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A new species of the *Liolaemus walkeri* clade (Squamata: Liolaemidae) in the volcanic chain of Arequipa, Peru

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Abstract. We describe a new species of *Liolaemus* lizard from southwestern Peru, within the volcanic chain represented by the Chachani, Misti and Pichu Pichu volcanoes that surround the city of Arequipa. The type locality is Simbral, in the district of Chiguata, Department of Arequipa. The diagnostic characters of the new species include small size (SVL < 50 mm), a pigmented subocular scale, vertebral line generally absent or highly fragmented (when present), scales smooth or slightly keeled on the dorsal side of thighs, partial or total ventral melanism, and absence of precloacal pores in males and females. The elevational distribution of the new species is 4135–5400 m a.s.l., with the upper limit representing the highest altitude record for a living squamate.

Key words. Andes, high elevation, lizard, systematics, taxonomy.

Introduction

Within Squamata the Neotropical genus *Liolaemus* (Liolaemidae), is the second most diverse of the world (Pincheira-Donoso et al. 2013), and occupies different habitats including the deserts of Chile and Peru, the Andes of Argentina, Bolivia, Chile, and Peru, Patagonia in Argentina and Chile, as well as the Atlantic coasts in Brazil and Uruguay. Throughout their distribution, *Liolaemus* species experience a variety of microclimates from 0–5400 m above sea level (a.s.l.). (Cerdeña et al. 2021).

Knowledge of the species richness of *Liolaemus* has improved in recent decades, and in both two recognized subgenera, *Eulaemus* (Argentine group) and *Liolaemus* sensu stricto (Chilean group, see Laurent 1983) except for the *Liolaemus walkeri* clade. Aguilar et al. (2013, 2015) considered this clade as part of the subgenus *Liolaemus* and included five species (*L. chavin* Aguilar, Wood, Cusi, Guzmán, Huari, Lundberg, Mortensen, Ramírez, Robles, Suárez, Ticona, Vargas, Venegas & Sites, 2013, *L. pachacutec* Aguilar, Wood, Cusi, Guzmán, Huari, Lundberg, Mortensen, Ramírez, Robles, Suárez, Ticona, Vargas, Venegas & Sites, 2013, *L. tacnae* (Shreve, 1941), *L. walkeri* Shreve, 1938, and *L. wari* Aguilar, Wood, Cusi, Guzmán, Huari, Lundberg, Mortensen, Ramírez, Robles, Suárez, Ticona, Vargas, Venegas & Sites, 2013). However, recent phylogenetic analyses using mitochondrial, nuclear, or genomic data showed that the *L. walkeri* clade diverged early from the two subgenera *Eulaemus* and *Liolaemus,* and that it is not phylogenetically nested in either of these subgenera (Esquerré et al. 2019, 2022, but see Portelli & Quinteros 2018, Quinteros et al. 2020).

The city of Arequipa in southern Peru lies at the foot of three volcanoes, the Chachani (6057 m a.s.l.), Pichu Pichu (5634 m a.s.l.), and the Misti (5822 m a.s.l.), resulting in a complex topography (Ceruti, 2013). Several species of *Liolaemus* are found around the city of Arequipa including *L. annectens* Boulenger, 1901, *L. anqapuka* Huamaní-Valderrama, Quiróz, Gutiérrez, Aguilar-Kirigin, Chaparro & Abdala, 2020, *L. etheridgei* Laurent, 1998, *L. tacnae* and *L. yarabamba* Quiróz, Huamaní-Valderrama, Gutiérrez, Aguilar-Kirigin, Chaparro & Abdala, 2021.

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Recently, researchers working on the western slopes of southern Peru have named six species within *Eulaemus*: *L. chiribaya* Aguilar-Puntriano, Ramírez, Castillo, Mendoza, Vargas & Sites, 2019, *L. nazca* Aguilar-Puntriano, Ramírez, Castillo, Mendoza, Vargas & Sites, 2019, *L. balagueri* Villegas-Paredes, Huamaní-Valderrama, Luque-Fernández, Gutiérrez, Quiróz & Abdala, 2020, *L. anqapuka* Huamaní-Valderrama, Quiroz, Gutiérrez, Aguilar-Kirigin, Huanca-Mamani, Valladares-Faúndez, Cerdeña, Chaparro, Santa Cruz & Abdala 2020, *L. warjantay* Ubalde-Mamani, Gutiérrez, Chaparro, Aguilar-Kirigin, Cerdeña, Huanca-Mamani, Cárdenas-Ninasivincha, Lazo-Rivera & Abdala, 2021, and *L. yarabamba* Quiróz, Huamaní-Valderrama, Gutiérrez, Aguilar-Kirigin, López-Tejeda, Lazo-Rivera, Huanca-Mamani, Valladares-Faúndez, Morrone, Cerdeña, Chaparro, & Abdala, 2021. However, no new species of the *L. walkeri* clade have been described from Peru in the past decade.

Aguilar et al. (2013) showed that specimens from the Arequipa Department are phylogenetically nested in the *L. walkeri* clade, but could not identify this population as a lineage distinct from *L. tacnae* because of small sample size (sequences from only one specimen, BYU 50229). We reassess the taxonomic status of populations assigned to *L. tacnae* (Lobo & Espinoza 1999, Lobo & Espinoza 2004, Quinteros 2012, Ocampo et al. 2012, Aguilar et al. 2013, Quinteros 2013, Quinteros et al. 2014, Abdala et al. 2015, Portelli & Quinteros 2018), *L. walkeri* (Zeballos et al. 2002), *L.* cf. *walkeri* (Gutierrez et al. 2010), and *L.* aff. *tacnae* (Cerdeña et al. 2021) in Arequipa by analyzing morphometric, meristic and pattern of coloration characters. As a result, we provide evidence of a new species, which we describe herein.

Material and methods

Field work

We worked in the locality of Simbral, District of Chiguata, Province and Department of Arequipa, Peru (-16.389830°, -71.314909°, 4185 m a.s.l., WGS84). We euthanized lizards by injecting them with an anesthetic solution containing a 6.5% sodium pentobarbital solution (100 mg/l). After euthanasia and observing no movements for more than 20 min, we extracted tissues (e.g., liver, muscle) and preserved tissue samples in 2 ml cryogenic tubes filled with 96% ethanol. Following tissue collection, we fixed specimens in 10% formalin and permanently stored them in 70% ethanol. We identified the sex of specimens by observing presence or absence of hemipenes. We examined specimens from the Museo de Historia Natural de San Marcos de Lima (MUSM) and the Museo de Historia Natural de la Universidad Nacional de San Agustín de Arequipa (MUSA).

Morphological data and analyses

We examined 81 specimens of five Peruvian species of the *L. walkeri* clade (*L. chavin*, *L. pachacutec*, *L. tacnae*, *L. walkeri* and *L. wari*), including the type material of *L. chavin*, *L. pachacutec*, and *L. wari* (Aguilar et al. 2013).

We considered morphological characters and terminology of the color pattern, utilized in taxonomic studies of *Liolaemus*, subgenus *Liolaemus* sensu stricto (*chilensis* group) (Lobo & Espinoza, 1999, Quinteros, 2012, Quinteros et al. 2020) and the *L. walkeri* clade (Aguilar et al. 2013). To describe coloration in life, we used photographs taken in the field and laboratory with a digital camera Canon 7D Mark II and light box Godox LSD.

We scored the following 12 morphometric characters: (SVL) snout–vent length; (WC-C) snout width (between the edges of the canthal scale); (WSc-Sc) distance between the posterior edge of the superciliary series; (LeSo) length of the subocular scale; (WB) body width; (WP) upper width of the pygal area; (LeP) length of the pygal area; (LeF-R) length from the back of the forearm to the rostral scale; (LeI-R) length from posterior part of interparietal to rostral scale; (LeE-R) length from ear to rostral scale; (LeT) tibia length; (LeR-4F) length between base of radius to fourth finger without nail. We also scored three meristic characters: (MBS) number of midbody scales (counted transversely at the middle of the body), (DS) dorsal scales (counted from the interparietal scale to the anterior border of the thighs), and (VS) ventral scales (counted from the mental scales to the cloaca). Examination of scalation or pholidosis was performed using a binocular stereoscope (10–40×) Nikon SMZ 745T, and morphometric measurements were made with a Spi2000 caliper with 0.01 mm resolution. Measurements and counts were taken from the right side of the animal.

We calculated descriptive statistics (averages ± standard deviation, and range values) and Principal Component Analyses (PCA) using morphological variables to compare species of the *L. walkeri* clade (*L. chavin*, *L. pachacutec*, *L. tacnae*, *L. walkeri*, and *L. wari*), considering males only because of sexual dimorphism (N = 59). In addition, we compared males and females (N = 43) of populations from different localities of *L. tacnae* from the Moquegua and Tacna departments, including near the type locality of the Toquepala mine (Tacna), with populations assigned to *L. tacnae* from Arequipa.

We used R package FactoMineR (Husson et al. 2024) to perform PCA, and factoextra and ggplot2 (Kassambara & Mundt, 2022, Wickham et al. 2024) to extract and visualize the PCA results (we used the function scale to standardize numerical data). We used the R packages terra and sf (Hijmans et al. 2024, Pebesma et al. 2024) to produce a map representing the distribution of species in the *L. walkeri* clade (Aguilar et al. 2013). The type localities were taken from the original descriptions, and the records of other localities from related literature and MUSM and MUSA vouchers.

Nomenclatural acts

The electronic edition of this article conforms to the requirements of the amended International Code of Zoological Nomenclature, and hence the new names contained herein are available under that Code from the electronic edition of this article. This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the ICZN.

The LSID (Life Science Identifier) for this publication is: urn:lsid:zoobank.org:pub: 767C1151-391D-42AD-A847-67724AA549A9. The electronic edition of this work was published in a journal with an ISSN and has been archived and is available from the following digital repositories: www. zenodo.org and www.salamandra-journal.com.

Results

Liolaemus misti sp. n.

