Liolaemus fittkaui* (Laurent 1986) and pictures of the holotype, paratypes, and specimens of *L. fittkaui* collected by F. B. Steinbach, as well as other species of the Andes of Central Bolivia that could be misidentified with *L. fittkaui*.

Results

In November 2012, I. De la Riva and P. A. Burrowes collected a male *Liolaemus fittkaui* (MNCN 46645) on a southern slope above Quewiñacocha Lake, Tiraque Province (4105 m a.s.l.), where puna grasslands had been partially converted into potato fields (Locality 6 in Figure 1B). Subsequently, we returned together with T. Camacho-Badani and O. Quinteros-Muñoz in September 2013 to the exact area where *L. fittkaui* had been observed by Aguayo *et al.* (2008) (Locality 5 in Figure 1B). We found *L. fittkaui* between 4090 and 4260 m a.s.l., documenting an increase in the known elevation range of the species. In the following days, we searched similar sites of the same mountain range, always paying special attention to areas with wet puna grasslands (*sensu* Navarro and Maldonado 2002). As a result, we found *L. fittkaui* at some additional localities, extending its known range 24 km WNW of Koari-Quewiñacocha (Localities 1–4, Figure 1B). These localities are: Laguna de San Isidro (3860 m a.s.l.; Figure 4A), and Laguna Robada (3870 m a.s.l.) in Chapare Province; and Cerro Rodeo (4180 m a.s.l.), and Laguna de Sallamani (4050 m a.s.l.) in Tiraque Province. Although most individuals were released after morphometric measures and photographs were taken, eight individuals were preserved: a female from Cerro Rodeo (MNCN 46646), and five males (CBF 4284–4287; MNCN 46647) and two females (CBF 4288; MNCN 46648) from Laguna Robada.

In January 2013 Jhony Salguero photographed a lizard (Figure 4B) about 3800 m a.s.l. in the highlands above Pojo, Carrasco Province, Cochabamba Department (Locality 7 in Figure 1A). The lizard later was identified as a female *Liolaemus fittkaui*, based on the morphology of dorsal and lateral scales, coloration pattern and morphometry. This is the most notable potential distributional expansion for *L. fittkaui,* increasing its known range by about 72 km E Koari-Quewiñacocha.

Examining *Liolaemus fittkaui* from the new localities, we found more phenotypic variation than originally described. The ventral coloration of the species was described as "whitish" (Laurent, 1986). This is true for all the females we observed, but not for living males. In the populations east of Tiraque (Sallamani and Koari-Quewiñacocha), most of the males have a white ground color ventrally, and a few are yellow or yellowish. However, west of Tiraque (Cerro Rodeo, Laguna Robada, and Laguna de San Isidro), most males have a red ventral ground color, whereas others have either yellow or white ventral ground colors, and their pairwise combinations (Figure 5). The five males from Laguna Robada (CBF 4284–4287; MNCN 46647) that were preserved in ethanol lost the red coloration within a year after their fixation.

The five specimens from Pusuq'huni, Arque Province are significantly different than the original description of *Liolaemus fittkaui,* as well as the specimens that we observed (Table 1). Two (CBF 2249 and 2251) are *Liolaemus variegatus* (Aguilar-Kirigin, pers. comm.), a species that also occurs in Tiraque and other provinces of Cochabamba (Laurent 1984, Aguilar-Kirigin 2013). This species is easily distinguished from *L. fittkaui* by morphometry and color patterns (Table 1 and Figures 2 and 3). The other three specimens from the same locality (CBF 2247–2248 and 2250) lack particular diagnostic traits of *L. fittkaui*, such as the dorsal and lateral scales and the dorsal coloration pattern (Table 1 and Figures 2 and 3). The ventral coloration of specimens from Arque matches neither the original description nor our observations of *L. fittkaui* (i.e., whitish background in both sexes, with a conspicuous reticulated black pattern in males, which in females is absent or blurred). Laurent (1986) based his description on only one female. Among the females that we have seen in the field and the specimens of F. B. Steinbach in the UMMZ collection, none has such a conspicuous reticulate pattern as female CBF 2250 or a ventral pattern as dark as CBF 2248.

