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Behavioural observations of the Caylloma Smooth-throated Lizard, *Liolaemus annectens* Boulenger, 1901, following snowfall events in the highlands of southern Peru

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The genus *Liolaemus* has a wide latitudinal and elevational distribution, diverse biotic and abiotic conditions have led to complex adaptive strategies related to foraging (Espinoza et al., 2004), reproduction (Schulte et al., 2000), and thermoregulation (Valdecantos et al., 2013). Numerous *Liolaemus* species inhabit high-elevation environments, even surpassing 5000 m in elevation (Medina et al., 2012; Cerdeña et al., 2021), where individuals experience harsh environmental conditions mainly associated with low temperatures (Marquet et al., 1989; Mella et al., 2010). Consequently, highland species of *Liolaemus* exhibit diverse physiological and behavioural adaptations to extreme temperatures, such as maintaining elevated body temperatures (Valdecantos et al., 2013).

Liolaemus annectens is a member of the *L. montanus* species group (Pincheira-Donoso et al., 2008; Lobo et al., 2010; Chaparro et al., 2020) and occurs at elevations ranging from 3500–4688 m (Pincheira-Donoso et al., 2013). Localities include several in the Arequipa Region, such as Sumbay, Caylloma, Chivay, and Cothahuasi (Laurent, 1992; Salas-Ybañez et al., 2024). However, only the trophic niche of this species is known (Salas-Ybañez et al., 2024), while other ecological aspects remain unknown and behavioural information is lacking entirely. Here, I present novel observations of a *L. annectens* population in the highlands of Arequipa, Peru, following snowfall events and provide some insights into the behaviour of these lizards under harsh environmental conditions.

As part of short-term monitoring conducted from 9–15 February 2015, I collected data on the herpetofauna in a sector known as Pariguanas in Orcopampa District, Castilla Province, Arequipa Region, Peru (centred on 15.1455°S, 72.1854°W). Five monitoring sites were surveyed using visual encounter surveys along 100 x 4 m transects, each lasting 30 ± 5 min. At each monitoring site, four transects were surveyed by two observers. Using these data, the abundance of *L. annectens* was estimated (Table 1). During the sampling period, several snowfall events occurred (Fig. 1A). Despite these harsh climatic conditions, I detected active *L. annectens* at all sampling sites. Accordingly, I am able to increase the elevational range of this species to 3500–4937 m. One survey site near an Andean wetland (PB1) was almost entirely covered by snow on several occasions (Fig. 1A). There, individuals were detected in refuges beneath the snow. As the hours passed and the snow melted, I observed lethargic individuals partially submerged in water (Fig. 1C). Later, individuals became fully active and were observed basking (Fig. 1B). I also observed individuals escaping into rocks and crevices partially filled with water, suggesting that these microhabitats may function as escape sites.

These observations provide evidence that *L. annectens* is adapted to withstand the extreme environmental temperatures of this highland habitat. Consistent with the hypothesis that closely related lizards exhibit similar thermal traits (Bodensteiner et al., 2021; Laspiur et al., 2024), there is evidence that preferred body temperature may be a conservative trait within *Liolaemus* (Medina et al., 2009, 2012). Therefore, *L. annectens* is expected to exhibit preferred body temperatures similar to those of its closely related species *L. signifer* (33°C; Pearson and Bradford, 1976; Ibargüengoytía et al., 2021). This value is markedly higher than the environmental temperatures recorded at the study site (mean: 9.5°C, range: 0.6–18.4°C; SENAMHI, 2026), suggesting that behavioural thermoregulation may play a key role. The presence of individuals partially covered by ice-cold water suggest that *L. annectens* may be able to tolerate very low minimum lethal temperatures, a hypothesis that should be tested experimentally.