Figs 1–5

LSID: urn:lsid:zoobank.org:act:78CA833C-4C24-493D-9FE7-DA076494BFC2

Liolaemus tacnae, Lobo & Espinoza 1999: 138, 2004: 867, Quinteros 2012: 120, 2013: 28, Ocampo et al. 2012: 417, Aguilar et al. 2013: Supplementary file 4, Quinteros et al. 2014: 28, Abdala et al. 2015: 114, Portelli & Quinteros 2018: Supplemental file S1.
Liolaemus aff. *tacnae,* Cerdeña et al. 2021: 34
Liolaemus walkeri, Zeballos et al. 2002: 30
Liolaemus cf. *walkeri,* Gutiérrez et al. 2010: Holotype. MUSA 5708, adult male, from Simbral, Chiguata District, Arequipa Province and Department, Peru, -16.389830°, -71.314909°, 4185 m a.s.l., collected by R. Bejarano, A. Canazas-Terán, and R. Santa-Cruz, on 23 December 2020.

Figure 1. Adult male holotype of *L. misti* sp. n. in life (MUSA 5708), SVL 49.1 mm, TL 55.0* mm. (A) Dorsolateral, (B) ventral, (C) lateral head, (D) dorsal, and (E) absent precloacal pores. [* = Regenerated or broken tail.]

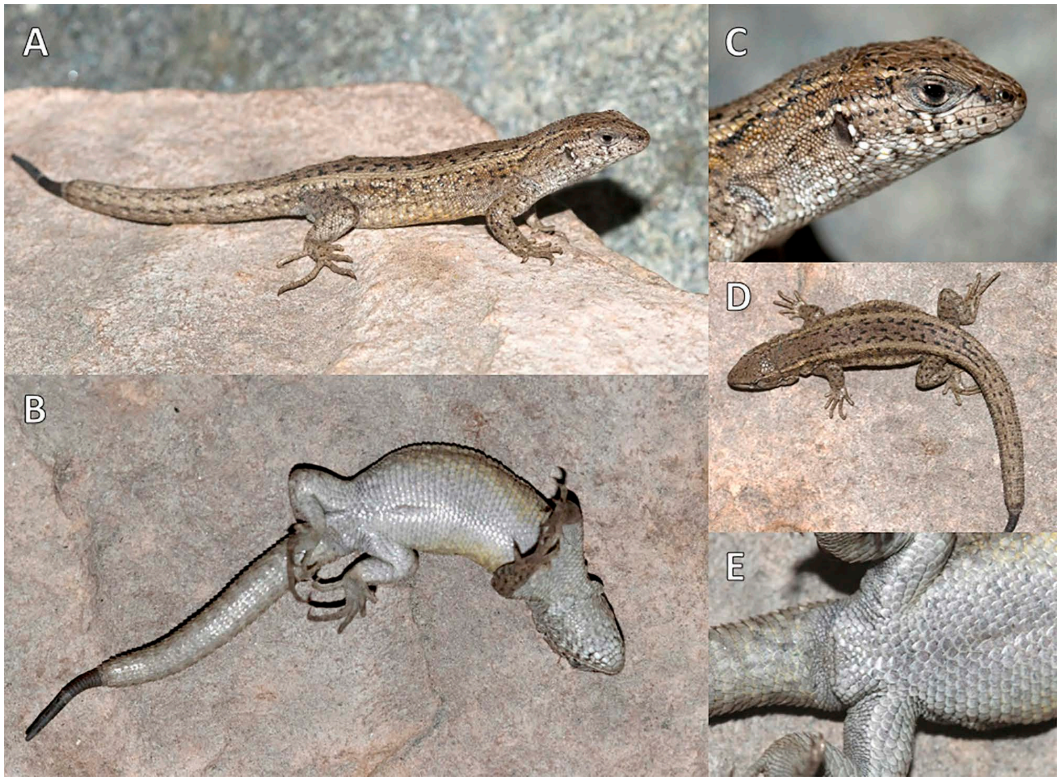

Figure 2. Adult female paratype of *L. misti* sp. n. in life (MUSA 5709), SVL 45.5 mm, TL 45.2* mm. (A) Dorsolateral, (B) ventral, (C) lateral head, (D) dorsal, and (E) absent precloacal pores. [* = Regenerated or broken tail.]

Figure 3. Dorsolateral, dorsal, and ventral views of *L. misti* sp. n. in life. (A–C) adult female paratype (MUSM 40547), SVL 48.7 mm, TL 51.7* mm; (D–F) adult male paratype (MUSM 40545), SVL 48.5 mm, TL 59.9* mm. [* = Regenerated or broken tail.]

Paratypes: Eight adult specimens: (MUSM 40545–40546), two males, (MUSA 5709, MUSM 40547–40548), three females, collected from the type locality by R. Bejarano, A. Canazas-Terán, and R. Santa-Cruz, on 23 December 2020. (MUSA 5844–5845), two males, (MUSA 5843), one female, collected near the type locality, -16.385830°, -71.317269°, 4135 m a.s.l., by R. Bejarano, A. Canazas-Terán, Diana Arhuire, Graciela Meza, and R. Santa-Cruz, on 2 May 2021.

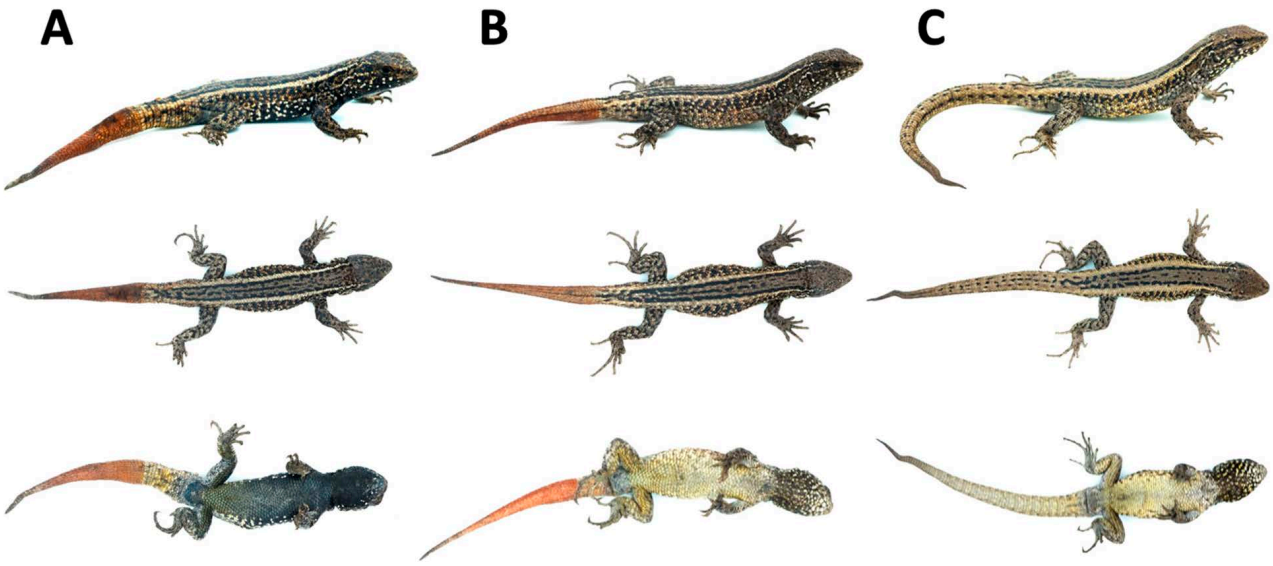

Figure 4. Dorsolateral, dorsal, and ventral views of *L. misti* sp. n. adult males in life, from left to right: (A) paratype (MUSA 5844), SVL 45.4 mm, TL 39.8* mm; (B) paratype (MUSA 5845), SVL 47.5 mm, TL 45.1* mm; (C) unvouchered specimen. [* = Regenerated or broken tail.]

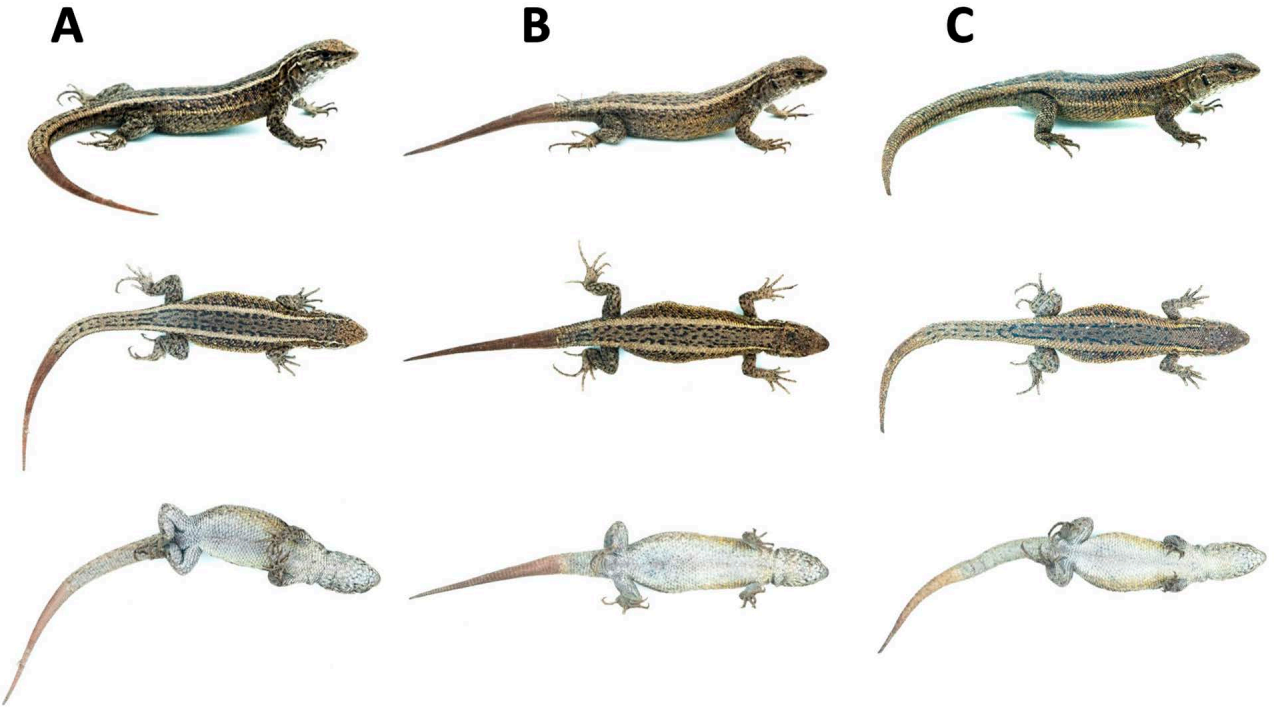

Figure 5. Dorsolateral, dorsal, and ventral views of *L. misti* sp. n. adult females in life, from left to right: (A) paratype (MUSA 5843), SVL 43.4 mm, TL 51.3* mm; and (B–C) unvouchered specimens. [* = Regenerated or broken tail.]