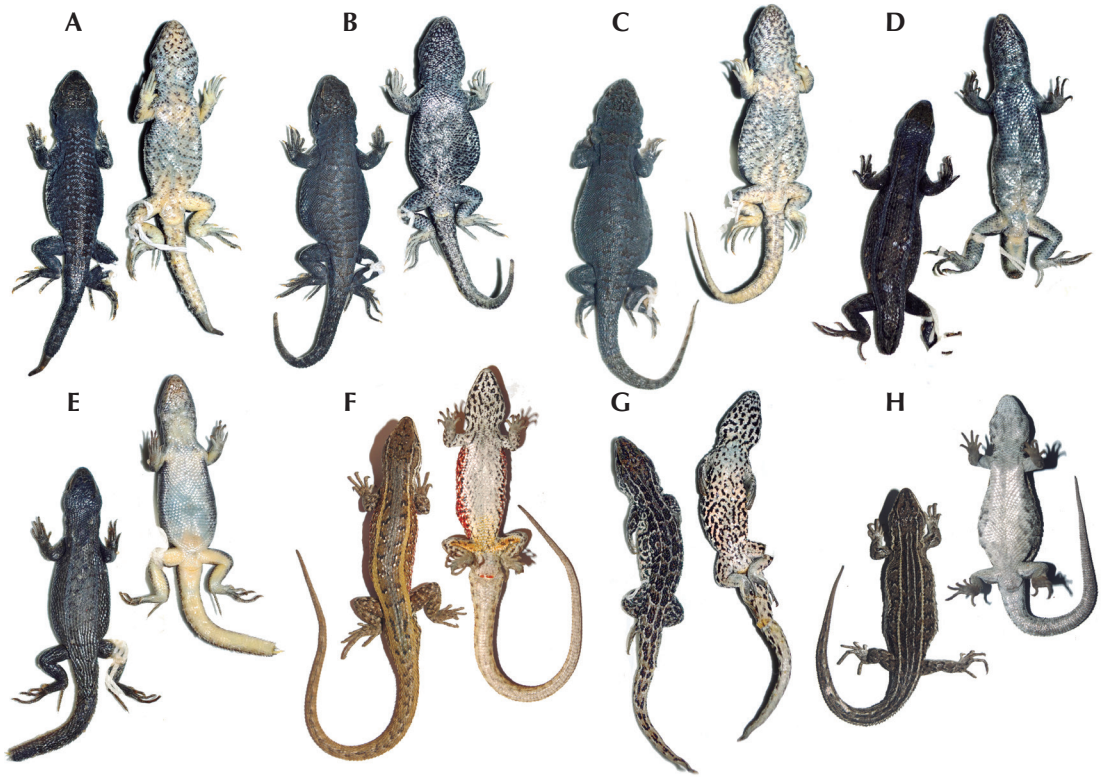

Figure 2. Specimens of *Liolaemus* collected by E. Yensen and T. Tarifa in Pusuq'huni, Queñua Sandora woodland, Palli Palli, Arque Province: *Liolaemus* sp. (**A**) male CBF 2247, (**B**) female CBF 2248, and (**C**) female CBF2250; *Liolaemus variegatus* (**D**) CBF 2249; and (**E**) CBF 2251. Other *Liolaemus* from the Cordillera de Tiraque: (**F**) male *Liolaemus variegatus* MNCN 46649 in life, from K'aspikancha, Tiraque Province; (**G**) male *Liolaemus fittkaui* MNCN 46647 from Laguna Robada, Chapare Province (its ventral coloration in life can be seen in Figure 5C); and (**H**) female *Liolaemus fittkaui* MNCN 46645 in life, from Cerro Rodeo, Tiraque Province. Photographs by Bruno Miranda (CBF-MNHN) and O. Jiménez-Robles.

