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Intradermal infections by chigger mites (*Hannemania* spp.) in the Andean frog *Telmatobius atacamensis* (Anura, Telmatobiidae)

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Amphibians are hosts for a wide range of infectious organisms, including microparasites such as viruses, bacteria, and fungi, and macroparasites such as trematodes, nematodes, cestodes, acanthocephalans, mites, and copepods (DENSMORE & GREEN 2007, BLAUSTEIN et al. 2012). While some of these organisms cause relatively little damage to their hosts, others can induce a variety of sublethal or lethal effects (BLAUSTEIN et al. 2012).

Several species of mites have evolved special ecological relationships with amphibian hosts. The parasitic mites associated with amphibians belong to the families Hydrachnidae (GOLDSCHMIDT et al. 2002), Thermaparidae (MARTIN & SCHWOERBEL 2002), Trombiculidae and Leeuwenhoekiidae (e.g., EWING 1926, HYLAND 1950, DUSZINSKI & JONES 1973, SHATROV & KUDRYASHOVA 2006, WOHLTMANN et al. 2006). The larvae of *Endotrombicula* EWING, 1931 (Trombiculidae), *Vercammenia* AUDY & NADCHATRAM, 1957 (Trombiculidae), and *Hannemania* OUDEMANS, 1911 (Leeuwenhoekiidae) parasitise the integument of amphibians by invading the epidermal tissues of the host and causing extensive red-orange vesicular skin lesions (HYLAND 1950, DUSZINSKI & JONES 1973, WELBOURN & LOOMIS 1975). Several morphological and ecological costs have been described to mite infestation such as ulcerative dermatitis (ANTHONY et al. 1994, SLADKY et al. 2000), decreased growth and malformations (KUPFERBERG et al. 2009), external inflammation and bleeding (STUNKARD & CABLE 1931), and perhaps a negative impact on the fitness of the host (ANTHONY et al. 1994, MAKSIMOWICH & MATHIS 2000). Additionally, mites can cause hypersensitivity reactions and transmit rickettsiae and lethal viruses to their hosts (VAN DER GEEST et al. 2000). Here, we report the infection of adults of the Andean frog *Telmatobius atacamensis* (Anura, Telmatobiidae) by leeuwenhoekiid mites of the genus *Hannemania* and describe the

histological characteristics of the normal and infected skin and the mite's larval capsule.

We analysed a total of 96 tadpoles at stages 32 and 45 of GOSNER (1960) and 11 juveniles/adults of *T. atacamensis*, all of which were collected in the Los Patos stream (24°14'50" S, 66°13'57.9" W, 3,885 m a.s.l.), Salta Province, Argentina, during different seasons and years. The specimens were fixed in the field (10% formalin) and 48 hrs later preserved in 70% alcohol and are deposited in the Herpetological Collection of the Museo de Ciencias Naturales (MCN), Universidad Nacional de Salta (Argentina) with the following collecting dates (collection numbers in parentheses): March 2005 (MCN 937), November 2005 (MCN 1050), December 2005 (MCN 1026), and April 2010 (MCN s/n). Histological serial sections of the adult skin were made in order to characterize the histomorphology of normal and infected skin and describe the parasite capsule. Dissected skin pieces were dehydrated, embedded in paraffin, sectioned at 6 µm, and stained with hematoxylin-eosin. Besides the external aspect of the infecting pustules, we identified the larval mites as representing the genus *Hannemania* based on the presence of: six, rather than seven, segments on each leg; a small projection in the anteromedian region of the scutum; and the presence of teeth on greatly modified and expanded cheliceral blades (Fig. 1A) as characterized by BROWN et al. (2006). We classified it down to genus level (*Hannemania* sp.) only because identifying larval forms of this genus to species level is difficult (DUSZINSKI & JONES 1973, MCCALLISTER et al. 1995, HATANO et al. 2007, TORRENCE et al. 2007, ATTADEMO et al. 2012) and would exceed the scope of this report whose main objective is to report mite infestation in a vulnerable anuran species. However, a preliminary morphometric description of the mites is presented (Table 1) in order to allow comparisons with data from the literature.

Of the anuran specimens analysed, eight of the 11 adults were infected, while out of 96 tadpoles only one (at stage 45) was infected (Fig. 1B). Externally, infections appear as conspicuous red pustules, with one mite being immersed in each (Fig. 1C–F). Infected pustules occur indistinctly on

fore and hind limbs, in ventral and dorsal body wall skin, and in the gular region (Fig. 1C–F). We found up to three pustules per adult specimen.