Additional specimens: MUSA 4581–4588: four males and four females, collected at Toccra, Caylloma province, Arequipa Department, Peru, -15.857571°, -71.556774°, 4135 m a.s.l., in 1999. MUSA 734–735: two females, collected at near the Chachani volcano, Arequipa Province and Department, Peru, -16.168214°, -71.494334°, 4870 m a.s.l., in 2005. MUSA 1239–1240: one male and one female, collected near Huito-Moche, Arequipa Province and Department, Peru, -16.348299°, -71.221163°, 4260 m a.s.l., in 2007. MUSA 4724, MUSA 4727–4731, MUSA 4733–4735: two males and eight females, collected at Simbral (near the type locality), Arequipa Province and Department, Peru, -16.391608°, -71.316823°, 4120 m a.s.l., in 2013. MUSA 5300, female, collected at Simbral (near the type locality), Arequipa Province and Department, Peru, -16.369297°, -71.321425°, 3730 m a.s.l., in 2014 (Fig. 6).

Diagnosis: We assign *Liolaemus misti* sp. n. to the *L. walkeri* clade, lizards with throat or belly melanistic or with spots in males (Aguilar et al. 2013), small and slender (49.3 mm

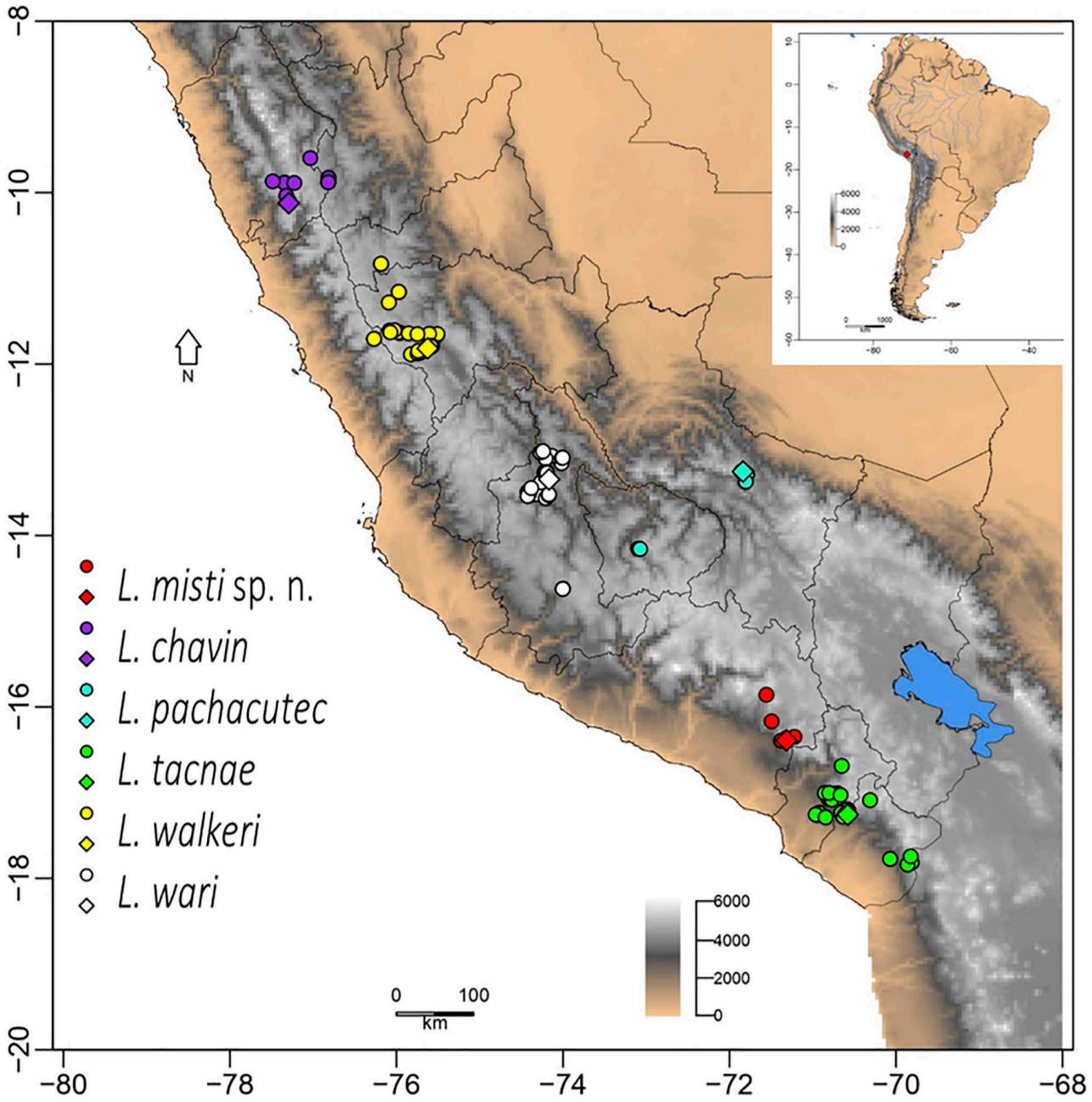

Figure 6. Map of central and southern Peru showing the distribution of members of *L. walkeri* clade. Type localities are indicated by diamonds, additional localities by circles. The red diamond indicates the type locality of *L. misti* sp. n.

maximum SVL). Males of *L. misti* sp. n. differ from *L. chavin* and *L. wari* by their smaller size (less than 50 mm SVL vs 51.7–59.3 mm and 51.5–60.8 mm, respectively). *Liolaemus misti* sp. n. differs from *L. tacnae* by a lower number of mid-body scales and dorsal scales (40–50 vs 48–59, 43–55 vs 53–61, respectively). The subocular scale and loreal scales are strongly pigmented in *L. misti* sp. n. whereas in *L. walkeri* these scales are lighter (Fig. 7). The lateral fields in *L. misti* sp. n. have scattered black and white scales forming spots (males) or scattered black and brown scales (females), which are absent in *L. pachacutec*. Paravertebral marks appear as black complete marks or as fragmented lines (more noticeable when parallel to the dorsolateral stripe) in *L. misti* sp. n. (Figs 8A–9A), but they are absent or fuzzy in *L. pachacutec*; *L. tacnae* has paravertebral markings as black dots perpendicular to the dorsolateral stripe, with light scales behind the black scales (Figs 8C–9C). The vertebral line is generally absent or highly fragmented in *L. misti* sp. n., but it is well differentiated in *L. chavin, L. pacachutec, L. walkeri,* and *L. wari*. *Liolaemus tacnae* has keeled scales on the dorsal side of thighs, which are absent in *L. misti* sp. n. (Fig. 10). *Liolaemus misti* sp. n. also differs from *L. pachacutec, L. walkeri,* and *L. wari* in males lacking precloacal pores.

In Peru, three species of the *L. alticolor-bribonii* group have been confused with species of the *L. walkeri* clade: *L. alticolor* from Puno, *L. chungara* from Tacna, and *L. incaicus* from Cusco (Aguilar et al. 2013, Lobo et al. 2007, Quinteros et al. 2014, Valladares et al. 2021). Here we report key morphological differences between these species and *L. misti* sp. n. *Liolaemus misti* sp. n. has 49–58 scales around the body, more than *L. incaicus* (34–46). *Liolaemus misti* sp. n. lacks keeled temporal scales which are present in *L. chungara*, *L. incaicus* (weakly keeled), and *L. alticolor* (markedly keeled). Dorsal scales in *L. misti* sp. n. are keeled and without a mucron, whereas a mucron is present in *L. chungara*. *Liolaemus misti* sp. n. has partial or total ventral melanism, which is absent in *L. alticolor* and *L. incaicus*. *Liolaemus misti* sp. n. lacks precloacal pores in males and females, which are present in some or all females of *L. incaicus*, and present in males of *L. alticolor*, *L. chungara* and *L. incaicus*.

