

Rediscovery of *Liolaemus rabinoi* (Iguania: Liolaemidae) after 35 years: redescription, biological and phylogenetic information, and conservation challenges

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Abstract. *Liolaemus* is one of the most diverse genera of vertebrates, currently comprising 267 species classified into several monophyletic groups. Among them is the *Liolaemus wiegmanni* clade, including obligate sand-dwelling lizards with particular morphological traits and behavioural patterns associated with their habitat. One member of this group is *Liolaemus rabinoi*, a species from Argentina that has formerly been considered extinct. It was first found in 1972 on the margins of the El Nihuil dam in San Rafael, Mendoza, Argentina. Four additional specimens of *L. rabinoi* were recorded in 1974–75, but subsequent searches were unsuccessful and resulted in the inclusion of this species in red conservation lists. In November 2010, new specimens of lizards assignable to *L. rabinoi* were found in an area of large sand dunes, 10 km from where it had been searched for in vain for years. We present a new diagnosis and redescription based on nine of these specimens (four males and five females) and provide biological, current distribution, and phylogenetic relationship data within the genus *Liolaemus*. We also analyse the particular human-induced effects on the environments where *L. rabinoi* occurs and discuss possible conservation measures to mitigate habitat loss.

Key words. Squamata, Sauria, *Liolaemus rabinoi*, redescription, phylogeny, taxonomy, biology, conservation, Mendoza, Argentina.

Introduction

Over the last years, human intervention has caused an accelerated increase in extinction rates worldwide (PRIMACK et al. 2001, CEBALLOS et al. 2010, 2015, DIRZO et al. 2014). Human-induced ecosystem degradation and destruction processes (mainly transformation and fragmentation) are known as some of the main causes of the current environmental crisis and biodiversity loss (TURNER 1996, PRIMACK et al. 2001, BENNET 2004, PIMM et al. 2006). Accordingly, habitat loss can directly result in animal mortality and have subsequent indirect long-term effects on survival and reproduction (VITT & CALDWELL 2014, CEBALLOS et al. 2015). This means that surviving individuals become demographically unstable, resulting in a reduced genetic variability and increased susceptibility to stochastic events, potentially reducing populations to extinction levels (PRIMACK et al. 2001, ROCHA & GASCA 2007).

The significance and extent of extinction may vary according to the context; such is the case of a species that is considered extinct when none of its representatives can be found alive. However, a species can be extinct in the wild but survive in captivity with “ex situ” plans, or it may be “locally extinct” when it is no longer present in a region where it used to occur, but still lives in other natural regions (CLARK & ROSENZWEIG 1994, MOILANEN 1999). The latter definition might apply to *Liolaemus rabinoi*, a species that was considered extinct for several years, until 2010.

Liolaemus rabinoi is a small lizard (60 mm in snout-vent length), belonging to a small exclusive group of sand-dwelling *Liolaemus* species that exhibit a very particular morphology and behaviour (ETHERIDGE 2000, ABDALA 2005). It was described by CEI (1974) based upon two adult specimens found in December of 1972 on the shores of the El Nihuil dam, near the Club de Pescadores, San Rafael Department, Mendoza Province, Argentina (J.M. CEI pers.

comm. 15 January 2002). Later, in 1974, Mr. RABINO (J. M. CEI's chauffeur) found an additional specimen and finally, during the course of 1975, CEI, VIDELA, and TUZI (IBA UNC-1203) found three more specimens, in both cases in areas adjacent to the El Nihuil dam. Several herpetologists and naturalists continued visiting the area in search of *L. rabinoi* individuals; however, despite their search efforts and planning, no other individuals were found until 2010. Those thirty-five years of unsuccessful searching eventually saw *L. rabinoi* being included in red conservation lists (AVILA et al. 2000, CHÉBEZ & KACOLIRIS 2008, IUCN 2013), and several authors considered it extinct (BERTONATTI 1994, HALLOY et al. 1998, ETHERIDGE 2000, 2001, AVILA et al. 2000, 2009). Nonetheless, despite the disheartening results and 16 field surveys over 11 years of ceaseless searching by the authors of the present work conducted at the type locality and in surrounding areas, including the near-shore islands of El Nihuil dam (relicts of sand dunes that had never been covered by water before) and areas surrounding the dam by up to 40 km, an isolated population of *L. rabinoi* was eventually discovered in a large sand

dune system about 10–15 km from the type locality in December of 2010 (Fig. 1).

While pinpointing the causes that have led to the extinction of the *L. rabinoi* population from the type locality and surrounding areas can be a complex task, strategies may and should be applied to conserve this current population found in dunes with scarce psammophilous vegetation. Unfortunately, this region is used by off-road vehicles for recreation and competition purposes, including the “Dakar Rally” challenge, which have left permanent scars in the area and certainly caused an important degradation to the population structure of *L. rabinoi*.

Biological, ethological, and morphological data of *L. rabinoi* used to be very scarce or null because the original description of this species (CEI 1974) is brief and very simple, and it was not possible to conduct a detailed a posteriori study because the species had disappeared from the type locality and adjacent areas. Thus, ETHERIDGE (2000) contributed further morphological data, but these were based on the material previously collected and studied by CEI (1974, 1986).