The dorsal skin of uninfected adult specimens of *Telmatobius atacamensis* presents a structural organisa-

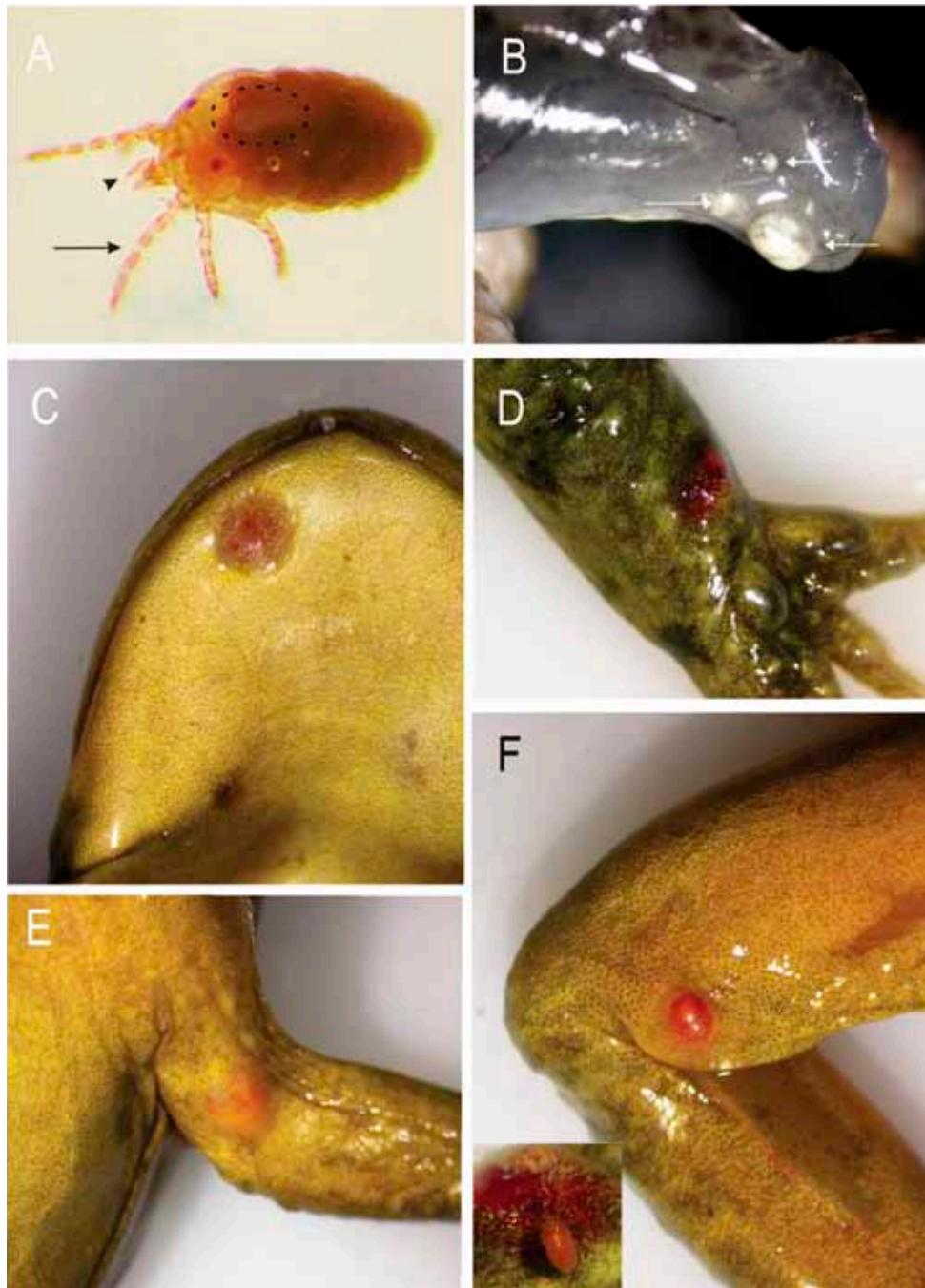


Figure 1. Specimens of *Telmatobius atacamensis* parasitised by *Hannemania* sp. larvae. A) *Hannemania* sp. larva with diagnostic features for the genus such as light red colour, expanded cheliceral blades (arrow), six segments on each leg (arrow), and the presence of only one dorsal shield, the scutum (encircled with a discontinuous line). B) Tadpole at Stage 45 of GOSNER (1960) with a multiple infection at the distal end of the resorbing tail. C–F) Adult specimens with infected red pustules in different regions of the body. C) Adult specimen with an empty pustule, showing the residual ulcerative lesion in the skin. D, E, F) Infections on fore and hind limbs. In (F), detail of the larvae after its removal from the pustule (square).