Description of the holotype: Adult male MUSA 5708; snout–vent length SVL 49.1 mm (Fig. 1); tail length 56.0 mm; head length 10.8 mm; head width 8.2 mm; head length/head width 1.32; head height 6.2 mm; neck width

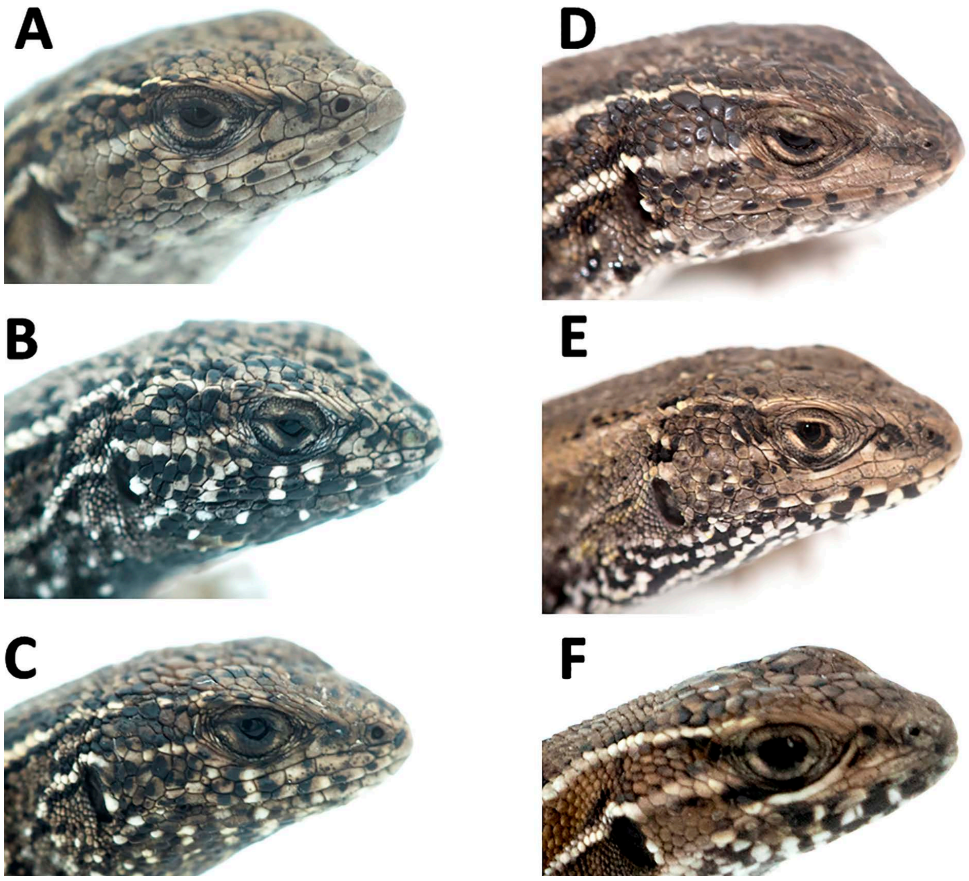

Figure 7. Lateral view of head showing the subocular scale and loreal scales, in adults *L. misti* sp. n. (A) female, paratype (MUSA 5843); (B) male, paratype (MUSA 5844); (C) male, paratype (MUSA 5845), and *L. walkeri*; (D) female (MUSA 5856); (E) male (MUSA 5857); and (F) male, unvouchered specimens.

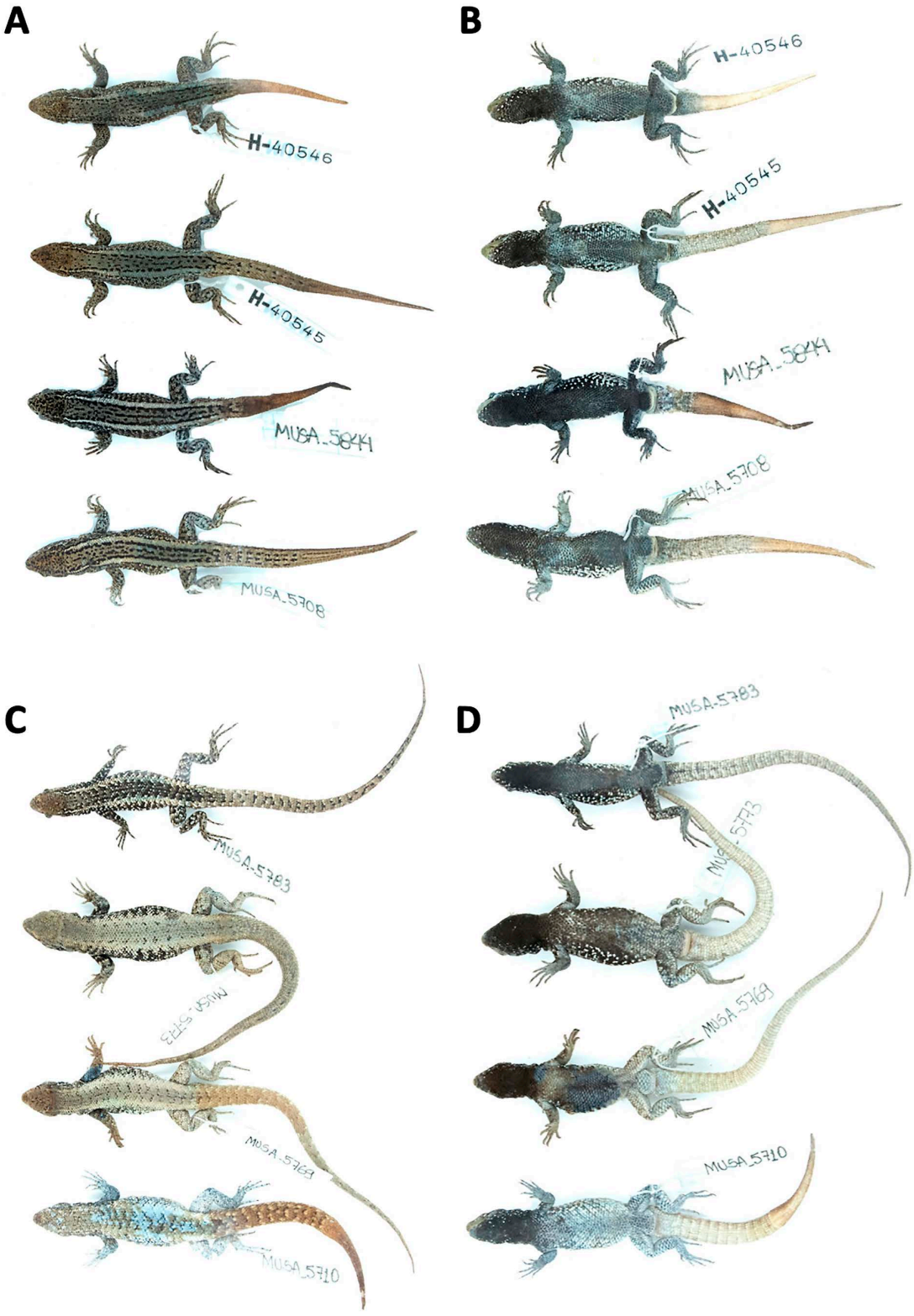

Figure 8. Views of adult males in preservative: (A–B) dorsal and ventral of *L. misti* sp. n., top to bottom MUSM 40546 paratype, SVL 47.4 mm, TL 35.4* mm; MUSM 40545 paratype, SVL 48.5 mm, TL 59.9* mm; MUSA 5844 paratype, SVL 45.4 mm, TL 39.8* mm; MUSA 5708 holotype, SVL 49.1 mm, TL 55.0* mm. (C–D) Dorsal and ventral of *L. tacnae,* top to bottom MUSA 5783, SVL 46.5 mm, TL 85.8 mm; MUSA 5773, SVL 54.9 mm, TL 90.4 mm; MUSA 5769, SVL 49.1 mm, TL 85.0 mm; MUSA 5710, SVL 52.0 mm, TL 58.4* mm. [* = Regenerated or broken tail.]