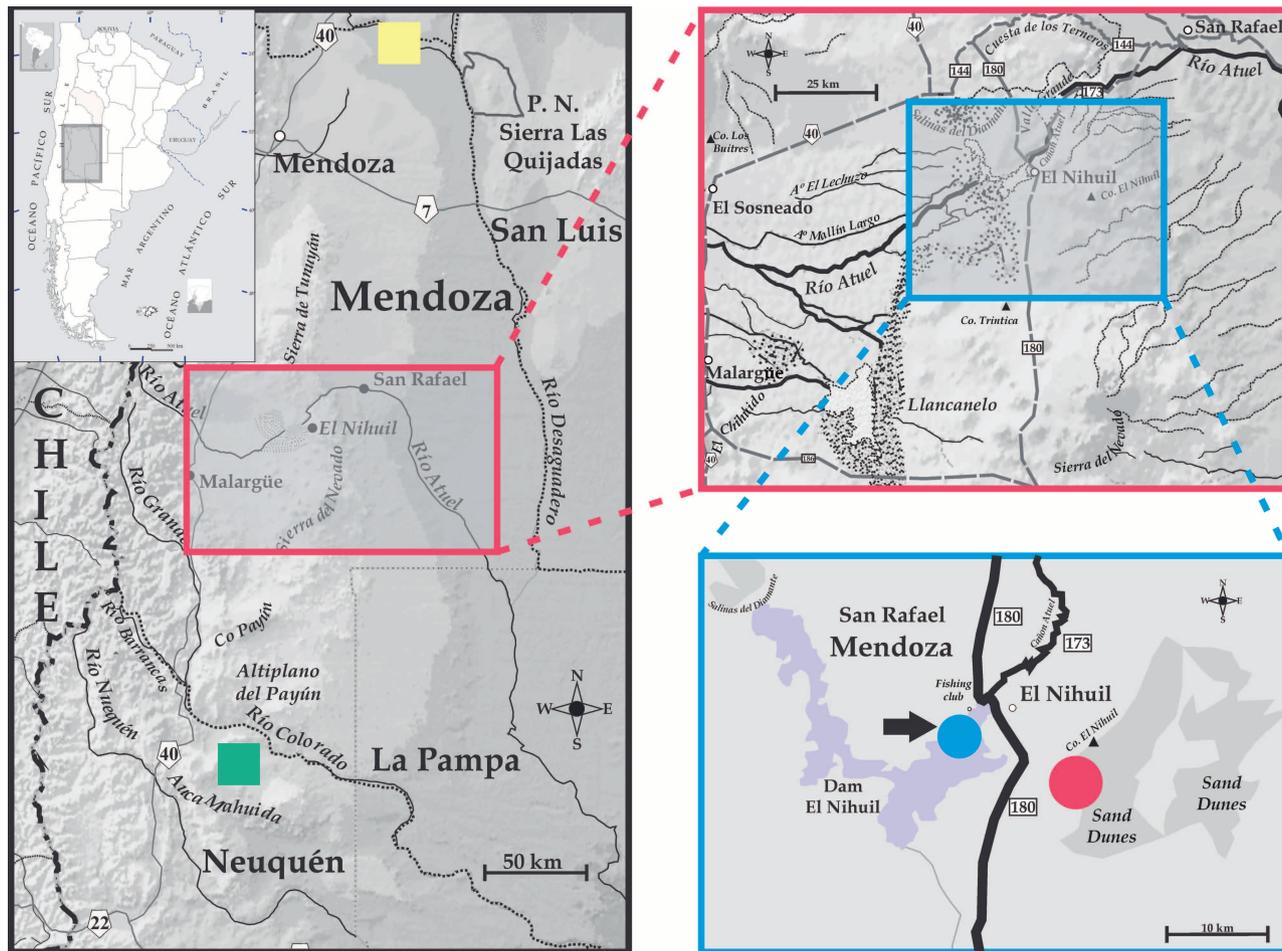


Figure 1. Known distribution of *L. rabinoi* in El Nihuil, Department of San Rafael, Mendoza, Argentina. Blue circle: locations documented by J. M. CEI and collaborators in 1974 and 1975 (now apparently extinct at these localities). Red circle: new population of *Liolaemus rabinoi* (35°05'08.0" S, 68°37'21.7" W). The arrow indicates the type locality. Yellow square: *Liolaemus riojanus*. Green square: *Liolaemus cuyumuhue*.

Table 1. Comparison of morphological characters among species of the *L. wiegmanni* clade. For quantitative characters, the range of values and, in parentheses, the average value are provided. SAM – number of scales around the body; DS – number of dorsal body scales; VS – number of ventral body scales; GS – number of gular scales; NS – number of scales on the neck; PPM – number of preloacal pores in males; PPH – number of preloacal pores in females; Max SVL – maximum snout–vent length (in mm). Source: all species this study, except *L. arambarensis* (VERRASTRO et al. 2003).

Species / Character	SAM	DS	VS	GS	NS	PPM	PPH	Max. SVL
<i>Liolaemus rabinoi</i>	70–80 (74.1)	82–94 (88.6)	84–89 (87.3)	31–37 (33.4)	33–46 (41.3)	5–8 (6.5)	0	55.9
<i>Liolaemus arambarensis</i>	60–66 (62.3)	57–64 (60.1)	51–60 (55.3)	--	--	4–7 (5.2)	3–4 (3.6)	60
<i>Liolaemus azarai</i>	35–44 (41.5)	39–42 (40.5)	72–79 (75.5)	20–29 (23.7)	35–47 (40.5)	5–6 (5.6)	0	51.4
<i>Liolaemus cuyumhue</i>	63–71 (66.7)	76–83 (79.1)	88–103 (93.1)	30–33 (31.7)	36–37 (36.3)	7–9 (8.0)	0	56.5
<i>Liolaemus lutzae</i>	56–64 (60.7)	62–73 (67.1)	92–104 (96.0)	31–45 (37.8)	36–50 (44.6)	5–6 (5.5)	0	60.1
<i>Liolaemus multimaculatus</i>	68–81 (73.7)	73–85 (80.1)	85–96 (90.1)	30–34 (31.8)	45–55 (50.9)	6–9 (7.7)	0	67.4
<i>Liolaemus occipitalis</i>	65–75 (69.8)	73–80 (77.0)	89–97 (92.6)	35–42 (38.8)	46–58 (52.4)	8–11 (9.6)	0	66.9
<i>Liolaemus riojanus</i>	63–72 (68.1)	77–89 (83.1)	82–97 (89.0)	33–42 (36.1)	43–49 (45.7)	8–9 (8.3)	0–3	57.5
<i>Liolaemus salinicola</i>	60–70 (64.4)	71–82 (75.7)	87–106 (96.3)	35–46 (41.5)	49–56 (52.6)	7–9 (7.4)	0–5	76.6
<i>Liolaemus scapularis</i>	54–66 (58.7)	60–68 (63.1)	79–86 (82.9)	30–41 (36.3)	43–54 (47.7)	7–9 (8.0)	0–5	73.6
<i>Liolaemus wiegmanni</i>	48–56 (51.8)	49–57 (53.6)	72–87 (81.7)	26–36 (28.6)	41–49 (46.1)	5–7 (5.9)	0–4	54.5

Within the framework of our findings, we here redescribe *L. rabinoi*, provide for the first time biological and ethological data, and update both its distribution information and phylogenetic position within the genus *Liolaemus*. Furthermore, the specific effects of human activities on the environments where *L. rabinoi* is distributed might pose an effective risk and potential threat of extinction for which reason we discuss new challenges for the species' conservation.