Table 1. Measurements of *Hannemania* sp. (n = 3)

	Average (in μm)
Cheliceral digitus	39
Idiosoma length	580
Idiosoma width	316
Scutum length	133.73
Scutum width	49.11
Coxa I	29.21
Trochanter I	21.80
Femur I	60.37
Genu I	42.98
Tibia I	52.42
Tarsus I	82.87
Coxa II	26.73
Trochanter II	19.94
Femur II	44.47
Genu II	31.12
Tibia II	37.05
Tarsus II	51.74
Coxa III	29.65
Trochanter III	20.01
Femur III	60.32
Genu III	47.43
Tibia III	55.27
Tarsus III	66.79

tion that reflects the generalized pattern present in most anurans (Fig. 2A). The integument is formed by two layers, an outer epidermis and an inner dermis, each one with two distinct strata. In the epidermis, the stratum corneum and the stratum germinativum are present; the stratum corneum is the more external layer of the epidermis and consists of flattened and thin dead cells derived from the stratum germinativum, which, in turn, consists of five to seven layers of cuboidal cells. In the dermis, the stratum spongiosum consists of loose connective tissue in which mucous and serous glands, blood vessels, and nerve fibres are embedded. The melanocytes are seen on top of the stratum spongiosum below the basal lamella of the epidermis; they have a granular aspect and form an almost continuous layer. The stratum spongiosum represents the most developed layer and its thickness is more than twice that of the other layers. The stratum compactum is formed by lamellae of collagen fibres arranged in alternating layers. Below the dermis, the hypodermis contains numerous blood vessels and nerve fibres (Fig. 2A).

The histological sections of the infected skin containing the red pustule show that the entire capsule is located within the stratum spongiosum of the dermis (Fig. 2B). The relationship between the capsule and the stratum compactum of the dermis is not clear since there is a structural alteration in the dermis that prevents the clearly identification of the boundaries between the two strata. Each capsule

is formed by a layer of dense connective tissue surrounding the lumen in which a single chigger resides. The capsule wall has a homogeneous thickness and is complete all around the chigger except below the chelicerae of the mite where an apparent break is seen (Fig. 2B). Although we did not examine the early stages of the infection (entering the integument, encapsulation) we clearly observed a structural alteration in the skin of infected specimens. The epidermis, just above the capsule, shows signs of cell proliferation since it is thicker than in non-parasitised areas (Fig. 2A, B); in the dermis, there is a disruption in the structural organisation of both the stratum spongiosum and compactum (i.e., loose connective tissue and compact collagen fibres, respectively), which makes distinguishing between these two layers difficult. In the surroundings of the capsule, glands and melanocytes are absent and only blood vessels are present (Fig. 2B). In the areas of the skin containing the encapsulated chiggers, the skin thickness triples compared to that of normal skin, probably due to the accumulation of lymphocytes in response to the infection.