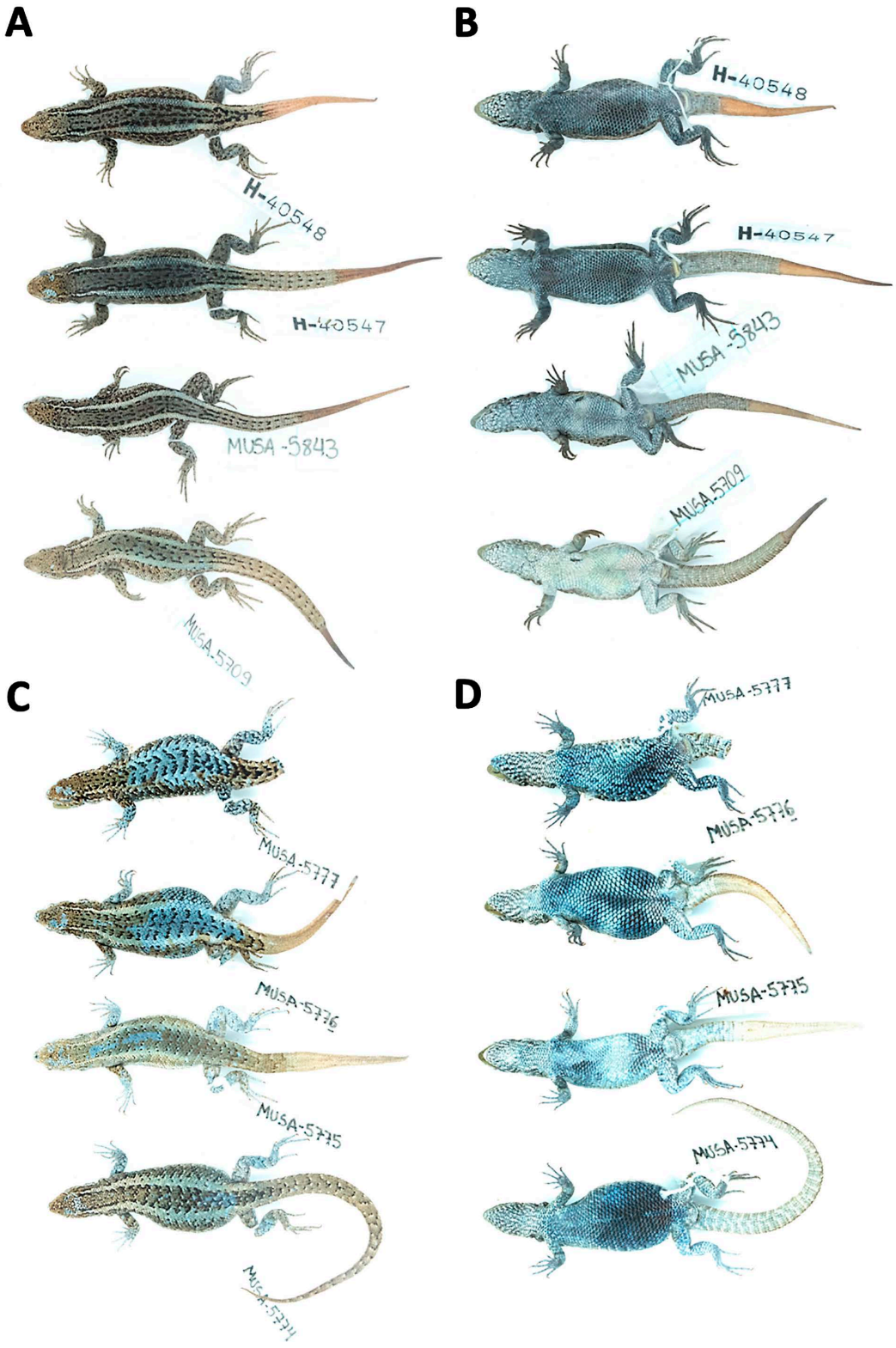

Figure 9. Views of adult females in preservative: (A–B) dorsal and ventral of *L. misti* sp. n., top to bottom MUSM 40548 paratype, SVL 49.2 mm, TL 34.0* mm; MUSM 40547 paratype, SVL 48.7 mm, TL 51.7* mm; MUSA 5843 paratype, SVL 43.4 mm, TL 51.3* mm; MUSA 5709 paratype, SVL 45.5 mm, TL 45.2* mm. (C–D) Dorsal and ventral of *L. tacnae,* top to bottom MUSA 5777, SVL 52.2 mm, TL 10.5* mm; MUSA 5776, SVL 52.0 mm, TL 39.4* mm; MUSA 5775, SVL 51.2 mm, TL 47.1* mm; MUSA 5774, SVL 55.0 mm. TL 79.5 mm. [* = Regenerated or broken tail.]

7.1 mm; eye diameter 3.0 mm; interorbital distance 6.3 mm; orbit–auditory meatus distance 4.2 mm; auditory meatus height 2.1 mm; auditory meatus width 1.7 mm; orbit–mouth opening distance 5.1 mm; internasals distance 2.5 mm; posterior to the interparietal to mouth opening distance 9.1 mm; snout width at the edge of the canthal scale 4.0; subocular scale length 3.3 mm; femur length 9.8 mm; tibia length 7.7 mm; hind limb length without claw 26.9 mm; humerus length 6.0 mm; forearm to fourth finger distance without claw 12.1 mm; pygal region length 5.4 mm; upper width of the pygal area 5.5 mm; back of the forearm to the tip of the mouth distance 22.6 mm; length of the rostral scale 2.3 mm; rostral height 1.1 mm; length of the mental scale 2.3 mm; mental scale width 1.2 mm.

Dorsal surface of head rough; hellmich index of 10 scales (interparietal–rostral); eight scales around the interparietal; rostral trapezoidal surrounded by eight scales; nasal in contact with the rostral; nasal surrounded by six scales, separated from canthal by two scales; preocular in contact with third and fourth lorilabials scales; six superciliaries scales and nine upper ciliaries scales; four differential scales at anterior margin of auditory meatus; eight temporary scales; four lorilabials scales in contact with subocular; five supralabials; eight supraoculars; seven lorilabials; six infralabials; three pairs of chin shields, the first pair in contact; number of scales around midbody 49; number of dorsal scales 57, between the occiput and the level of the anterior edge of the thigh, rhomboidal, imbricate, keeled and without mucron; scales on forelimbs rhomboidal, imbricate, and not keeled; on hindlimbs rhomboidal, imbricate, and slightly keeled; on dorsal tail, imbricated, laminar, keeled, and slightly mucronated; 72 ventral scales from the mental to the cloacal region, following the ventral midline of the body, subimbricated and laminar; 21 subimbricated gulars, not keeled; neck with longitudinal fold with 41 granular scales, without keel; ear fold present; antehumeral fold present; scales on forelimbs and hind legs ventrally granular, without keel; 15 subdigital lamellae on the 4th finger of the hand; 22 subdigital lamellae of the 4th toe; plantar scales with keel; ventral tail, imbricated, laminar without a keel; lacking precloacal pores.

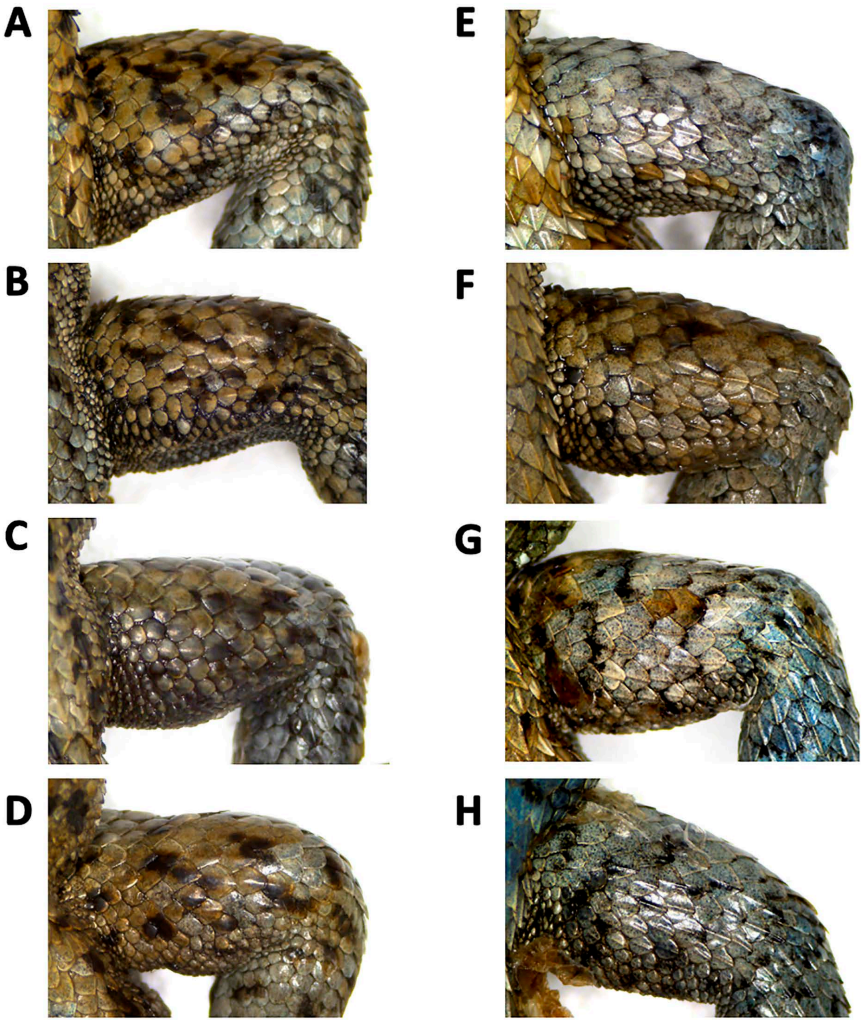

Figure 10. Dorsal view of thighs without keeled scales in adults *L. misti* sp. n. (A) Holotype, male (MUSA 5708); (B) paratype, male (MUSM 40545); (C) paratype, female (MUSM 40548); and (D) female (MUSA 4730). Dorsal view of thighs with keeled scales in adults *L. tacnae* (E) male (MUSA 5710), (F) male (MUSA 5773), (G) female (MUSA 5774), and (H) female (MUSA 5776).

Morphological variation: 26 specimens (11 males, 15 females); dorsal surface of head rough with hellmich scales 9–12 scales (10.0 ± 0.5); nasal surrounded by 6–8 scales (6.8 ± 0.6); supralabials 5–7 scales (5.7 ± 0.7); lorilabials 5–8 scales (6.7 ± 0.8); and one line of lorilabial scales; infralabials 5–6 scales (5.4 ± 0.5); supraoculars 5–6 scales (5.3 ± 0.5); interparietals surrounded by 5–9 scales (7.5 ± 1.1); gulars 21–27 scales (23.5 ± 1.6); scales around midbody 48–59 (52.3 ± 2.7); dorsal scales between the occiput and the level of the anterior edge of the thigh 53–61 (56.2 ± 2.6); subdigital lamellae of the fourth finger of the forelimb 15–19 scales (16.5 ± 1.0); subdigital lamellae of the fourth toe of the hindlimb 19–23 scales (21.5 ± 1.3); number of organs in the postrostral scales 6–15 (9.1 ± 2.3); number of ventral scales 72–86 (78.9 ± 3.9); precloacal pores males and females without pores. SVL males 41.5–49.3 mm (46.2 ± 2.4) and females 42.8–49.2 mm (46.3 ± 2.1); subocular length 2.1–3.5 mm (2.9 ± 0.3); meatus auditory higher 1.6–2.3 mm (1.9 ± 0.2); distance between posterior edges of superciliary series 5.1–6.3 mm (5.6 ± 0.3); head length 9.0–10.8 mm (9.8 ± 0.6); snout width at the edge of the canthal scale 3.2–4.0 mm (3.6 ± 0.2); distance between the back of the interparietal scale to the tip of the mouth 7.3–9.1 mm (8.1 ± 0.4); distance from the posterior part of the radius–ulna to the fourth finger of the hand, without claw 10.4–12.6 mm (11.4 ± 0.6); distance from the back of the forearm to the tip of the mouth 14.5–22.6 mm (17.7 ± 2); length between armpits 8.3–10.3 mm (9.1 ± 0.5); hind limb length 21.6–27.0 mm (24.0 ± 1.2); tibia length 6.6–8.2 mm (7.4 ± 0.4); upper width of the pygal area 3.1–5.9 mm (4.5 ± 0.7); length of the pygal area 3.1–5.6 mm (4.3 ± 0.6); body width 9.8–15.6 mm (12.4 ± 1.5); tail length 41.5–60.0 mm (52.7 ± 5.4). The mass of adult *L. misti* sp. n. averages 2.7 g in four males, and 2.9 g in six females.