Materials and methods

A field trip was conducted during November of 2010. Our study area was a sand dune system located 10–15 km to the SE of the type locality of *L. rabinoi*, i.e., El Nihuil dam, San Rafael, Mendoza (35°05'08.0" S, 68°37'21.7" W) (Fig. 1). The area belongs to the Monte phytogeographic region and consists of a heterogeneous landscape of alternating grassland patches of *Sporobolus rigens* and *Panicum urvilleanum* plains with dunes of scarce *Suaeda divaricata* and *Hyalis argentea*. Individuals were counted using the Count on Specific Habitat method (OJASTI & DALLMEIER 2000). Frequency of use of microhabitats and ethological observations were recorded. Later, after the relevant census procedures had been completed, nine individuals (4 males and 5 females) were collected to conduct laboratory studies (redescription and morphology). Geographic coordinates were taken using GPS and geodetic datum WGS 84. Because the original description and historical records lack coordinate data, approximate latitude and longitude were reconstructed for distribution-mapping purposes. The lizards were collected by hand or noose, and faecal samples were taken to describe some aspects of their diet. Finally, these individuals were euthanised with sodium pentothal, fixed in 10% formaldehyde, preserved in 70% ethanol, and deposited in the herpetological collection of the Fundación Miguel Lillo (FML), Tucumán. Sporadic trips were made

in the last five years to observe behaviour and study the microhabitat and state of conservation of the place.

Colour in life was described based on field observations and photographs that were taken of captured specimens (Figs 2–4). Observations on squamation were made under a binocular microscope and body measurements taken with a precision calliper to the nearest ± 0.01 mm. Neck fold terminology follows FROST (1992) and ABDALA (2007), whereas body colour pattern terminology follows LOBO & ESPINOZA (1999) and ABDALA (2007).

For the phylogenetic analysis, we used a morphology-based matrix following ABDALA (2007) as modified by ABDALA & JUÁREZ HEREDIA (2013). The final data matrix contains 33 taxa and 142 characters (for the list of characters see PAZ 2012, ABDALA & JUÁREZ HEREDIA 2013), of which 33 were continuous and 109 were discrete characters. We include the following species in the matrix: all species included in the *L. wiegmanni* clade except *L. arambarensis* and *L. cranwelli* (Table 1); and representatives of all species in the *L. boulengeri* clade: *L. acostai*, *L. millcayac*, *L. pseudoanomalus* (*L. anomalus* clade); *L. abaucan*, *L. calchaquí*, *L. chacoensis*, *L. espinozai* (*L. darwinii* clade); *L. boulengeri*, *L. inacayali*, *L. purul*, *L. senguier* (*L. telsen* clade); *L. canqueli*, *L. fitzingerii*, *L. morenoi* (*L. fitzingerii* clade); and *L. cuyanus*, *L. goetschi*, *L. josei*, (*L. cuyanus* clade). The following species were used as outgroup: *L. lineomaculatus* (the root of the tree), *L. multicolor*, and *L. nigriceps*. Furthermore, the discrete characters were divided into binary polymorphic, binary non-polymorphic, multistate polymorphic, and multistate non-polymorphic. The binary and multistate polymorphic characters were treated as given (WIENS 1995). The “parsimony criteria” was employed for optimisation, selecting only shorter trees or those that had the fewest homoplasies. TNT 1.0 (Tree Analysis using New Technology; GOLOBOFF et al. 2003a) was used for the phylogenetic analysis. The continuous characters were analysed using the methodology proposed by GOLOBOFF et al. (2006) and these were “standardized” using the asso-

ciated script (mkstandb.run). The maximum transformation costs considered were 2 and 4. Heuristic searches were made to find the most parsimonious trees. TBR (“Tree Bisection and Reconnection”) was used for branch permuta-



Figure 2. *Liolaemus rabinoi* in life. Adult male: (A) dorsal view; (B) ventral view.



Figure 3. *Liolaemus rabinoi* in life. Adult female: (A) dorsal view; (B) ventral view.



Figure 4. Adult male of *Liolaemus rabinoi* submerged in the sand.

tion. The matrix was analysed using the “implied weights” method (GOLOBOFF 1993). Values from 3 to 15 were used for “K”. Twenty-eight runs were made with the total evidence matrix; for 14 of them, values of mkstandb = 2 were used, while those of mkstandb = 4 were used for the rest. For each value of mkstandb, one run was made with equal weights (EW) and 13 with implied weights (IW), with values of K ranging from 3 through 15. We estimated group support using symmetric resampling, a method not distorted by differential costs (GOLOBOFF et al. 2003b) with 500 replicates and a probability of 0.33 deletion.

All the analysed specimens belonging to the “*L. wiegmanni*” clade are listed in the Appendix with their specific names, localities, collection numbers, and acronyms.

Results

Liolaemus rabinoi (CEI, 1974)

Below we present a new diagnosis of *L. rabinoi* based on the type specimens and newly collected material (FML 28586–593), compared with all species known in the “*L. wiegmanni*” clade (Table 1), providing morphological and morphometric data for males and females. We also provide a detailed description of this species’ coloration in life (Figs 2, 3).

Diagnosis: *Liolaemus rabinoi* belongs to the “*L. boulengeri*” clade (ABDALA 2007) because it has a patch of enlarged scales in the posterior region of the thigh (ETHERIDGE 1995, ABDALA et al. 2006, ABDALA 2007). Within the “*L. boulengeri*” clade, it differs from species of the “*L. anomalus*” clade (ABDALA 2007, ABDALA & JUÁREZ HEREDIA 2013) and from the species of the “*L. darwini*” clade (ABDALA 2007) by having two rows of lorilabials (never one), six scales in contact with the mental (never four), a shovel-shaped snout, a prognathous lower jaw, infralabials forming a sharp edge, and scales with serrated margins on the lower part of arm and on the sides of tail.

Within the “*L. wiegmanni*” clade (Table 1), *L. rabinoi* can be distinguished from *L. arambarensis* by having two rows of lorilabials (never one), dorsal body scales without keels or slightly keeled, juxtaposed (never with evident keels and imbricate), a lack of precloacal pores in females (present in *L. arambarensis*), a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 60–66, \bar{x} = 62.3), and a different colour pattern, with conspicuous postscapular spots (absent in *L. arambarensis*), blue spots and scales on the whole dorsum (only on body flanks in *L. arambarensis*), lack of dorsolateral bands (evident in *L. arambarensis*), and belly with dark dotted spots in males (immaculate in *L. arambarensis*).

Liolaemus rabinoi can be distinguished from *L. azarai* by having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 35–44, \bar{x} = 41.5), a higher number of ventral scales (84–89, \bar{x} = 87.3 vs 72–79, \bar{x} = 75.5), a higher number of dorsal body scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 39–42, \bar{x} = 40.5), temporal and dor-

sal body scales without keels or slightly keeled, juxtaposed (never with evident keels and imbricate), lack of prelocaal pores in females (present in *L. azarai*), and a different colour pattern, with blue spots and scales on the dorsal body (only on body flanks in *L. azarai*), lack of dorsolateral bands (evident in *L. azarai*), and belly with dark dotted spots in males (immaculate in *L. azarai*).