The present report constitutes a new record of an anuran species being parasitised by *Hannemania* sp. and an interesting case in a species inhabiting high-altitude and semi-arid to arid landscapes. At present, *Hannemania* sp. infections have been mentioned in numerous anuran species from different environments of North and South America (EWING 1931, DUSZINSKI & JONES 1973, WELBOURN & LOOMIS 1970, LYNCH & McDIARMID 1987, KÖHLER et al. 1995, DE LA RIVA & LYNCH 1997, DE LA RIVA 1998, KÖHLER & LÖTTERS 1999, SALAZAR MARTÍNEZ et al. 2004, LANOO 2005, MALONE & PAREDES 2005, WOHLTMANN et al. 2006, HATANO et al. 2007, TORRENCE et al. 2007, JUNG et al. 2001, ESPINO DEL CASTILLO et al. 2011, WALTERS et al. 2011, ATTADEMO et al. 2012). In Argentina, it has been reported in *Pleurodema kriegi* and *Odontophrymnus occidentalis* from a high-altitude plain in the Sierras de Córdoba, central Argentina, at an altitude around 1500 m a.s.l. (ALZUET & MAURI 1987, SALAZAR MARTÍNEZ et al. 2004), in *Leptodactylus ocellatus*, from the lowlands of Buenos Aires and Santiago del Estero, eastern and central Argentina, respectively (ALZUET & MAURI 1987, SALAZAR MARTÍNEZ et al. 2004), in *Leptodactylus chaquensis*, from wetlands and agricultural lands in mid-eastern Argentina (ATTADEMO et al. 2012), and in *Leptodactylus latrans*, *Pleurodema bufonina*, *P. bibroni*, and *Nannophryne variegata*, from the southern Andes, in the Rio Negro Province, at an altitude of around 800 m a.s.l. (EWING 1931). However, there is no previous report of the presence of *Hannemania* in this semi-arid to arid environment above 2,000 m a.s.l. Several other anuran species have been mentioned as being parasitised by *Hannemania* on the eastern slopes of the Bolivian Andes at a similar altitude, such as *Pristimantis llojsintuta*, *P. platydactylus*, *Rhinella quechua*, *Yunganastes fraudator*, and *Y. mercedesae*, but in pristine environments of mountain rainforests where amounts of rainfall are very high (LYNCH & Mc DIARMID 1987, KÖHLER et al. 1995, DE LA RIVA & LYNCH 1997, DE LA RIVA 1998, KÖHLER & LÖTTERS 1999, WOHLTMANN et al. 2006).

SCHWOERBEL (1987) and MARTIN & SCHWOERBEL (2002) described other mites, *Thermacarus nevadensis* and *Thermacarus andinus*, parasitising the anuran species *Rhinella spinulosa* at high Andean altitudes; but these mites belong to a different clade (Parasitengona: Hydrachnidia) that only lives in hot springs.

Unlike the wet environments of South America where *Hannemania* species are typically found, *Telmatobius atacamensis* occurs in an arid area where annual precipitation does not exceed 120 mm (KOTTEK et al. 2006). Chigger mites use semi-moist habitats, and *Hannemania* species seem to prefer terrestrial-aquatic to aquatic habitats (MURPHY 1965, SLADKY et al. 2000, WOHLTMANN et al. 2006). MURPHY (1965) found that in several ranid species occurring in the same area, terrestrial-aquatic species were frequently infested, while more aquatic species were not. RANKIN (1937) suggested that *Hannemania* parasitism in amphibians was limited to those species that used terrestrial habitats for long periods of time, whereas WOHLTMANN et al. (2006) infer that very high humidity levels are required for the survival of *Hannemania*. In this context, parasitism by a presumptive terrestrial *Hannemania* larva on the fully aquatic *T. atacamensis* at 3,885 m a.s.l in the arid environment of the Argentinean Puna represents an

exceptional case among parasitised amphibian species and in the chigger mites' life cycle as well.

A comparison of the measurements obtained from the *Hannemania* larvae parasitising *Telmatobius atacamensis* with the morphometric ranges described in other species revealed differences that do not allow it to be assigned to any species described so far (*H. hylae* HOFFMAN, 1952, *H. hegengeri* HYLAND, 1956, *H. bufonis* LOOMIS & WELBOURN, 1969, *H. anurae*, *H. monticola*, and *H. saxicola* WELBOURN & LOOMIS, 1970, *H. minor* and *H. achalai* ALZUET & MAURI, 1987, and *H. yungicola* and *H. chaparensis* WOHLTMANN, KÖHLER & MARTIN, 2006). While it is important to emphasize that in this study we have not conducted a comprehensive and detailed description of the morphology of the *Hannemania* larvae, the differences in metric characters along with a reduced number of non-specialized setae in the legs (2–3 in all segments except in the tarsus where the number increases) and the presumptive few solenidia on genu I (2–3) suggest this species is new to science.