Color of holotype in life: Head dorsally brown with black spots. Pigmented subocular. Dorsum with fragmented vertebral line, inconspicuous in some individuals. Vertebral field with two black fragmented lines parallel to the body, separated by fragments or spots of small horizontal black lines. Paravertebral field with a yellowish cream dorsolateral stripe. Lateral field with black, yellow, and brown crosshatch pattern with white dots. Lateral stripe of the head tenuous, from the postocular, passing through the superior margin of the auricular meatus, continuing along the longitudinal fold of the neck, until before the base of the forelimb. Anterior and posterior extremities the same color as the paravertebral fields. Ventral color melanic, of greater intensity in the throat with scattered light spots on the sides; dark belly with yellowish hue. (Figs 4–5).

Color of holotype in preservative: Compared to the original coloration the preserved specimen shows significant fading. Only the black markings remain distinct, while the background color has faded to a greyish-brown tone (Figs 8A–B).

Etymology: The scientific epithet "misti" refers to the volcano Misti, in Quechua language means "a white man" referred to the snow or white blanket that covers the volcano, one of the greatest symbols and the most striking element of the landscape of the city of Arequipa. Misti is the most distinctive volcano of the three that surround the city, along with Chachani and Pichu Pichu. Arequipans say: "not in vain is one born at the foot of a volcano", the presence of the Misti greatly influences the noble spirit of its inhabitants.

Distribution and natural history: *Liolaemus misti* sp. n. occurs in four localities, separated by up to 67 km by airline distance. The vegetation at all localities is an ecotone with species from two high Andean ecosystems (pajonal and tolar), with scattered individuals of *Polylepis rugulosa* (Rosaceae). Vegetation structure includes shrub and herbaceous strata composed of *Azolla compacta*, *Baccharis genistelloides, B. tricuneata*, *Caiophora rosulata*, *Chuquirauchercio rotundifolia*, *Festuca orthophylla, Loricaria graveolens, Lupinus misticola, Mniodes argentea, M. caespititia, Mutisia lanígera, Parastrephia quadrangularis, Perezia coerulescens, P. multiflora, Senecio crassilodix, S. nutans, Valeriana nivalis* among others (Fig. 11). Sympatric reptile species include *Tachymenis peruviana* Wiegmann, 1834 and *Liolaemus etheridgei*.

Figure 11. (A–B) Landscape views the Misti volcano and the habitat of *L. misti* sp. n.

Table 1. Descriptive statistics of morphometric and meristic characters for male individuals of *L. walkeri* clade from Peru. The first row shows ranges and the second shows means and standard deviations. For abbreviations see Material and methods.

	L. misti sp. n. (N = 11)	*L. chavin* (N = 6)	*L. pachacutec* (N = 8)	*L. tacnae* (N = 10)	*L. walkeri* (N = 11)	*L. wari* (N = 13)
SVL	41.5–49.3	51.7–59.3	41.3–52.0	47.6–54.9	50.3–60.7	51.5–60.8
	46.2±2.4	55.1±2.7	46.1±3.2	50.5±2.2	54.9±3.7	57.0±2.7
WC-C	3.3–4.0	4.0–4.6	3.2–3.6	3.6–4.1	3.7–4.5	3.6–4.2
	3.7±0.3	4.2±0.2	3.4±0.1	3.9±0.2	4.1±0.3	4.0±0.2
WSc-Sc	5.1–6.3	6.3–7.3	5.1–6.0	5.8–6.7	5.9–6.9	6.0–7.0
	5.7±0.3	6.8±0.4	5.6±0.3	6.2±0.3	6.3±0.3	6.5±0.4
LeSo	2.1–3.5	3.5–4.0	2.9–3.7	3.2–3.6	3.0–5.0	3.1–4.0
	3.0±0.4	3.7±0.2	3.3±0.3	3.5±0.1	3.7±0.5	3.6±0.3
WB	9.8–14.2	13.1–17.3	9.0–12.5	10.3–13.2	12.6–16.7	12.0–15.5
	11.8±1.3	15.5±1.7	11.0±1.1	12.1±0.9	14.1±1.3	14.0±1.0
WP	4.3–5.9	5.4–6.6	4.3–5.4	5.4–6.7	5.3–6.7	5.3–6.8
	5.0±0.5	6.3±0.5	4.8±0.4	6.0±0.4	6.2±0.5	6.0±0.4
LeP	4.1–5.6	5.7–7.0	4.0–5.3	5.2–6.2	5.2–7.3	5.3–6.7
	4.8±0.5	6.6±0.5	4.7±0.4	5.5±0.3	6.2±0.6	6.2±0.4
LeF-R	16.4–22.6	19.3–22.6	17.8–19.6	17.7–21.9	19.5–23.8	20.7–23.2
	18.3±2.0	21.3±1.3	18.6±0.7	20.3±1.3	21.3±1.6	22.0±0.7
LeI-R	7.8–9.1	8.1–10.7	7.6–9.3	8.2–9.0	8.5–11.1	8.8–10.6
	8.3±0.4	10.0±1.0	8.3±0.5	8.6±0.3	9.6±0.8	9.9±0.5
LeE-R	9.2–10.8	12.0–13.3	9.3–11.3	10.3–11.6	11.0–13.6	11.1–12.8
	10.2±0.6	12.6±0.6	10.3±0.7	10.9±0.4	12.1±0.9	12.1±0.5
LeT	6.9–8.2	7.7–9.0	6.4–8.2	8.1–9.2	8.1–9.5	8.5–9.7
	7.5±0.5	8.5±0.4	7.6±0.6	8.6±0.4	8.8±0.5	9.2±0.3
LeR-4F	10.4–12.6	13.3–14.1	11.5–13.3	11.9–13.7	13.0–15.2	13.1–14.9
	11.6±0.6	13.7±0.3	12.6±0.8	12.6±0.6	14.1±0.7	14.0±0.5
DS	53–59	61–71	47–52	43–55	53–61	44–57
	55.3±1.9	66.0±3.7	49.8±1.7	49.5±4.3	56.6±2.3	50.9±3.3
MBS	49–58	55–65	41–48	43–50	51–58	47–57
	52.4±2.6	61.5±4.0	45.6±2.2	46.6±2.4	54.6±2.3	52.1±3.4
VS	72–81	77–87	66–79	63–79	71–85	70–88
	76.5±2.8	80.8±3.8	73.3±3.9	72.8±4.6	77.6±4.4	75.2±4.8

Table 2. Summary statistics and Principal Component Analysis factor loadings for the morphometric and meristic characters for male individuals of *L. walkeri* clade from Peru.

	PC1	PC2
Standard deviation	3.075	1.454
Proportion of variance	0.641	0.143
Cumulative proportion	0.641	0.785
Eigenvalue	9.455	2.113
SVL	0.306	0.121
WC-C	0.283	-0.072
WSc-Sc	0.289	0.040
LeSo	0.213	0.085
WB	0.272	-0.133
WP	0.276	0.099
LeP	0.296	0.004
LeF-R	0.273	0.187
LeI-R	0.291	0.009
LeE-R	0.308	0.002
LeT	0.275	0.243
LeR-4F	0.274	0.156
DS	0.119	-0.572
MBS	0.180	-0.485
VS	0.092	-0.512

Descriptive statistics and PCA analyses: Morphometric and meristic data analyses (Tables 1, 3). We showed that the population of *L. misti* sp. n. is distinct from all species of *L. walkeri* clade, along the ordination of Principal Components (PC) 1 and 2 (Fig. 12A). PC1 accounts for 64.1% of the proportion of variance in the data and loads most heavily for LeE-R, SVL, LeP, and LeI-R; PC2 accounts for an additional 14.3% of the proportion of variance and loads most heavily for DS, VS, and MBS (Fig. 12B, Table 2). Also showed the population of *L. misti* sp. n. separately of *L. tacnae*: while males and females of *L. misti* sp. n. are overlapping, males and females of *L. tacnae* are separated along (PC) 1 and 2 (Fig. 13A). PC1 accounts for 54.4% of the proportion of variance in the data and loads most heavily for WP, LeE-R, LeR-4F, and LeT; PC2 accounts for an additional 12.4% of the proportion of variance and loads most heavily for LeI-R, DS, and WB. (Fig. 13B, Table 4). These variables showed marked sexual dimorphism in *L. tacnae* (Figs 14–15), but less noticeable dimorphism in *L. misti* sp. n. (Fig. 13A).

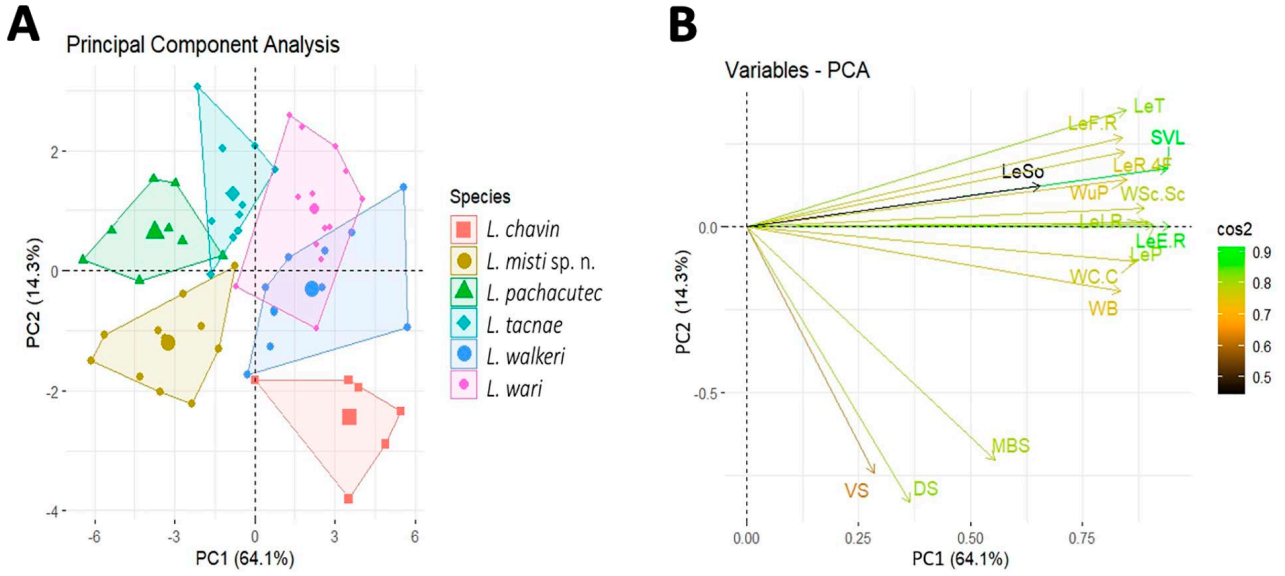

Figure 12. Visualization of (A) PCA of the species of males in the *L. walkeri* clade based on morphometric and meristic variables, and (B) Cos2 for factor loadings of the characters, color green for high attributes. For abbreviations see Material and methods.

