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The salt flats fighter: agonistic survival of *Liolaemus fabiani* in the Salar de Atacama

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Abstract

Liolaemus fabiani is a lizard that lives in the Salar de Atacama, located in the center of the Atacama Desert, northern Chile, one of the driest places on the planet. Likely due to the extreme environmental conditions of their habitat, *L. fabiani* has colonized all watercourse shores of the Puilar pond where the primary source of food, flies, are confined. By 'owning' these shores, they can retain resources, explaining their natural sense of territory and their world-renowned aggressive territorial behavior. From the perspective of the lizard, the battlefield is a narrow stretch between mountains of halite salt and the water, which leads to a winner-take-all type territory. The winning lizard is rewarded with control of the food supply, access to females and a privileged space to survive. This modern gladiator faces his opponent with an unmatched ferocity, although there are rarely, if ever, deaths between the contenders. Like other vertebrates, the defense of the territory is a cooperative job with the alpha female. She releases pheromone compounds, conferring an advantage to her partner to proceed ruthlessly to attack the intruder, on land or in water, in order to obtain victory. The victorious lizard gains ownership of the land, leaving no doubts of his claim to other would-be challengers.

Keywords:

Agonistic behavior, *Liolaemus*, Atacama

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Excluding the poles, the Atacama Desert in northern Chile is the driest place on Earth. Sunny days typically exceed 300 per year, and in spring-summer, temperatures can exceed 40 °C by day and then plummet to below 0 °C at night. Rainfall is sparse and falls in intermittent cycles generated by the austral Andean winter (Ortlieb, 1995). The desert covers approximately 2,800 km^2 and its altitude ranges between 2400 and 2500 meters elevation above sea level (Marquet *et al.,* 1998). This unique environment is home to various animals living in this extreme area, offering diverse examples of successful survival strategies (Pincheira-Donoso, 2012). One such creature is *Liolaemus fabiani,* (Yáñez & Núñez, 1983), a lizard known to dwell around San Pedro de Atacama. *L. fabiani* is probably one of few animals in the Salar de Atacama whose survival strategy includes agonistic skills (Veloso *et al.* 1982; Núñez y Fox 1985, Núñez y Veloso, 2001).

Although initially described in the northern salt flats (26°46'S, 68°14'W), *L. fabiani* has been reported in vegetative patches and waterways such as the wide lagoons of Cejar and Chaxa, and the smaller lagoons of Puilar and Punta Brava (Labra *et al.,* 2001). In this report, the agonistic behavior is described in the shores of the Agua de Quelana lagoon (Fig. 1). Only one other lizard, *Liolaemus constanzae* is known to inhabit this area. *L. fabiani* can be spotted darting over the salt crust; its orange, red, yellow, green, and blue skin flashing as it dashes over the rough, irregular, white ground surrounding of the lagoons. *L. fabiani*'s presence in the salt halites is not casual. Indeed, the waterways of northern Atacama host an abundance of flies (Valdovinos, 2006), its main source of food. These insects congregate on the banks of the lagoons, salt lakes, rivers, and streams within the vast salt flats.

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L. Fabiani, like other members of the genus, responds to chemical stimuli in a highly distinctive manner that facilitates its identification (Pough *et al,* 1998; Labra, 2011). *Liolaemus* lizards use chemoreception (odors, feces, skin and precloacal secretions) for various social and sensory purposes (Labra *et al.,* 2002; Labra, 2008). This has allowed individuals to develop self-recognition (i.e., to discriminate between their own odors and those of other members of the species) and to evaluate the sex of other lizards (Labra, 2008; Aguilar, Labra, & Niemeyer, 2009). The precloacal secretions of sympatric *Liolaemus* species differ in their chemical compositions (Escobar, Labra, & Niemeyer, 2001). Therefore, these secretions serve as distinguishing features (Pough *et al,* 1998). According to Labra, (2008), this taxon depends primarily on visual and chemical signals for communication and, to a lesser extent, on acoustic signals. Previously, Paulo (1988) created a set of guidelines and elementary movements that the lizards use for social (agonistic, reproductive) and non-social (thermoregulation, defense against predators, obtaining food) ends.