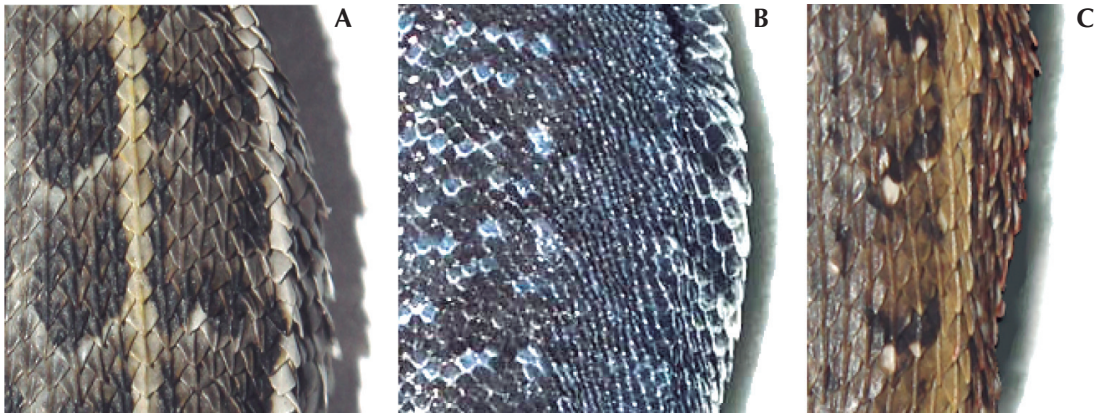

Figure 3. Dorsal and dorsolateral scales on the right part of midbody of (**A**) *Liolaemus fittkaui* female in life from Cerro Rodeo (not collected), (**B**) *Liolaemus* sp. CBF 2247 preserved, from Pusuq'huni, Arque Province, and (**C**) *Liolaemus variegatus* male MNCN 46649 in life, from K'aspikancha, Tiraque Province. Photographs by Bruno Miranda (CBF-MNHN) and O. Jiménez-Robles.

Discussion

These findings have extended the known range of *Liolaemus fittkaui* nearly 20 km NNW in the provinces of Chapare and Tiraque. The population near Pojo, is only represented by photographs and its identity needs to be confirmed; if it is *L. fittkaui,* the species would might have a discontinuous range along nearly 100 km in the highlands of the Cordillera de Tiraque (including the Province of Carrasco). Specimens CBF 2247–2248 and 2250 from Pusuq'huni, Arque Province, should not be considered *L. fittkaui*. Therefore, although likely within the *L. montanus* series (*sensu* Schulte *et al.* 2000, Lobo *et al.* 2010), the taxonomic status of these specimens needs to be clarified.

Currently, the known elevational distribution of *Liolaemus fittkaui* is from 3800–4260 m a.s.l., in the Cordillera de Tiraque, but further exploration of these mountains may reveal populations at greater or lesser elevations. Colomi Valley, at less than 3300 m a.s.l., may act as a dispersal barrier for *L. fittkaui* at present. Similarly, the mountains of Koari Macho (4260 m a.s.l.) and

Figure 4. *Liolaemus fittkaui* found in both extremes of the Tiraque range: (**A**) male of Laguna San Isidro, Chapare Province (3860 m a.s.l., westernmost known locality); (**B**) female in Pojo highlands, Carrasco Province (approximately 3800 m a.s.l., easternmost known locality). Photographs by O. Jiménez-Robles and J. Salguero (*Inbox* magazine).