It differs from *L. cuyumhue* in having a higher number of scales around the midbody (70–80, \bar{x} = 74.1 vs 63–71, \bar{x} = 66.7), fewer ventral scales (84–89, \bar{x} = 87.3, vs 88–103, \bar{x} = 93.1), a higher number of dorsal scales, from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 76–83, \bar{x} = 79.1), and a different colour pattern, such as more numerous light blue scales and spots on dorsum and tail flanks, and conspicuous postscapular spots (absent in *L. cuyumhue*).

It can be distinguished from *L. lutzae* in having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 56–64, \bar{x} = 60.7), fewer ventral scales (84–89, \bar{x} = 87.3 vs 92–104, \bar{x} = 96.0), a higher number of dorsal scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 62–73, \bar{x} = 67.1), dorsal scales of the body without keels or slightly keeled, juxtaposed (never with evident keels and imbricate), and a different colour pattern, with conspicuous postscapular spots (absent in *L. lutzae*), blue spots and scales on the whole dorsum (absent in *L. lutzae*), and belly with dotted spots in males (immaculate in *L. lutzae*).

It differs from *L. multimaculatus* by having a higher number of dorsal scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 73–85, \bar{x} = 80.1), fewer scales on the neck from the ear opening to the antehumeral fold (33–46, \bar{x} = 41.3 vs 45–55, \bar{x} = 50.9), and a different colour pattern, with highly numerous light blue scales and spots on the dorsal body and the flanks of the tail, and males with an immaculate throat, never with the same spots or speckles as those present ventrally, as in *L. multimaculatus*.

Liolaemus rabinoi differs from *L. occipitalis* by having fewer ventral scales (84–89, \bar{x} = 87.3 vs 89–97, \bar{x} = 92.6), a higher number of dorsal scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 73–80, \bar{x} = 77.0), dorsal scales without keels or slightly keeled (never with evident keels), a lower number of scales on the neck from the ear opening to the antehumeral fold (33–46, \bar{x} = 41.3 vs 46–58, \bar{x} = 52.4) and a different colour pattern, with the most outstanding features being the presence of a postscapular spot (absent in *L. occipitalis*), dorsal body with blue spots and scales (absent in *L. occipitalis*), and belly with dark pointed spots in males (immaculate in *L. occipitalis*).

It can be distinguished from *L. riojanus* by having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 63–72, \bar{x} = 68.1), edges of gular scales more rounded than pointed, and a different dorsal colour pattern of a brown background with shades of grey (reddish in *L. riojanus*), more evident and larger blue spots on the dorsal body than in *L. riojanus*, and an immaculate throat in males, never with the same dotted spots as those on the venter as in *L. riojanus*.

It differs from *L. salinicola* by having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 60–70, \bar{x} =

64.4), fewer ventral scales (84–89, \bar{x} = 87.3 vs 87–106, \bar{x} = 96.3), a higher number of dorsal scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 71–82, \bar{x} = 75.7), fewer scales on the neck from the ear opening to the antehumeral fold (33–46, \bar{x} = 41.3 vs 49–56, \bar{x} = 52.6), and a different colour pattern, with well-marked paravertebral spots (irregular and diffuse paravertebral spots in *L. salinicola*), conspicuous postscapular spots (absent in *L. salinicola*), blue spots and scales on the whole dorsum (absent in *L. salinicola*), immaculate throat in males (dark throat in *L. salinicola*), and venter with dark dotted spots in males (absent in *L. salinicola*).

It differs from *L. scapularis* by having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 54–66, \bar{x} = 58.7), a higher number of ventral scales (84–89, \bar{x} = 87.3 vs 79–86, \bar{x} = 82.9), a higher number of dorsal scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 60–68, \bar{x} = 63.1), fewer scales on the neck from the ear opening to the antehumeral fold (33–46, \bar{x} = 41.3 vs 43–54, \bar{x} = 47.7), and a different colour pattern, with less evident and smaller paravertebral spots on the dorsum (well-defined and large in *L. scapularis*), less evident and smaller postscapular spots than in *L. scapularis*, blue spots and scales on the whole dorsum (absent in *L. scapularis*), immaculate throat in males (evident and well-delimited black spots in *L. scapularis*), and belly with dark dotted spots in males (absent in *L. scapularis*).

It differs from *L. wiegmanni* by having a higher number of scales around midbody (70–80, \bar{x} = 74.1 vs 48–56, \bar{x} = 51.8), a higher number of ventral scales (84–89, \bar{x} = 87.3 vs 72–87, \bar{x} = 81.7), a higher number of dorsal body scales from the occiput to the hind limbs (82–94, \bar{x} = 88.6 vs 49–57, \bar{x} = 53.6), temporal and dorsal body scales without keels or slightly keeled and juxtaposed (never with evident keels and imbricate), and a different colour pattern, with less evident and delimited paravertebral spots in *L. wiegmanni*, blue spots and scales on the dorsal body (only on the flanks in *L. wiegmanni*), absence of dorsolateral bands (evident in *L. wiegmanni*), and belly with dark dotted spots in males (immaculate in *L. wiegmanni*).

Variation in squamation (based on nine specimens, 4 ♂, 5 ♀; Table 1): Snout wedge-shaped, with a prognathous lower jaw, and smooth dorsal surface of head. Dorsal scales of the head, between rostral and occiput, 18–22 (\bar{x} = 20.3; SD = 1.2); scales between rostral and frontal 6–9 (\bar{x} = 7.4; SD = 1.1); nasal scale in contact with 8–9 scales (\bar{x} = 8.7; SD = 0.5), not in contact with rostral and separated from the canthals by two scales; infralabials 8–9 (\bar{x} = 8.1; SD = 0.4), forming a sharpened edge that protrudes from the lower jaw; second infralabial in contact with one or two scales on the posterior edge; supralabials 8–12 (\bar{x} = 9.4; SD = 1.6), with two rows of lorilabials, the lower one with 8–10 (\bar{x} = 9; SD = 0.8) lorilabials in one row; lorilabials 3–6 (\bar{x} = 4.6; SD = 0.9) contacting with supraocular; two scales between preocular and lorilabials; postocular not divided; well-differentiated, projected with comb-shaped ciliaries, upper ciliaries 11–16 (\bar{x} = 14; SD = 1.6), and superciliaries