Interested in the mechanisms and communicational behavior of this genus, in the spring of 2015 and 2016, we observed the territorial defense method of *L. fabiani* in the Salar de Puilar, a small area within the Salar de Atacama (Fig 1). Both males and females are easily recognizable by their external characteristics, as well as their relative maturity, where one male and one female occupy a small territory of 50 m^2 and both participate in its defense. Although only males actually fight off intruders (Fig 2a and b), the females actively collaborate in their own way. It is the females who watch for interlopers and, once one is detected, she approaches him in quietly, holding his attention and luring him in close to her tail with a series of lateral movements that probably also deliver a chemical signal (Fig. 2c). In our observations, every single invading male succumbed

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to these invitations from the females. Meanwhile, the local male waits, crouched and attentive until the invader is fully distracted (Fig. 2d). When the moment is right, the territorial male attacks. The female's contribution to the ensuing fight, which might last from a few seconds to several minutes, creates a clear advantage for the local male. We witnessed why *L. fabiani* has earned a reputation of being a ferocious fighter, and has aroused the curiosity of the wild-life researchers.

After the first approach, the young challenger must choose between two escape routes; though neither of which is a simple dash to safety (Fig 3a). The first route is over the salt flats, a trajectory likely to bring him into contact with other males, causing more agonistic confrontations (Fig 3b). Thus, lizards often reject this route in favor of the second option: an aquatic escape route (Fig. 3c). Despite their small size (only ~10 cm total length) and even following a ferocious battle, *L. fabiani* males are great swimmers, able to navigate across bodies of water measuring 10 to 20 m wide (Yáñez & Núñez, 1983). In spite of the ruthless fighting, the outcome is rarely, if ever fatal (Fig. 3d). No matter how vicious the fights may be, the loser is always allowed to escape.

Based on our observations, in this report we nicknamed *L. fabiani*, as *the salt flats fighter.* This lizard is a paragon of tenacity, surviving in an extreme habitat and relying on ethological factors that are probably directly related to feeding, reproduction, and habitat (Khannoon *et al.,* 2011). Here, we reported the contribution of the female distracting invading males, which allows to her partner to catch the intruder off-guard, giving the resident male a great advantage in the ensuing battle. The cooperative behavior of the female described herein is a novel finding that allows us

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to further understand the social behavior of these lizard which live in the difficult conditions of the Chile's Atacama Desert.

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167 **Figure legends**

168 Figure 1. Studied area. The pond of Puilar has a superficial water contributor, where species of
169 *L. fabiani* were observed. Located in the central-north area of the Salar de Atacama in northern
170 Chile.

171

172 Figure 2. a) The homeowner male. b) The young intruder male. c) Female secreting
173 pheromones by cloacae exposure. d) Intimidating homeowner male ready to fight.

174

175 Figure 3. a) Homeowner male attacking aggressively. b) Challenger young male trying to
176 escape to the halite salt crust. c) The fight continues in water, where both males demonstrated
177 their excellent swimming skills. d) After the combat, resting and retreat of the young contender,
178 the homeowner male maintains his territory, aided by the female partner.