In anurans, chigger mites encapsulate in the stratum spongiosum of the dermis, and the capsule is located entirely within this layer, has no opening to the outside, and is not associated with any layer of the epidermis (DUSZYNSKI & JONES 1973), probably in relation to the looseness of the collagen fibres. The stratum spongiosum develops at metamorphic stages (TAMAKOSHI et al. 1998) whereas the typical configuration of tadpole skin consists of a two-layered epidermis and a dermis in which only the stratum compactum is differentiated (Fig. 2C). In all reported cases of *Hannemania* larvae parasitising amphibians that include histological descriptions (HYLAND 1961, DUSZYNSKI & JONES 1973, GROVER et al. 1975, BROWN et al. 2006, WOHLTMANN et al. 2006; Fig. 2), the infection features are quite similar: (1) the entire capsule is located within the stratum spongiosum of the dermis, (2) the capsule is formed by dense connective tissue, (3) it has no opening to the outside, (4) there is a thickening of the epidermis above the capsule, and (5) there is a distortion of the stratum compactum directly beneath the capsule. As described by WOHLTMANN et al. (2006), we observed cell fragments in the capsule where the chelicerae pierced the inner layer (Fig. 2B). In the present case, the practically acellular condition of the capsule could be considered as an old reaction, as proposed by HYLAND (1961). The only exception to the generality of histological changes in the wake of a *Hannemania* infestation comes from the study of TORRENCE et al. (2007) who described *Hannemania* larvae parasitising *Spea multiplicata* that were not encysted in the dermis but superficially attached to the surface of the skin. With respect to the other families of parasitic mites, SPIELER & LINSENMAIR (1999) revealed a similar histological response of host tissue to the infestation by *Endotrombicula pillersi* in the African savannah frog (*Phrynobatrachus francisci*), but this differs in that the extremities of the larvae are completely embedded in the lining of the capsule and therefore leave the larval mites unable to move within the capsule. WOHLTMANN et al. (2007) also described a subcutaneous infesta-

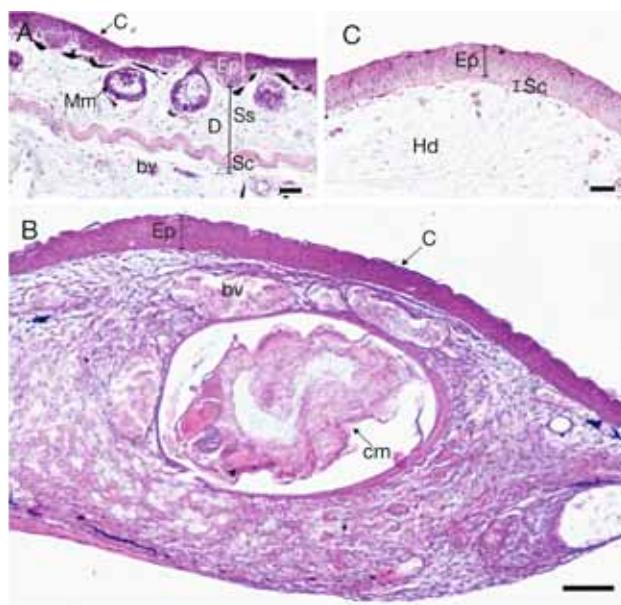


Figure 2. Transverse sections of the adult and larval skin in *Telmatobius atacamensis*. A) Section of dorsal skin of an uninfected specimen showing the structural organisation of the integument. B) Section of skin with a natural infestation by *Hannemania* sp., the capsule is complete and contains a single larva. C) Section of dorsal larval skin showing the structural organisation of the integument in which only the epidermis and the stratum compactum of the dermis are developed. Bv – blood vessels; C – stratum corneum; Cm – chigger mites; D – dermis; Ep – epidermis; Hd – hypodermis; Mm – mucous glands; Sc – stratum compactum; Ss – stratum spongiosum. Scale = 100 µm in A) and C), 200 µm in B).

tion by *Endotrombicula* larvae in several anuran species from the African continent and Madagascar, but these do not present the histological structure of the infected skin. Other trombiculids develop a feeding tube, or stylostome, on vertebrate hosts (HASE et al. 1978, SHATROV 2009), but such a tube was not detected in this study.

This study represents the first report of mite parasitism in the genus *Telmatobius*. Severe population declines have been reported in different *Telmatobius* species throughout their distributional ranges over the past few years (DE LA RIVA 2005), and it is now thought that members of *Telmatobius* are severely threatened (VAIRA et al. 2012). Although we cannot conclude that the observed mite infection can cause death in *T. atacamensis* individuals, the absence of any information about its biology (size and sex ratio within this population, the possible existence of other populations, their reproductive strategies or reproductive potential, and their seasonal activity), their vulnerability, and the previously reported infection with chytridiomycosis (BARRIONUEVO & MANGIONE 2006, VAIRA et al. 2012), make necessary a continuous monitoring of the population to assess the effect of mite and other infections in order to evaluate their possible role in population declines.

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