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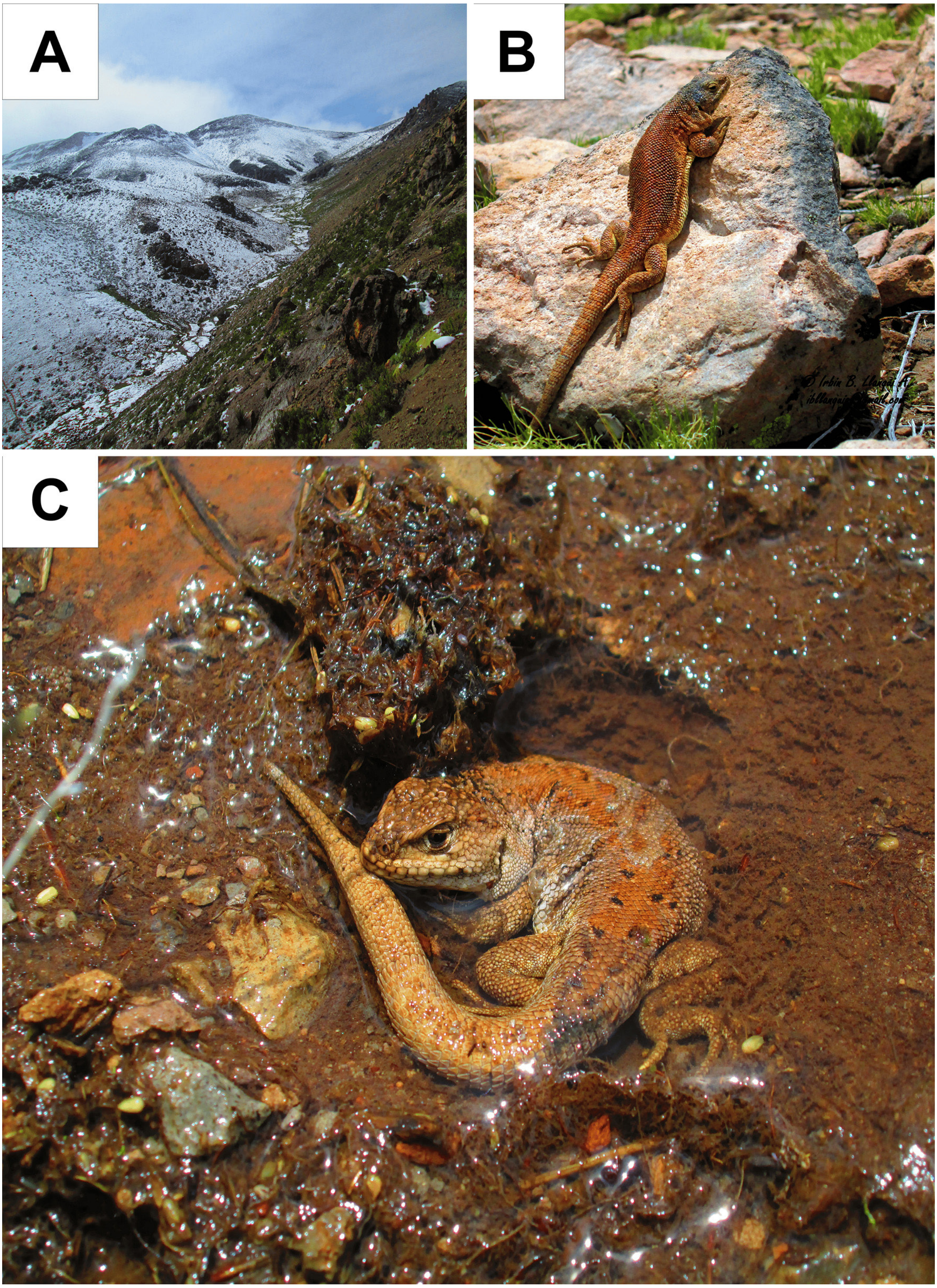

Figure 1. (A) Snowfall in an Andean wetland at PB1, Orcopampa, Arequipa, Peru. (B) *Liolaemus annectens* basking in the morning. (C) *L. annectens* partially submerged in cold water.

Table 1. Relative abundance (individuals per observation hour) of *L. annectens* at five monitoring sites (PB1–PB5) in Pariguanas, Orcopampa, Arequipa, Peru. Latitude, longitude, and elevation (m) for each site are provided.

Site	Latitude	Longitude	Elevation	Abundance
PB1	15.1570°S	72.1876°W	4639	2.31
PB2	15.1489°S	72.1787°W	4937	0.94
PB3	15.1428°S	72.1848°W	4736	0.28
PB4	15.1423°S	72.1809°W	4788	1.40
PB5	15.1365°S	72.1952°W	4728	3.68

These lizards adopted a curled body posture (Fig. 1C) similar to that described for *Timon lepidus* under extreme cold exposure (Fei et al., 2012), a response that may also occur in other members of the genus *Liolaemus*.

Ectotherms employ three strategies to cope with low temperatures: behavioural avoidance, freeze avoidance (i.e., supercooling), and freeze tolerance (Storey, 2006; Costanzo and Lee, 2013; Storey and Storey, 2017). Previous observations include a frozen dead lizard found near the study area (Gianfranco Paniura, pers. comm.), although I did not directly observe any dead or dying lizards. Therefore, I hypothesize that *L. annectens* primarily relies on behavioural and freeze-avoidance strategies rather than freeze tolerance. These mechanisms are common in reptiles (Storey, 2006) and particularly well developed in lizards (Costanzo and Lee, 2013). Freeze avoidance would involve complex behavioural, physiological, and biochemical adjustments, including gut evacuation, accumulation of cryoprotective compounds, and partial tissue dehydration, as reported for other cold-tolerant species (Costanzo and Lee, 2013). Therefore, supercooling represents a plausible physiological mechanism that warrants future investigation, as it could explain the persistence of populations in high-elevation environments exposed to frequent snowfall.

Although my approach to lizards was not standardised, their escape into rocks and crevices partially filled with water likely represents an antipredator response and reflects the use of extreme microhabitats as refuges when individuals are under high predation risk. Similar escape behaviour has not been reported in other wetland-associated *Liolaemus* species, such as *L. qalaywa* Chaparro et al., 2020, *L. wiegmannii* (Duméril & Bibron, 1837), or *L. zapallarensis* Müller & Hellmich, 1933 (Kacoliris et al., 2006; Chaparro et al., 2020; Chávez-Villavicencio and Rivadeneira, 2020). Nevertheless, additional observations are required to determine whether this behaviour is typical or rare among *Liolaemus* species under extreme environmental conditions.

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