3–4 ($\bar{x} = 3.6$; SD = 0.5) imbricate and conspicuously projecting like an “eave”; supraoculars 5–6 ($\bar{x} = 5.7$; SD = 0.5), the frontal one divided in 2–4 ($\bar{x} = 3.3$; SD = 0.8) scales; with the interparietal being larger than the parietals, surrounded by 7–10 ($\bar{x} = 8.0$; SD = 1.1) scales; temporals 11–15 ($\bar{x} = 13.6$; SD = 1.5) without keels; auricular scales 1–4 ($\bar{x} = 2.3$; SD = 1.1), and 1–3 ($\bar{x} = 1.6$; SD = 0.8) scales on the upper edge of the ear opening. Scales on the anterior margin of the external auditory meatus rounded and non-projecting; nuchal scales 33–46 ($\bar{x} = 41.3$; SD = 4.3), granular, without keels on the neck; neck folds developed, suprascapular fold present; with slightly developed anterior and posterior bulbs on the postscapular fold; with several enlarged scales in the antehumeral region; a row of enlarged, triangular scales without keels or cone-shaped or lanceolate, from the upper arm to the forearm; dorsal body scales with rounded edges, most of them without keels, some slightly keeled and juxtaposed or subjuxtaposed; dorsolateral body scales granular, without keels, juxtaposed, and with several heteronotes that can be distinguished between scales; scales around midbody 70–80 ($\bar{x} = 74.1$; SD = 3.8); dorsal scales 82–94 ($\bar{x} = 88.6$; SD = 4.3) between the occiput and hind limbs; gular scales 31–37 ($\bar{x} = 33.4$; SD = 2.1), with rounded posterior edges, ventral scales 84–89 ($\bar{x} = 87.3$; SD = 2.1), larger than dorsals and triangular, imbricate and without keels; males with 5–8 ($\bar{x} = 6.5$; SD = 1.3) preloacal pores, and females without preloacal pores; a femoral patch is evident in the posterior part of the thigh, with juxtaposed scales, cone-shaped, tapering in a pronounced tip in males; granular, with rounded edges in females, without notches or keels in either sex; infratarsals with granular, juxtaposed scales, without keels; fourth finger with 19–21 ($\bar{x} = 20.4$; SD = 0.8) subdigital lamellae; fourth toe with 23–25 ($\bar{x} = 24.3$; SD = 0.7) subdigital lamellae; sides of tail with large, triangular scales, forming a serrated margin, as in arms.

Morphometric variation (based on nine specimens, 4 ♂, 5 ♀; see Appendix): Head longer ($\bar{x} = 13.69$ mm; SD = 0.89) than both wide ($\bar{x} = 10.82$ mm; SD = 1.31) and deep ($\bar{x} = 7.05$ mm; SD = 1.09); head 1.23–1.37 ($\bar{x} = 1.30$; SD = 0.07) times longer than wide and 1.69–2.17 ($\bar{x} = 1.95$; SD = 0.18) times longer than tall; tympanum opening small, 1.13–2.82 ($\bar{x} = 2.15$ mm; SD = 0.64) times longer than wide; head height 3.37–4.88 ($\bar{x} = 4.13$; SD = 0.52) times greater than ear opening height. Maximum snout–vent length 55.9 mm in males and 52.1 mm in females. Snout–vent length 2.83–3.24 ($\bar{x} = 3.06$; SD = 0.17) times longer than body width; 4.75–5.62 ($\bar{x} = 5.04$; SD = 0.31) times longer than thigh length; 5.91–6.60 ($\bar{x} = 6.33$; SD = 0.29) times longer than arm length; 6.74–7.87 ($\bar{x} = 7.45$; SD = 0.41) times longer than forearm length; and 4.93–5.99 ($\bar{x} = 5.46$; SD = 0.40) times longer than hand length. Body trunk 1.18–1.61 ($\bar{x} = 1.36$; SD = 0.15) times longer than wide; tail 1.03–1.11 ($\bar{x} = 1.08$; SD = 0.04) times longer than snout–vent length.

Colour in life (based on 18 specimens observed and photographed in their habitat; Figs 2, 3): *Liolaemus rabinoi* exhibits evident sexual dichromatism only in the ventral col-

our pattern, with females lacking spots on chest and belly (present in males), whereas the dorsal colour pattern does not differ between the sexes. In many *Liolaemus* species that are phylogenetically closely related to *L. rabinoi*, such as *L. wiegmanni* and *L. azarai*, the males exhibit light blue scales on the body and tail flanks. This also occurs in several species of the *L. darwini* and *L. telsen* clades; however, in *L. rabinoi*, size and number of light blue spots and scales on the dorsum and sides of the body and tail do not exhibit differences between males and females (Figs 2, 3).

The head is greyish brown and marked with numerous black, dark brown, light brown, and white scales and small spots. Two fine dark lines or stripes are noticeable on the head sides, one extending from the posterior edge of the eye across the temporal region to the occipital region, and the other from the anterior part of the eye or the preocular scale across the canthal region to the nostrils. The subocular is white, as are the supraoculars, and may have some small dark spots. The superciliaries are dark brown in most specimens.

The dorsal patterns of head and trunk have a spotted and striped appearance, resembling the dune sands where these lizards live. Numerous small, dark and light spots are scattered in the vertebral region, without a vertebral line. Paravertebral spots are small, sometimes fragmented into several smaller dark brown or black spots of variable shapes, and have irregular edges. Adults lack dorsolateral bands, whereas juveniles exhibit noticeable pseudo-bands composed of grouped small dark spots. Large light blue spots and other smaller reddish brown ones are noticeable between the paravertebral spots and the dorsolateral region of the body. Light blue spots vary in size and shape, and light blue scales are found irregularly distributed between the spots. All specimens exhibit a black postscapular spot that can vary in size between individuals but without an ontogenic and/or sexual relationship; several females present a larger and more evident postscapular spot than other females (Fig. 3). Some individuals exhibit one or several small spots in the prescapular region, in the same colour as the postscapular spot, but not forming an antehumeral arc, and small black or dark brown spots, with some white and light blue scales irregularly distributed on the body sides. There is a remarkable mid-lateral line on each side of the body, with dark spots similar to those on the belly below the line. Fore and hind limbs match the pattern of the dorsal body. Dorsally, dark paravertebral spots are clearly discernible on the tail, and so are numerous small black or dark brown spots, with some light blue and white scales scattered between the spots. The paraventral spots are bordered with, or delimited by, light brown longitudinal bands. As mentioned above, sexual dichromatism is evident in the ventral colour pattern, in that the males exhibit numerous and noticeable mole-shaped dark or brown spots, whereas the females present no such spots (Figs 2, 3). Moreover, the ventral sides are slightly yellowish in males; and the throat, vent, limbs, and tail are immaculate white like the entire ventral region of females, which do not have spots or the yellow colour on the belly

(Fig. 3). Juvenile specimens present the same colour pattern as adults; however, ventral spots are absent in males or, when present, are more diffuse.