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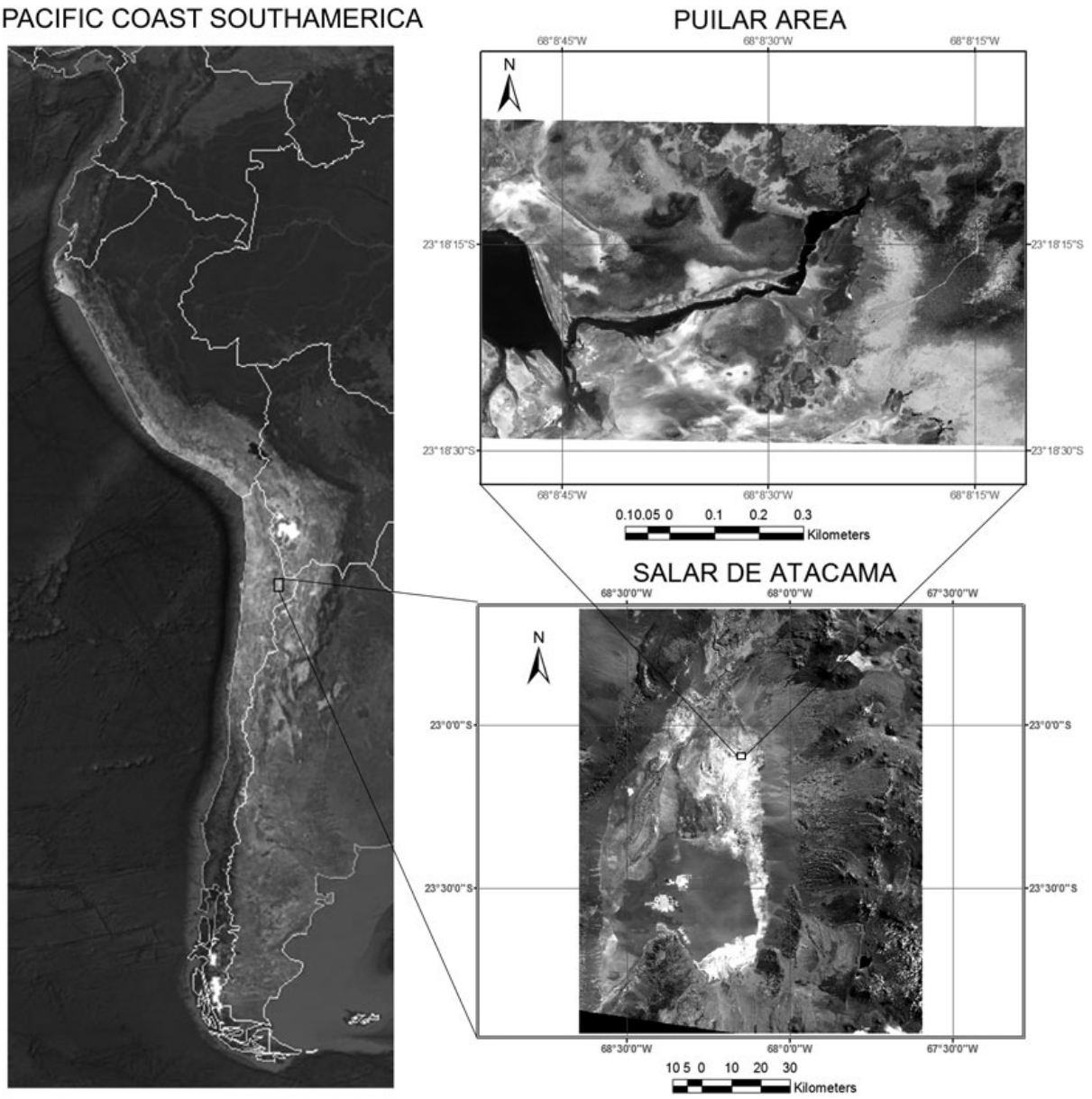
179 Figure 1



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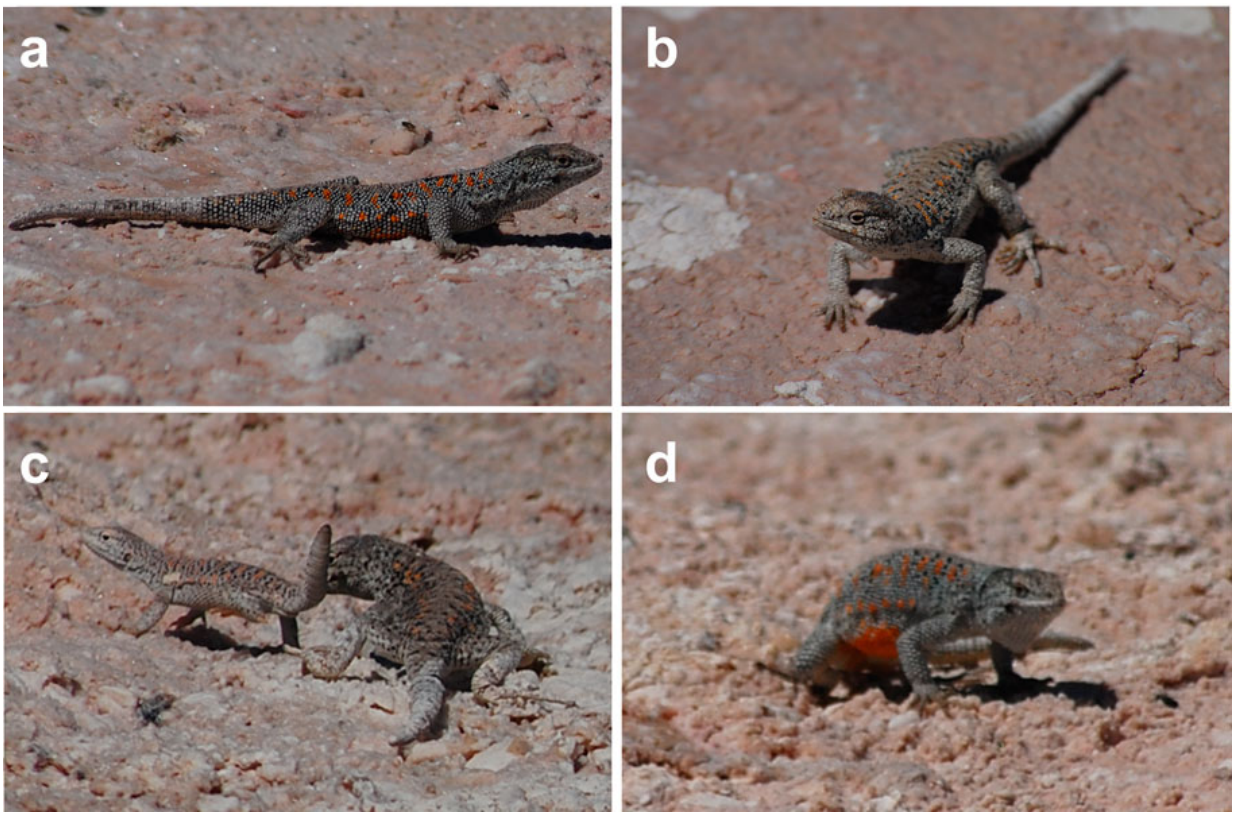
181 Figure 2