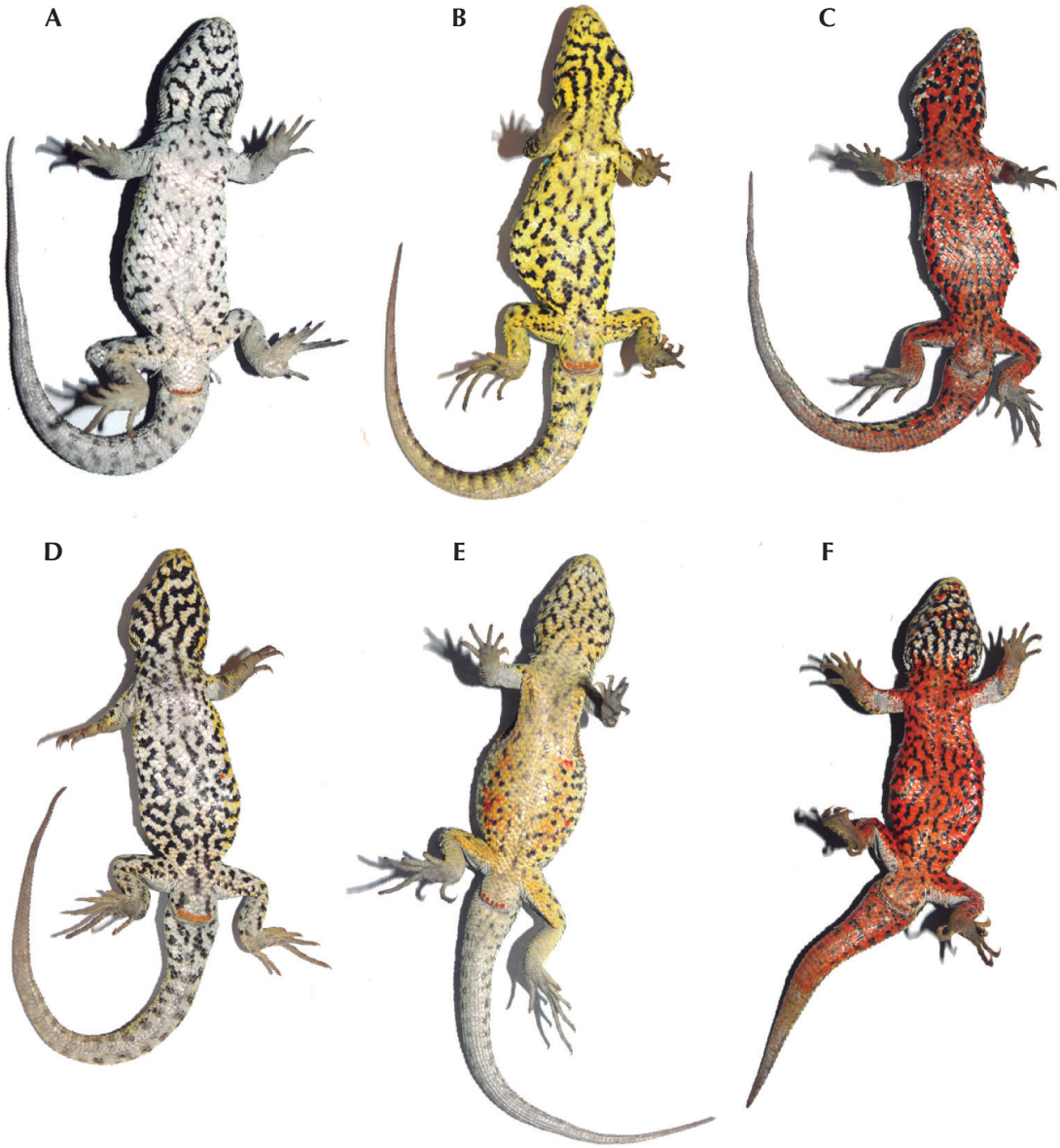

Figure 5. Ventral color variation of *Liolaemus fittkaui* males in life, along the species' known range in the Cordillera de Tiraque. The first row would represent single colors morphs: (**A**) white (Sallamani); (**B**) yellow (Koari-Quewiñacocha); (**C**) red (Laguna Robada, MNCN 46647). The second row, combinations of them: (**D**) white-yellow (Koari-Quewiñacocha); (**E**) yellow-red (Cerro Rodeo); and (**F**) red-white (Cerro Rodeo). Another picture of the specimen MNCN 46647 after preservation can be seen in Figure 2G with most of the red pigmentation lost, less than two years after fixation.

Table 1. Some differences among *Liolaemus fittkaui*, and the other two species which have been misidentified before as *L. fittkaui: Liolaemus* sp. from Pusuq'huni and *L. variegatus.*

Traits	***Liolaemus fittkaui***	***Liolaemus* sp.** from Pusuq'huni	***Liolaemus variegatus***
Body size (mm)	50–65	56–63.6	50–65
Relative tail length (for non-regenerated tails)	Up to 1.5 and 1.4 of body size in males and females, respectively	Up to 1.04 of body size	Up to double length or 1.69 of body size in males and females, respectively
Dorsal scales	Big, strongly keeled, imbricated, triangular, and acuminate	Small, slightly keeled, almost granular and smooth	Big, strongly keeled, imbricated, rhomboidal, and acuminate
Lateral scales	Same size as dorsal scales, imbricated, triangular, acuminate and with keels that disappear towards the ventral region	Smaller than dorsal scales, granular	Same size as dorsal scales, imbricated, rhomboidal, acuminate and with keels that disappear towards the ventral region
Dorsal coloration	(In life and in ethanol) Two dorsal longitudinal rows of dark chevrons posteriorly bordered with white lines, in males and most of females. A pair of longitudinal dorsal and dorsolateral stripes in females and and most of males (In life) Some males with red, blue and yellow stripes and scattered scales	(In ethanol after their fixation in formaline in 2000) Dark grey with darker transversal irregular stripes, posteriorly bordered with lighter bluish irregular transversal stripes	(In life and in ethanol) Grey with two pairs of darker longitudinal rows (dorsal and dorsolateral) with approximately a dozen of black transversal patches, posteriorly bordered with two or three white spots (generally absent in females). Between both pairs of rows of dark patches, there are a pair of grey dorsolateral stripes and a dorsal stripe, all of them grey
Ventral coloration	(In ethanol) Whitish background in both sexes, with a conspicuous reticulated black pattern in males, which in females is absent or blurred. (In life) Blackground color can be either white, yellow or red, and intermediate combinations	(In ethanol after their fixation in formaline in 2000) Whitish background, with a reticulated black pattern in male CBF 2247 and female CBF 2250. In female CBF 2248, most of the scales have black pigmentation, giving the appearence of a dark grey ventral surface	(In ethanol and in life) Whitish with a black reticulated pattern, conspicuous in the gorge and blurred striped on the belly