Natural history: *Liolaemus rabinoi* inhabits the dunes on El Nihuil, located in the San Rafael plain, Andean pedemont, central-western Mendoza (TRIPALDI 2010). This aeolian system comprises linear and parabolic dunes, principally covered by small patches of *Sporobolus rigens* (unquillo), *Suaeda divaricata* (vidriera), and interspersed *Hyalis argentea* (clavelillo) associated with the ramps and crests (Fig. 5). Individuals of *L. rabinoi* were only observed occupying the bare sand on the top of crests from 10:00 to 12:00 h, and sheltering half-buried beneath the patches of *H. argentea* when the substrate temperature exceeded 60°C during the warmest hours of the day (13.00–15.00 h).

Some ethological aspects were recorded. The first one was observed during our active search. Immediately after perceiving our presence, the individuals used sand-diving as an escape strategy, with some of them first running some metres before diving into the sand (Fig. 4). At 12:00 h, instead of sand-diving in the same site where they were seen, the lizards fled rapidly to refuges under *H. argentea* herbs, and buried themselves at these microsites. Once captured and taken to the laboratory, some specimens were kept alive in a terrarium that contained the same sand substrate as that of the collection site. Their diving behaviour could be elicited twice, allowing us to detect certain movements of interest. Sand-diving started with the head inclined down until the individual had completely buried the snout. At that moment, lateral oscillations from the neck transmitted to the entire body allowed the lizard to wriggle its whole body under the sand, with the hind limbs propelled by the oscillations, which decreased in intensity once the tail was partially or completely covered with sand. When the lateral oscillating movement stopped, it was in some cases possible to observe that the head subtly re-emerged, with only the upper tip up to the level of the eyes showing (Fig. 4).

Another observed behaviour was defensive inflation in at least two captured individuals (Fig. 3a). This defensive



Figure 5. General view of the habitat of *Liolaemus rabinoi* in 2010.

behaviour has been reported from other *Liolaemus* species (ABDALA 2007), and is similar to that of the rock-dwelling lizards of the genus *Phymaturus* MOLINA, 1782 (Liolaemidae), which wedge themselves in rock crevices to avoid capture. *Liolaemus rabinoi* increased its volume by inflating the lungs until the body became globose (Fig. 3a). Once such specimens were released into their terraria, it took them some seconds to return to their normal shape.

A preliminary dietary analysis based on faecal samples revealed *L. rabinoi* to be carnivorous, principally feeding on Formicidae (76%), Hemiptera (14.2%), and Coleoptera (9.5%). Indeed, no vegetal items were found in the faeces.

Finally, *L. rabinoi* occurs in syntopy with *L. grosseorum*, *L. gracilis*, *Pristidactylus fasciatus*, *Leiosaurus bellii* and *Homonota darwini* at its type locality and the adjacent sand fields.

Distribution: The historical distribution of *L. rabinoi* comprises the sand dunes on the margins of El Nihuil dam, while the type locality (“sandy coasts of Nihuil Lake, 1,200 m a.s.l.”) might be located at any point of the sand dunes around El Nihuil dam. Anyhow, the type specimens were collected in a sandy area near Club de Pescadores (fishing club) on the northeastern shore of the dam (J. M. CEI pers. comm. 15 January 2002). The newly-found population is located between 2 and 3 km from Puesto Durán, 3.6 km from Provincial Route 180, 8 km from the El Nihuil locality, and 9.8 km from the Club de Pescadores (35°05'08.0" S, 68°37'21.7" W) of El Nihuil, San Rafael Department, Mendoza Province, Argentina (Fig. 1). This new population inhabits a very small area, not exceeding 6 km².

Phylogenetics: In all the trees that were generated, the topologies obtained for the large groups were influenced by the value of K, independent of whether they had used a mkstandb of 2 or 4. Analyses of the largest clades of the *L. boulengeri* group yielded a total of three trees for mkstandb = 2 and three for mkstandb = 4. In both cases, for the first two of the three hypotheses, the algorithm was run using equal weights, with K = 3 and 4, and the rest with K = 5 through 15. Given that all the presented hypotheses are valid and that the values assigned to “K” and mkstandb are arbitrary, the leading hypothesis was selected as the most frequently repeated tree and was at the same time most congruent with previous phylogenetic studies (ABDALA 2007, PAZ 2012, ABDALA & JUÁREZ HEREDIA 2013). Based on these criteria, the selected tree had the following values: mkstandb = 2, constant “K” = 8 through 13, and mkstandb = 4 with a constant “K” = 7 through 12 (Fig. 6). The phylogenetic results indicate that the *L. wiegmanni* clade presents a well-supported monophyly and, in agreement with the hypothesis by ABDALA (2007), is a sister clade of the *L. darwini* clade supporting the *L. laurenti* clade. Likewise, the *L. wiegmanni* clade includes *L. chacoensis* as basal species, which is allied to *L. wiegmanni* and *L. azarai* and shares with these strongly keeled and mucronate temporal scales, light blue spots and scales on the dorsal body

and flanks, similar body size and shape, and conspicuous sexual dichromatism. The obligate sand-dwelling species (*L. cuyumuhue*, *L. multimaculatus*, *L. rabinoi*, *L. riojanus*, *L. salinicola*, *L. scapulari*) make up a defined and well-supported clade that includes *L. rabinoi*. This clade of lizards is grouped into two small subclades and exhibits ethological, morphological, and ecological similarities such as being strictly psammophilous, diurnal sand-burying, having slightly keeled or no keeled, juxtaposed dorsal scales, a shovel-shaped snout, well-developed ciliaries, modified scales of fingers, a cryptic colour pattern that resembles sand, and a sexual dichromatism limited to the ventral face. In addition, (*L. occipitalis* + *L. lutzae*) it is sister to a more numerous clade composed of six species concentrated in two clades (*L. salinicola* + [*L. multimaculatus* + *L. scapularis*]) + (*L. cuyumuhue* + [*L. riojanus* + *L. rabinoi*]) (Fig. 6). It should be noted that this clade has a support of close to 100%, with 96% support of the relationship with *L. riojanus* (sister species).

Discussion

Liolaemus rabinoi was originally described as *Ctenoblepharis rabinoi*, i.e., in a genus that was subsequently synonymised with *Liolaemus* by ETHERIDGE (1995). The original description of this taxon is brief and provides few data, mostly because in 1974, the genus *Ctenoblepharis* was composed of no more than ten species (ETHERIDGE 1995).