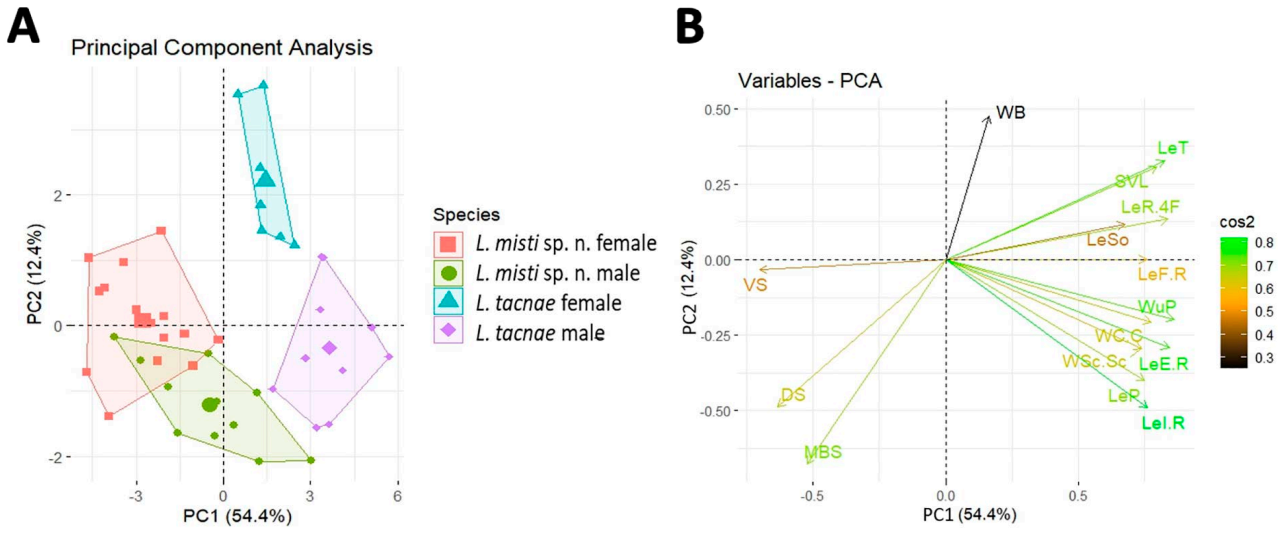

Figure 13. Visualization for (A) PCA of males and females of *L. misti* sp. n. and *L. tacnae* based on morphometric and meristic variables, and (B) Cos2 for factor loadings of the characters, color green for high attributes. For abbreviations see Material and methods.

Table 3. Descriptive statistics of morphometric and meristic characters for male and female individuals of *L. misti* sp. n. and *L. tacnae*. First row shows ranges and second row shows means and standard deviations. For abbreviations see Material and methods.

	L. misti sp. n. males (N = 11)	*L. misti* sp. n. females (N = 15)	*L. tacnae* males (N = 10)	*L. tacnae* females (N = 7)
SVL	41.5–49.3	42.8–49.2	47.6–54.9	47.5–55.0
	46.2±2.4	46.3±2.1	50.5±2.2	51.3±2.3
WC-C	3.3–4.0	3.2–3.7	3.6–4.1	3.5–3.9
	3.7±0.3	3.5±0.1	3.9±0.2	3.7±0.2
WSc-Sc	5.1–6.3	5.1–6.0	5.8–6.7	5.0–6.0
	5.7±0.3	5.5±0.3	6.2±0.3	5.6±0.4
LeSo	2.1–3.5	2.3–3.2	3.2–3.6	3.0–3.6
	3.0±0.4	2.9±0.3	3.5±0.1	3.3±0.2
WB	9.8–14.2	10.3–15.6	10.3–13.2	12.2–17.3
	11.8±1.3	12.9±1.5	12.1±0.9	13.9±1.8
WP	4.3–5.9	3.1–5.1	5.4–6.7	4.3–5.9
	5.0±0.5	4.1±0.7	6.0±0.4	5.1±0.5
LeP	4.1–5.6	3.1–4.9	5.2–6.2	3.8–4.9
	4.8±0.5	4.0±0.5	5.5±0.3	4.3±0.4
LeF-R	16.4–22.6	14.5–20.3	17.7–21.9	19.0–21.1
	18.3±2.0	17.2±1.8	20.3±1.3	20.1±0.8
LeI-R	7.8–9.1	7.3–8.4	8.2–9.0	7.6–8.3
	8.3±0.4	7.9±0.4	8.6±0.3	8.1±0.2
LeE-R	9.2–10.8	9.0–10.1	10.3–11.6	9.5–10.3
	10.2±0.6	9.5±0.4	10.9±0.4	9.9±0.3
LeT	6.9–8.2	6.6–7.8	8.1–9.2	8.1–9.0
	7.5±0.5	7.3±0.3	8.6±0.4	8.5±0.4
LeR-4F	10.4–12.6	10.4–12.1	11.9–13.7	11.7–12.8
	11.6±0.6	11.2±0.6	12.6±0.6	12.3±0.4
DS	53–59	53–61	43–55	45–51
	55.3±1.9	57.0±2.8	49.5±4.3	49.0±2.5
MBS	49–58	48–59	43–50	40–46
	52.4±2.6	52.1±2.6	46.6±2.4	43.7±2.1
VS	72–81	72–86	63–79	72–80
	76.5±2.8	80.7±3.6	72.8±4.6	75.7±3.0

Table 4. Summary statistics and Principal Component Analysis factor loadings for the morphometric and meristic characters for male and female individuals of *L. misti* sp. n. and *L. tacnae*.

	PC1	PC2		PC1	PC2
Standard deviation	2.824	1.346	LeP	0.266	-0.297
Proportion of variance	0.544	0.124	LeF-R	0.268	0.001
Cumulative Proportion	0.544	0.668	LeI-R	0.269	-0.365
Eigenvalue	7.972	1.811	LeE-R	0.298	-0.218
SVL	0.282	0.227	LeT	0.292	0.244
WC-C	0.274	-0.154	LeR-4F	0.296	0.100
WSc-Sc	0.262	-0.219	DS	-0.224	-0.362
LeSo	0.239	0.087	MBS	-0.185	-0.503
WB	0.058	0.353	VS	-0.248	-0.024
WP	0.305	-0.147			

Discussion

Lobo & Espinoza (1999) described new species of *Liolaemus* sensu stricto, and used two individuals as comparative material (FML 1544 from Arequipa, Peru, and SDSU 1924 from Tarapaca, Chile) that were assigned to *L. tacnae*. However, in 2004, when describing new species within the same group, they examined the type material of *L. tacnae* (MCZ 45806-08) and concluded that neither FML 1544 nor SDSU 1924 corresponded to *L. tacnae*. Despite this correction, subsequent studies continued to use FML 1544 and SDSU 1924 as *L. tacnae*. Troncoso-Palacios & Etheridge (2012) reviewed SDSU 1924 and concluded that insufficient evidence supported its assignment to *L. tacnae*. They emphasized the need for further collecting efforts in the region to characterize the Chilean population accurately. In this study, we deduce that the specimen FML 1544 by distribution would belong to *L. misti* sp. n.

The original diagnosis of *L. tacnae* mentioned ventral melanism generally restricted to the throat and chest (Shreve, 1941). Aguilar et al. (2013) stated the character "complete or partial melanistic belly" as absent in *L. tacnae*, but mentioned that although this character was fixed in their sample, the alternative state might be present in a larger sample. We found some males with partial or total ventral melanism in *L. misti* sp. n. (Fig. 4) and *L. tacnae* (Fig. 14). This character is also found in adult males of *L. chavin*, *L. pachacutec*, *L. walkeri*, and *L. wari*, but at different frequencies. Partial or total ventral melanistic belly might be still a good diagnostic character among species of the *walkeri* clade if most of the individuals in a sample show this state and few of them the alternative state (no melanistic belly).

Liolaemus misti sp. n. is endemic to Arequipa with a distribution within and close to the Reserva Nacional de Salinas y Aguada Blanca, a protected area in the region, 3730–5400 m a.s.l. *Liolaemus misti* sp. n. has the highest elevation record for a living squamate (Cerdeña et al. 2021). On the other hand, our results limit the geographic distribution of *L. tacnae* to Moquegua and Tacna, outside any protected area, but near numerous mining concessions. These mining activities might have caused significant habitat fragmentation and pollution, and population extirpation. We would like to recommend a long-term monitoring of *L. tacnae* and revision of its current category (NT) in the IUCN Red List of Threatened Species.