Cuturi Punta (4224 m a.s.l.) are only about 4 km and 24 km, respectively, south of the Cordillera de Tiraque, and separated by small depressions (3600 m a.s.l. and 3400 m a.s.l., respectively). Until further searches in neighboring mountains are conducted, we cannot discount the presence of *L. fittkaui* in other wet puna grasslands of Cochabamba Department.

The paratype toponym "Tiraque, Depto. de Cochabamba" probably does not refer to the village of Tiraque but to the province of Tiraque. Thus, it may be inaccurate (as type locality). Unfortunately, it is too late to know whether the species was present in Tiraque in the past and, in that case, if climate warming might have caused its extinction (as hypothesized by Sinervo *et al.* 2010). However, given the habitat requirements of *Liolaemus fittkaui,* we doubt about its presence in the village of Tiraque (3370 m a.s.l), even in 1927.

The scant knowledge about the distribution of *Liolaemus fittkaui* seems to reflect a spatially fragmented range along the Cordillera de Tiraque. This distribution is typical of mountain endemics and usually creates opportunities for intraspecific evolution, resulting in marked patterns of genetic structure along the range of the species (Milá *et al.* 2013). In fact, the spatial differences we found in the occurrence of the different color morphs may reflect differences in the genetic flow among different areas (Calsbeek *et al.* 2010). Molecular studies might elucidate the degree of distinctiveness among populations along this complex topography.

The trimorphic coloration of male *Liolaemus fittkaui* may reflect an intra-population dynamic of reproductive strategies following a rock-paper-scissor game, as occurs in other species of lizards (Rand 1990, Sinervo and Lively 1996, Sinervo *et al.* 2001, Huyghe *et al.* 2007, Sinervo *et al.* 2007, Bastiaans *et al.* 2013, Galeotti *et al.* 2013). Other *Liolaemus* also are polymorphic with respect to ventral color (e.g., *L. ornatus, L. orientalis*; O. Jiménez-Robles, unpublished). We do not think that this polymorphism represents seasonal color variation, because we observed the range of phenotypic variation simultaneously. Further behavioral research is necessary to confirm the cause of these phenotypic polymorphisms in *Liolaemus*.

The Amazonian slopes of the Cordilleras de Tiraque and Cochabamba were identified as an exceptionally high center of endemism in the study of Swenson *et al.* (2012). Our data and other studies (Balderrama 2006, Tarifa *et al.* 2007) also reveal the biogeographic importance of the highlands of these mountain ranges for the conservation of several endemic organisms. To preserve this high diversity, we must map the distribution of endemic species, in addition to collecting more data on their ecology, habitat requirements, and population status.

In most cases, *Liolaemus fittkaui* was found in areas where wet puna grasslands (*sensu* Navarro and Maldonado 2002) were well conserved. The grasslands of Andean ecosystems (along with other elements) have received little attention from researchers and conservationists (Buytaert *et al.* 2011). In contrast, *Polylepis* forests, bogs, and wetlands have been the focus of several biodiversity and conservation studies in the Bolivian Andes, mainly dealing with plants, birds, and mammals (Balderrama 2006, Tarifa *et al.* 2007, Gareca *et al.* 2010, Loza-Herrera *et al.* 2015). In some cases, puna grasslands have been regarded as the degradation stage of pristine Andean forests (Kessler 2002). However, other studies have demonstrated that forests did not cover the entire alpine region and that puna grasslands were also a fundamental part of Andean highlands climax ecosystems (Gareca *et al.* 2010). In this study, we provide evidence that puna grasslands by themselves contribute to the particular diversity of the Andes, being fundamental for endemic species such as *L. fittkaui*.

Organisms with limited dispersal ability such as arthropods, amphibians, and reptiles, have higher endemism rates than birds, mammals, and plants (Anthelme *et al.* 2014), but they are also understudied. Further inventories of these taxonomic groups in the puna grasslands of different Andean ranges may reveal more endemic organisms.

