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ORIGINAL ARTICLE

Reptiles of the Atacama Region, northern Chile: localities, and representation in provinces, ecogeographic landscapes, vegetation formations and protected areas

Reptiles de la Región de Atacama, norte de Chile: localidades y representación en provincias, paisajes ecogeográficos, formaciones vegetacionales y áreas protegidas

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ABSTRACT

We provide a checklist of reptiles distributed throughout the Atacama Region, northern Chile. Twenty-two species were found inhabiting this region, and their representation in provinces, ecogeographic landscapes, vegetation formations and protected areas were registered. We documented 204 localities for reptiles in the Atacama region. Of the three administrative provinces into which the Atacama Region is divided, Copiapó is the one with the highest richness of reptile species, with 19 species in total. The species with the highest number of recorded localities are *Liolaemus nigromaculatus* (n = 49 localities), *Callopistes maculatus* (n = 40), *L. rosenmanni* (n = 32), *L. atacamensis* (n = 31) and *L. platei* (n = 30). In contrast, the species with the fewest recorded localities are *L. andinus*, with only one locality, *L. nigrocoeruleus*, with two localities, *L. zapallarensis* (n = 3), *L. robertoi* and *L. fuscus* (n = 4). The species present in the largest number of ecogeographic landscapes (n = 7) was *C. maculatus*, while at the other end, *L. fuscus*, *L. nigrocoeruleus*, *L. zapallarensis* and *Microlophus atacamensis* were only found in one ecogeographic landscape. The reptile species present in the greatest variety of vegetation formations were *L. platei* and *C. maculatus* (recorded in six formations), while *L. nigrocoeruleus*, *L. silvai* and *M. atacamensis* were recorded in only one type of vegetation formation. Finally, two species stand out that would not be protected in any area, namely *L. andinus* and *L. nigrocoeruleus*.

Keywords: Atacama Desert, conservation, distribution, lizards, snakes.

RESUMEN

Presentamos una lista de las especies de reptiles presentes en la Región de Atacama, en el norte de Chile. Veintidos especies habitan esta Región y detallamos su representación en provincias, paisajes ecogeográficos, formaciones vegetacionales y áreas protegidas. Documentamos 204 localidades con registro de reptiles para la Región de Atacama. De las tres provincias administrativas en las cuales se divide la Región, la Provincia de Copiapó es la de mayor riqueza, con 19 especies. Las especies con el mayor número de localidades registradas son *Liolaemus nigromaculatus* (n = 49), *Callopistes maculatus* (n = 40), *L. rosenmanni* (n = 32), *L. atacamensis* (n = 31) y *L. platei* (n = 30). En contraste, las especies con el menor número de localidades registradas son *L. andinus*, con una sola localidad, *L. nigrocoeruleus* (n = 2), *L. zapallarensis* (n = 3), *L. robertoi* y *L. fuscus* (n = 4). La especie presente en el mayor número de paisajes ecogeográficos (n = 7) fue *C. maculatus*, mientras que, en el otro extremo, *L. fuscus*, *L. nigrocoeruleus*,

L. zapallarensis y *Microlophus atacamensis* solo se encuentran en un paisaje ecogeográfico. Las especies de reptiles presentes en una mayor variedad de formaciones vegetales fueron *L. platei* y *C. maculatus* (registradas en seis formaciones), mientras que *L. nigrocoeruleus*, *L. silvai* y *M. atacamensis* se registraron en un solo tipo de formación vegetativa. Finalmente, se destacan dos especies que no estan en ningún área protegida: *L. nigrocoeruleus* y *L. andinus*.

Palabras claves: conservación, desierto de Atacama, distribución, lagartijas, serpientes.

INTRODUCTION

The Atacama Region is located in the north of Chile, between the 25°17' S - 29°30' S and 71°30' W - 66°14' W, and covering a surface of 75,176.20 km^2 (BCN 2019). It is limited in the north by the Antofagasta Region, in the south by the Coquimbo Region, in the east by Argentina and in the west by the Pacific Ocean (Fig. 1). A total of 19 rivers cross the region, with only five of any significance (Nenadovich 2010). Its altitude range varies from sea level to 6,983 meters above sea level (Ulloa & Ortiz de Zárate 1989).

The climate of this region, according to Ulloa and Ortiz de Zárate (1989), presents four climatic units, following the taxonomic classification by Köppen that is based on the characteristics of precipitation and temperatures (Allaby 2000): Coastal Desert with Abundant Cloudiness, Transitional Desert Climate, Cold Mountain Desert and High Mountain Tundra Climate (di Castri & Hajek 1976).