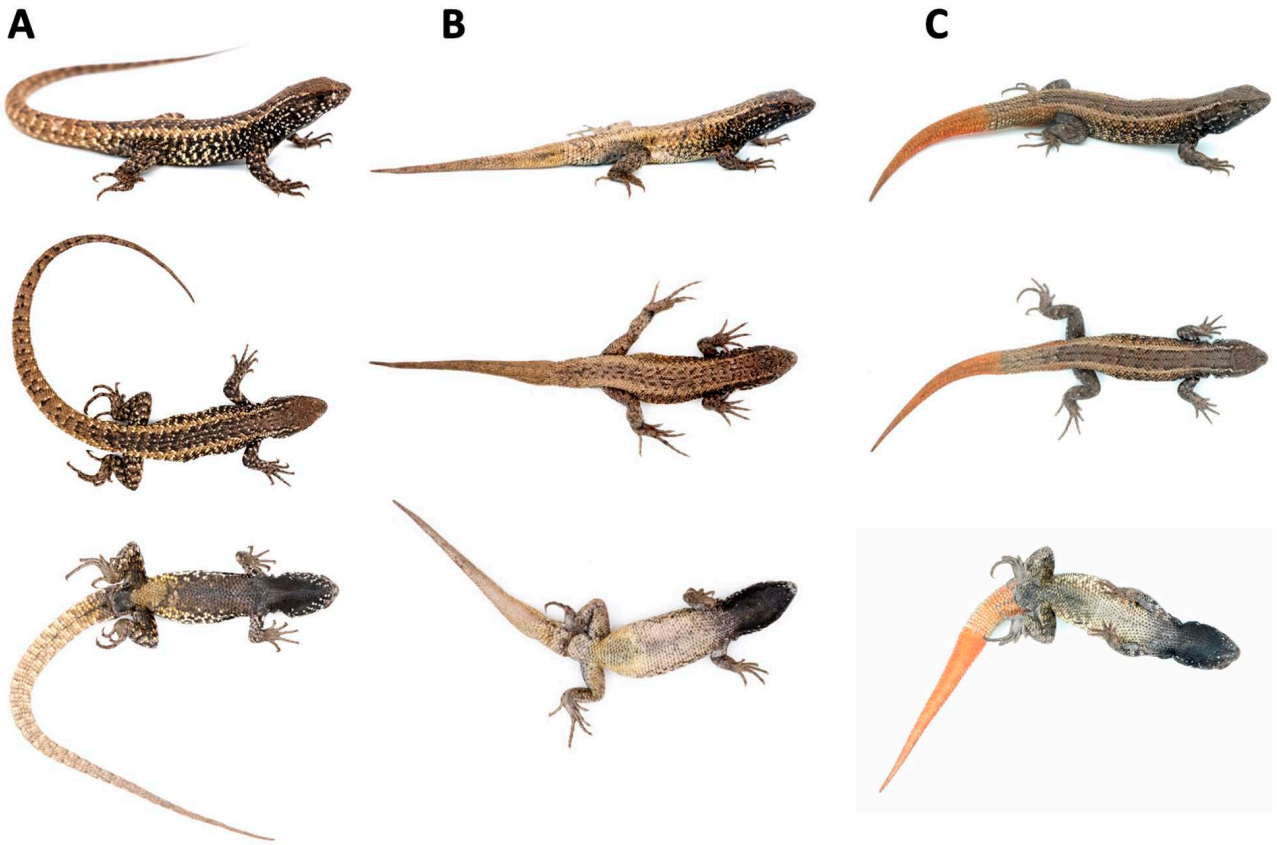

Figure 14. Dorsolateral, dorsal, and ventral views of *L. tacnae* adult males in life, from left to right: (A) (MUSA 5783), SVL 46.5 mm, TL 85.8 mm; (B) (MUSA 5839), SVL 49.4 mm, TL 46.3* mm; (C) (MUSA 5840), SVL 56.1 mm, TL 55.6* mm. [* = Regenerated or broken tail.]

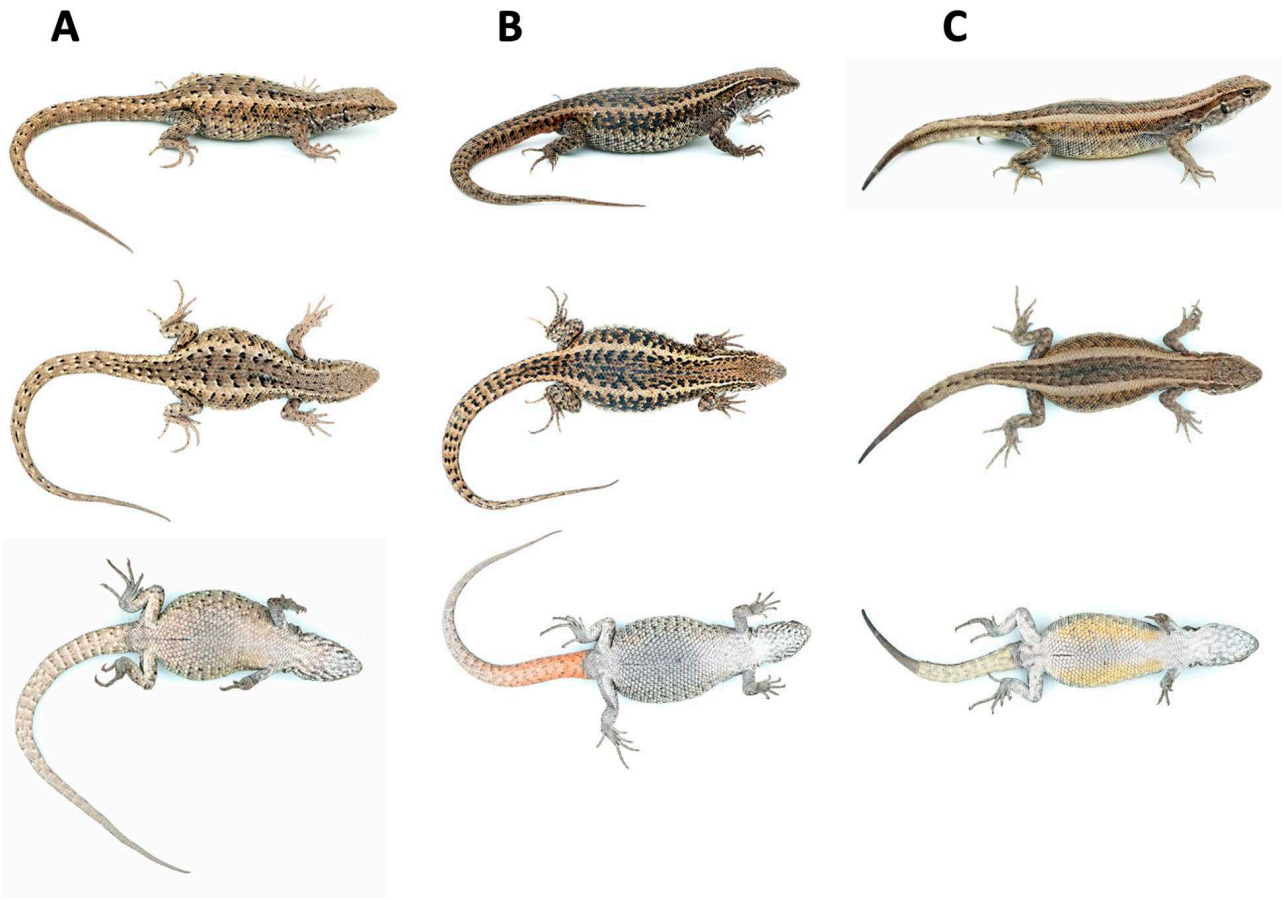

Figure 15. Dorsolateral, dorsal, and ventral views of *L. tacnae* adult females in life, from left to right: (A) (MUSA 5788), SVL 46.6 mm, TL 71.9 mm; (B) (MUSA 5841), SVL 53.2 mm, TL 70.7 mm; (C) (MUSA 5842), SVL 47.6 mm, TL 36.5* mm. [* = Regenerated or broken tail.]

Acknowledgments

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Appendix

Material examined in addition to the new species

Liolaemus chavin – Males (6): PERU: ANCASH: RECUAY: MUSM 25417 (holotype), MHNSM 25334 (paratype), MHNSM 20141 (paratype), MHNSM 20143 (paratype), MHNSM 20146 (paratype) from Conococha. MHNSM 20147 (paratype), from Carpa.

Liolaemus pachacutec – Males (9): PERU: CUSCO: PAUCARTAMBO: MUSM 29683 (holotype), MUSM 29681 (paratype), MUSM 29687 (paratype), MUSM 29678 (paratype), from Challabamba. CALCA: MUSM 29665 (paratype), MUSM 29668 (paratype), from Lamay. MUSM 29664 (paratype), from Pisac. APURIMAC: ANTABAMBA: MUSA 3801, from Juan Espinoza Medrano. AYMARAES: MUSM 31540 (paratype), from Pocohuanca-Tiaparo.

Liolaemus tacnae – Males (13): PERU: MOQUEGUA: MARISCAL NIETO: MUSA 4357, MUSA 5783, MUSA 5710, MUSA 5769–5770, MUSA 5773, MUSA 5779, MUSA 5840, from Torata. MUSA 4558, from San Cristobal de Calacoa. TACNA: CANDARAVE: MUSM 34516, from Suches Lake, MUSM 34509, MUSM 34503, from Tacalaya. TACNA: MUSA 5839, from Palca-Pucamarca. Females (10): PERU: MOQUEGUA: MARISCAL NIETO: MUSA 5771, MUSA 5774–5778, from Torata. TACNA: JORGE BASADRE: MUSA 5788, from Toquepala, MUSM 34512, from Ilabaya-Quebrada Citarrona. CANDARAVE: MUSA 5841–5842, from 7 km. Arañane.

Liolaemus walkeri – Males (12): PERU: JUNIN: HUANCAYO: MUSM 38123, from Acopallca. JUNIN: MUSM 20561 unknown data, MUSM 22039 from Carhuamayo. JAUJA: MUSA 3022, MUSA 4646–4648, from Vichecocha Lake, MUSA 3117 from Pachacayo. TARMA: MUSM 39892, MUSM 39894, from Palca. HUANCAVELICA: ANGARAES: MUSM 38126, from Ccochaccasa. HUANCAVELICA: MUSA 5857, from Pampachacra. Females (1): PERU: HUANCAVELICA: HUANCAVELICA: MUSA 5856 from Pampachacra.

Liolaemus wari – Males (13): PERU: AYACUCHO: HUAMANGA: MUSM 30837 (holotype), MUSM 30823 (paratype), from Abra Toccto. MUSM 30834 (paratype), MUSA 5720–5726, from high area above the Historic Sanctuary Pampas. LA MAR: MUSM 25703–25704 (paratypes), from Yanacocha Lake. LUCANAS: MUSM 31411 (paratype), about 45 Km west Puquio-Cusco roadway.