Nevertheless, it is understandable that the original description included limited morphological and biological characters because it was based on only two specimens. In spite of R. ETHERIDGE visiting the type locality twice, he unfortunately failed to find individuals; therefore, and the colour pattern described by ETHERIDGE (2000) was therefore based on photographs taken by Dr. CEI in 1974. ETHERIDGE (2000) included *L. rabinoi* in the *Liolaemus* clade of “sand-dwelling lizards” or “*L. wiegmannii*” clade and provided a complete diagnosis by adding new characters. ETHERIDGE (2000) furthermore proposed a phylogenetic hypothesis for the “*L. wiegmannii*” clade, which was subsequently supported by VERRASTRO et al. (2003), in which *L. rabinoi* would be included in the clade (*L. rabinoi* [*L. riojanus* CEI + *L. multimaculatus*]).

Over the last years, the genus *Liolaemus* has substantially increased in the number of species included (ABDALA et al. 2013, 2014, AVILA et al. 2015, TRONCOSO et al. 2015). This also applies to the “*L. wiegmannii*” clade (VERRASTRO et al. 2003, AVILA et al. 2009), which underscores the need for a more detailed diagnosis and characterization of *L. rabinoi*.

The results of this work substantially advance our knowledge of *L. rabinoi*. However, several factors still need to be addressed, especially with reference to the biology and conservation of this species. Because species biology tends to mirror phylogeny (PURVIS et al. 2005), closely related species tend to be similar and phylogenetic relationships should offer insights into conservation issues. Con-

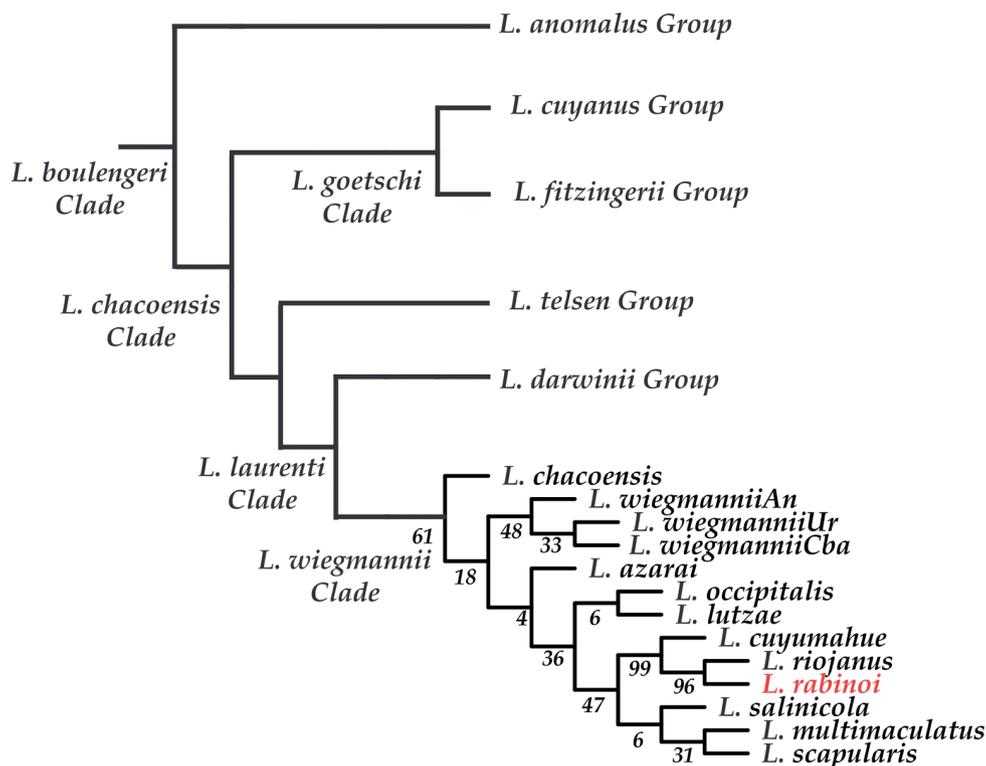


Figure 6. Phylogenetic relationships of *Liolaemus rabinoi* relative to other species of the *L. wiegmannii* clade, based upon parsimony. Values of K = 9 and mkstandb = 2. Fit = 253.64685. The support values (symmetric resampling) are given above the branches.

servation approaches tested in the closely related species, *L. multimaculatus* (KACOLIRIS et al. 2009, 2010, 2011), might be extrapolated to the newly discovered population of *L. rabinoi*. However, these types of actions could be undertaken only if a strongly supported phylogeny that is congruent with that of other authors is available. Unfortunately, there are only two phylogenies of the “*L. wiegmannii*” clade, which include *L. rabinoi* (ETHERIDGE 2000, this study). ETHERIDGE (2000) proposes that *L. rabinoi* is sister of the clade of (*L. multimaculatus* + *L. riojanus*). However, the addition of new characters and additional terminals leads to a partially congruent hypothesis with regard to the results obtained by ETHERIDGE (2000). The phylogeny presented here exhibits geographical congruence, since it relates *L. rabinoi* to the most geographically proximate species. *Liolaemus rabinoi* would be a sister species of *L. riojanus*, located 300 km northwards (northern portion of Mendoza and south of San Juan) from the *L. rabinoi* population, and also forms a clade with *L. cuyumuhue*, a species recently described by AVILA et al. (2009) from northern Neuquén, 300 km south of the *L. rabinoi* population. It should be noted that all obligate sand-dwelling species of the “*L. wiegmannii*” clade (*L. cuyumuhue*, *L. lutzae*, *L. multimaculatus*, *L. occipitalis*, *L. rabinoi*, *L. riojanus*, *L. salinicola*, and *L. scapularis*) exhibit disjunctive distribution patterns, with no evidence of sympatry or syntopy between these species.

The results of this work on *L. rabinoi* are also congruent in some biological and ethological aspects of other sand-dwelling species of the “*L. wiegmannii*” clade. As with *L. rabinoi*, VEGA (2001) and KACOLIRIS et al. (2009) stated that the density of *L. multimaculatus* populations was greater in dunes with low to medium plant cover, establishing a direct relationship between habitat use and a structural gradient of vegetation. Similar results were reported for the sand-dwelling species *L. occipitalis* and *L. lutzae* from southern Brazil (ROCHA 1991, CLÓVIS & VERRASTRO 2008) and *L. riojanus* from central-western Argentina (LASPIUR 2012). In agreement with studies conducted by KACOLIRIS et al. (2009, 2010) on *L. multimaculatus*, preliminary observations in *L. rabinoi* indicate that the species has a variety of escape strategies, with finding refuge and diving into the sand being the most important ones. However, these observations should be explored in more detail in a specific behavioural study. Another ethological trait recorded in some specimens of *L. rabinoi* was the defensive inflation behaviour, a characteristic behaviour also proposed by ABDALA (2007) for some species of the “*L. boulengeri*” clade. This behaviour is displayed when individuals are manipulated, and they are able to remain in such a state for several minutes. It constitutes the first record of this type of behaviour in a species of the “*L. wiegmannii*” clade (ABDALA 2007) (Fig. 3a).