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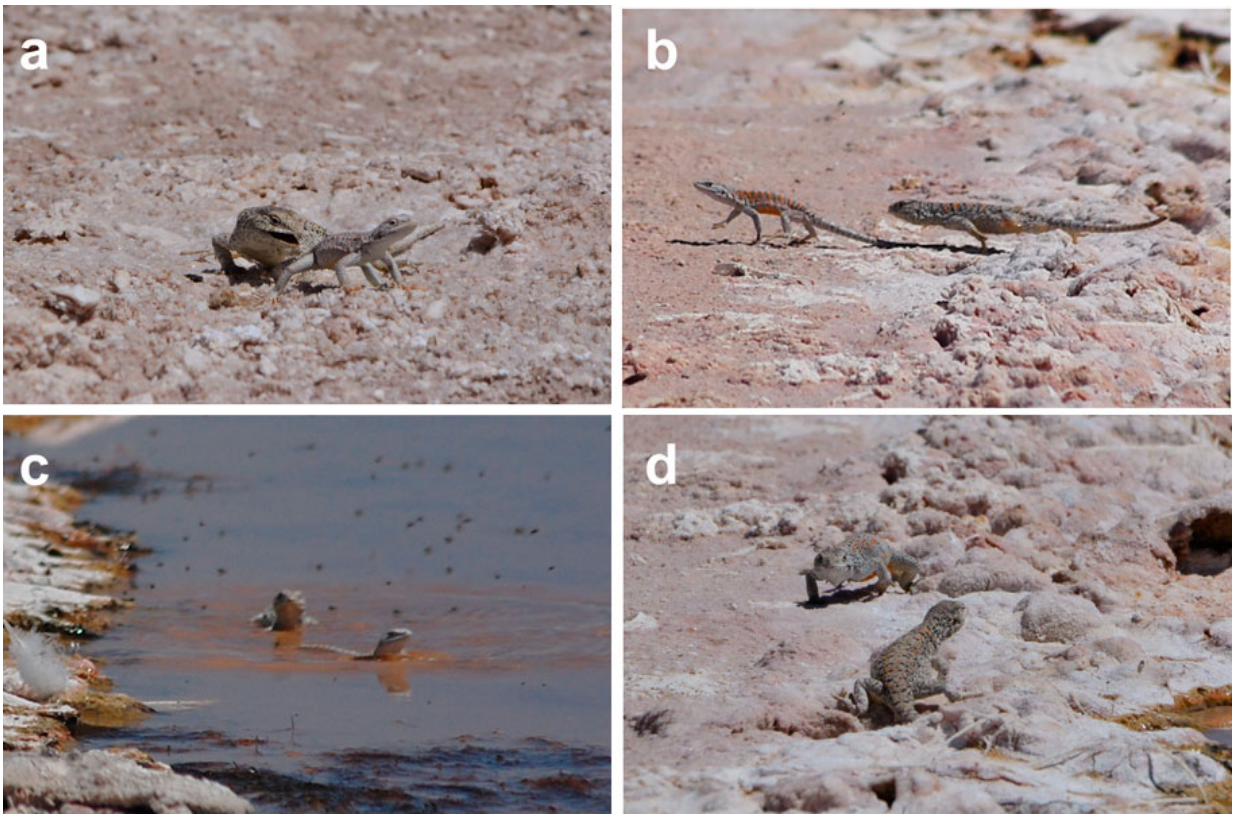
183 Figure 3.



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