In addition to the conclusions of former conservation evaluations (Embert 2007, Aguayo *et al.* 2009), we note that some populations of *Liolaemus fittkaui* (Pojo Highlands, Koari-Quewiñacocha, Sallamani and Cerro Rodeo) are in the Bolivian protected area network, within

the Carrasco National Park (Figure 1B). However, the management of this area currently is focused on the preservation of the evergreen forests of the northern versants, and we suspect that the included puna grasslands probably are considered as a buffer area. Protection of endemic puna organisms, such as *L. fittkaui*, should appear in the park conservation programs as well.

Even inside the protected area network, the main threat to *Liolaemus fittkaui* is habitat loss, mostly resulting from the increase of agricultural activity (mainly potatoes), including pesticide use, overgrazing, and frequent grassland burning (Centro de Biodiversidad y Genética 2008, Aguayo *et al.* 2009). Fire is used to burn the "pajonal" tussocks, killing the organisms that find refuge in them. These fires can become uncontrolled and cause significant and extensive habitat degradation. After uncontrolled burning in an area such as Sallamani Lake (Figure 6), it was difficult to locate proper pristine wet puna grasslands, and consequently, *L. fittkaui* was found in low densities. Other areas with well-conserved habitat, such as Koari-Quewiñacocha, Cerro Rodeo, and Laguna Robada had relatively higher densities of *L. fittkaui* (O. Jiménez-Robles, unpublished). However, some patches of these areas had been turned into small potato fields (Figure 6), and lizards scarcely could be found. These agricultural incursions are used for a short period, and then abandoned. Thus, preservation of the remnant extensions of pristine puna grasslands seems to be the most effective measure for the conservation of *L. fittkaui* and other endemic species.

The area of wet puna grasslands in the Cordillera de Tiraque is less than 500 km^2. Currently there are fewer than 10 disjunct populations of *Liolaemus fittkaui* in a landscape blighted by recent destruction of wet puna grasslands; thus, extent and quality of habitat for *L. fittkaui* continues to decline. Therefore, we conclude that the category of Vulnerable [VU B1ab(iii)+2ab(iii)] is adequate, according to the IUCN criteria (UICN 2012), for the conservation status of *L. fittkaui*.

We encourage the protection of these Andean highland ecosystems, increasing the areas already included in the national protected area network. The southern limits of the Carrasco National Park should be adjusted to include well-preserved patches of puna habitat. Other areas should be protected in the region to

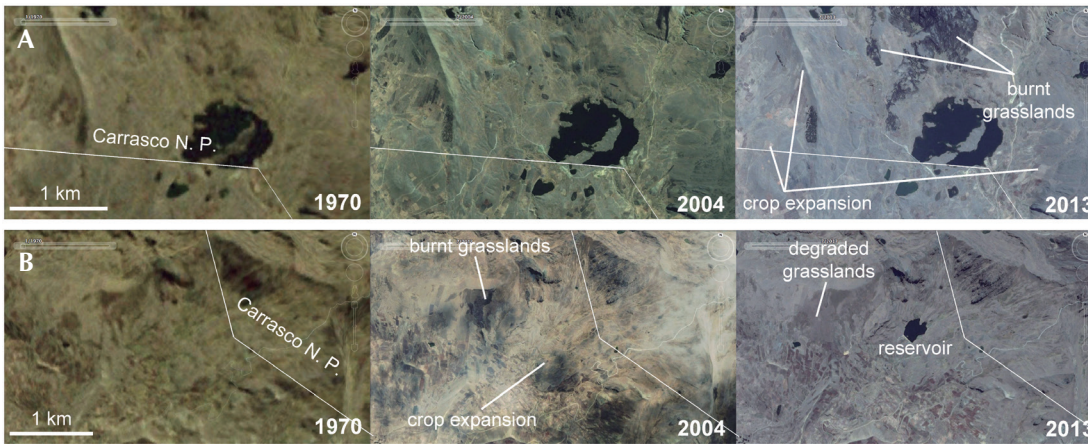

Figure 6. Habitat destruction and degradation in the areas of Sallamani (**A**) and Cerro Rodeo (**B**) observed in satellite images taken during 1970, 2004, and 2013. Source: GoogleEarth.

safeguard their endemic organisms (Soria-Auza and Hennessey 2005). Given the high levels of human activity in the Bolivian Andean region, protection measures should be accompanied by outreach to create awareness in the indigenous population for the value of these ecosystems, regarding their services such as carbon storage and water supply (Farley *et al.* 2013), and the need to preserve their unique species. In the same way, certain endemic organisms could be periodically surveyed, in order to monitor population trends and prevent particular areas from habitat degradation.

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