HALLOY et al. (1998) conducted a phylogeny of the *L. boulengeri* clade based on ethological characteristics and included four obligate sand-dwelling species of the *L. wiegmannii* clade. These authors described the diurnal sand-diving strategy in detail. The strategy employed by *L. rabinoi*

for diving during the day is in agreement with that observed by HALLOY et al. (1998) for sand-dwelling species of the *L. wiegmannii* clade (Fig. 4).

The results of our faecal analysis of *L. rabinoi* suggest an insectivorous diet, with a marked predilection for formicids. These results are similar to those for *Liolaemus multimaculatus*, which exhibits an insectivorous and generalist diet, even though it is composed predominantly of Coleoptera, Diptera, and Araneae (VEGA 1999). However, a more detailed study, involving a higher number of individuals and data from various seasons, would be needed to support the present results and specify the feeding habits of *L. rabinoi*.

Aspects related to conservation of *L. rabinoi* should be addressed first and foremost and made available due to the conservation status of this species (ABDALA et al. 2012). Because of the high degree of anatomical, ecological, and ethological specialization that characterizes obligate sand-dwelling species, small disturbances in the environment may have great negative effects on their populations. Undoubtedly, our rediscovery of *L. rabinoi* is an event that raises hopes for the conservation and knowledge of this species. However, there are new challenges and issues that have to be overcome. The main threat to this recently found *L. rabinoi* population is the use of off-road vehicles as a recreational activity in its natural habitat (Fig. 7). The intensive use of motorcycles and four-wheel drive vehicles (4WD) impacts on the sand dunes where *L. rabinoi* occurs. Direct effects on dune environments are evident in the increased erosion process and loss of vegetation (WEBB et al. 1978); thus, animals associated with sand dunes will be affected. Moreover, the off-road usage of these tracts of land has devastating effects in that new tracks will allow people to penetrate formerly remote areas and promote other biophysical impacts such as noise, pollution, exhaust fumes, and wildlife disturbance (PURVIS et al. 2005). Access to natural areas has been facilitated by the widespread use of off-road vehicles in recreational and tourism-related activities. Particularly, in the El Nihuil sand dunes, this recrea-



Figure 7. Activity of off-road vehicles in the *Liolaemus rabinoi* habitat. Note the intensive use of motorcycles and four-wheel drive vehicles in 2015.

tional activity is not only conducted by tourists and local users; the main impact is produced by a local racing event (Prime Multimarca), provincial competitions (Quadriders Dunas del Nihuil – Semana Santa 2010–2011–2013, Enduro Mendoza, Rally Multimarcas), a national challenge (Cross Country, Desafío al Nihuil), and international ones, such as the famous and destructive Dakar Rally (2010, 2012). No doubt, these excessive vehicle activities degrade the habitat of *L. rabinoi* and will certainly have direct effects on this population, exposing it to a high risk of extinction. It is imperative that the relevant authorities (Faunal Agency, Mendoza province, Secretaría de Turismo, Mendoza, and San Rafael, San Rafael Municipality, El Nihuil local authorities) take action urgently and protect *L. rabinoi* from vehicle-induced damage. Based on the issues observed in the region, we propose five measures aimed at conserving this species be taken: 1) The dune area, where *L. rabinoi* occurs, should be declared a protected natural area by the government of Mendoza province; 2) *L. rabinoi* should be declared a natural provincial monument; 3) The use of four-wheel drive vehicles in the dunes and areas influencing the habitat of *L. rabinoi* should be forbidden; 4) Official rally and motorbike competitions in the dunes and areas influencing the habitat of *L. rabinoi* should be forbidden; 5) The Faunal Agency of Mendoza province should allow and promote research on *L. rabinoi*.

Finally, this species was categorized as “Critically Endangered” (IUCN, unpublished data) and assigned to “Endangered” in the recent categorization of amphibians and reptiles of Argentina (ABDALA et al. 2012). Thus, *L. rabinoi* is one of the most severely threatened lizards of Argentina and exposed to an ever-increasing risk of extinction.

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Appendix

Specimens examined

- Liolaemus azarai*: UNNEC 00454, UNNEC 00564, UNNEC 00586, UNNEC 00593, UNNEC 11027–31: Araza Port, Apipe Grande Island, Corrientes, Argentina.
- Liolaemus cuyumhue*: MACN 38981 (holotype): 28.7 km NW Añelo, Añelo Basin, Neuquén, Argentina (38°11' S, 69°01' W, 259 m), FML 17592–594; MACN 38982–984 (paratypes): southern edge of Ruta Provincial 7, (38°13' S, 68°57' W, 260 m), Neuquén, Argentina.
- Liolaemus lutzae*: FML 12871–877: Cabo Frio, Rio de Janeiro, Brasil.
- Liolaemus multimaculatus*: FML 18261–3128: Claromecó, Buenos Aires, Argentina.
- Liolaemus occipitalis*: FML 12881–82; 12889–91; 2618; 26191–2; 2620: Tramandai, Rio Grande do Sul, Brasil.
- Liolaemus rabinoi*: IBA-UNC 8181–818-2 (holotype and paratype): sandy coasts of Lake El Nihuil, 1,200 m. Mendoza, Argentina. FML 28586–593 10–15 km to SE from the type locality, El Nihuil dam, San Rafael, Mendoza (35°05'08.0" S, 68°37'21.7" W).
- Liolaemus riojanus*: FML 30051–569: 110.7 km south of Villa Union, on provincial route 26, La Rioja, Argentina. FML 2738; FML 26261–265: Baldecitos, La Rioja, Argentina.
- Liolaemus salinicola*: FML 16782–89; FML 27441–48: Medani-tos, Catamarca, Argentina.
- Liolaemus scapularis*: FML 20221–2218: Campo los Pozuelos, Santa María, Catamarca, Argentina. FML 17418: In front of the Santa María Airport, Catamarca, Argentina. FML 22301–3019: Route between Amaicha and Santa María, Tucumán, Argentina.
- Liolaemus wiegmanni*AN: FML 35941–411: Agua de las Palomas, Andalgalá, Catamarca.
- Liolaemus wiegmanni*Ur: FML 16811–816: Piriapolis, Maldonado, Uruguay; FML: 20012: Pajas Blancas, Montevideo, Uruguay.
- Liolaemus wiegmanni*Cba: FML 12476–499: Laguna Oscura, Río Cuarto, Cordoba, Argentina.