Currently the reptiles of Chile comprise 135 species, 20 genera and 11 families (Ruiz de Gamboa 2016, 2020). The reptiles of the Atacama Region have been the focus of specific studies (Ortiz 1977, 1980; Núñez & Torres-Mura 1992; Moreno & Ortiz 2001;Vidal *et al.* 2002; Victoriano *et al.* 2003; Vidal & Ortiz 2004; Fariña *et al.* 2008; Valladares & Briones 2012; Troncoso-Palacios & Ferri-Yáñez 2013; Troncoso-Palacios 2014a; Ibáñez *et al.* 2015; Troncoso-Palacios *et al.* 2015), new species records (Ortiz 1987; Young-Downey & Moreno 1991; Núñez & Navarro 1992; Navarro & Núñez 1993; Núñez *et al.* 2001, 2003; Marambio-Alfaro & Troncoso-Palacios 2014), taxonomic updates (Troncoso-Palacios & Ferri-Yáñez 2012; Troncoso-Palacios & Garín 2013; Ruiz de Gamboa *et al.* 2018), specific lists (Troncoso-Palacios & Marambio-Alfaro, 2011; Troncoso-Palacios 2014a,Troncoso-Palacios 2014b), and studies that summarize its reptile fauna (Valladares 2011; Marambio-Alfaro & Hiriart-Lamas 2019), but without further details of its geographic distribution. With regards to endemism, this is the region of Chile with the highest percentage of endemic reptile species, reaching 95% (Mella 2019). On the other hand, the representativeness of its richness in protected areas has been analyzed in detail in two areas (Moreno *et al.* 2000, 2002) and at a general level (Squeo *et al.* 2008), there being no detailed evidence of its conservation at the regional level.

The aim of this work was to determine the distribution of reptile species in the Atacama Region, analyzing their representativeness at the ecogeographic and vegetation levels and in protected areas, whose implications are of great use in the conservation of these species.

MATERIALS AND METHODS

Reptile presence data

The information was extracted from the collections and observations obtained from the literature. General lists were reviewed (Veloso & Navarro 1988; Núñez & Jaksic 1992; Ruiz de Gamboa 2016), catalogs (Troncoso & Ortiz 1987; Núñez 1992; Moreno & Ibarra-Vidal 2004; Núñez & Gálvez 2015), and books of general use (Donoso-Barros 1966; Pincheira-Donoso & Núñez 2005; Vidal *et al.* 2008; Demangel 2016; Mella 2017). In addition, recent taxonomic changes were considered (Grazziotin *et al.* 2012; Trevine *et al.* 2022).

The first records of Donoso-Barros (1966), with localities, were added to the above, although without coordinates. Coding details of the specimens deposited in biological collections were obtained in the following museums or collections: MNHNCL HERP: National Museum of Natural History, Santiago, Chile; MRC = Regional Museum of Concepción; MUAP = Museum of the Sea, Universidad Arturo Prat; SSUC RE = Collection of Flora and Fauna Prof. Patricio

Sánchez Reyes of the Universidad Católica de Chile; MRA = Regional Museum of Atacama; MZUC = Museum of Zoology, Universidad de Concepción; MNHP = Muséum National d'Histoire Naturelle de Paris; DBGUCH = Department of Cell Biology and Genetics, Universidad de Chile; IZUC = Department of Zoology, Universidad de Concepción; UChV = Department of Biology, Universidad de Chile de Valparaíso; FML = Fundación Miguel Lillo.

In addition to records in collections and other findings from the literature, we updated our own unpublished field data. The herpetofaunal surveys started in 1999 with one to five independent outings per year by the authors. In each survey, transects between 100 to 300 m and between 09:00 h to 18:00 h were carried out. When the record did not consider collections (vouchers), the information was filtered with reliable evidence of the taxonomic identification of the species (e.g., photographs, taxonomic keys), in order to have accuracy in the records. The details of the specimens and other samples reviewed by species is indicated in Appendix 3.

Subdivisions of the Atacama region

The division of the Atacama Region in four contexts was used: (1) Provinces; (2) Ecogeographic landscapes; (3) Vegetation Formations and (4) Protected areas.

The Atacama region is divided into 3 provinces: Chañaral, Copiapó and Huasco (BCN 2019; Fig. 1), and has been subdivided into ecological regions structured under the notion of ecogeographic landscapes, according to the methodological approaches developed by CSIRO in Australia (Novoa *et al.* 2008). There are seven defined Ecogeographic Landscapes, of which the Andean (28.1% of the region) predominates; it is displaced to the west by the Altiplano (high plateau;18.5%) north of 27° S and the Serrano (mountain;21.3%), which is interrupted by the Copiapó river´s area of influence. The other landscapes defined correspond to the Pre-Andean (17.6%), Pampean (9.6%), Coastal (3.5%) and Valley (1.4%; Fig. 2) areas.

For their part, Luebert and Pliscoff (2017), divide this Region into seven bioclimates and 20 Vegetation Formations. In order to simplify understanding, the 20 formations initially described were grouped into eight more general formations (grouping similar categories, and assuming that reptile species use macro-environments), corresponding to: Andean tropical grassland, Mediterranean desert scrub, tropical desert scrub, tropical low scrub, Mediterranean tropical scrub, coastal Mediterranean desert scrub, interior Mediterranean desert scrub and interior tropical desert scrub (Fig. 3).

This study also considered units for the protection of the biodiversity of the Atacama Region defined in previous studies. These correspond to the units of the National System of Protected Wild Areas of the State (SNASPE, 1,287 km^2, 1.7% of the regional surface), the Isla Grande de Atacama Marine and Coastal Protected Area (AMCP) (96 land km^2, 0.1%), the area allocated for conservation by the Ministerio de Bienes Nacionales (MBN) Quebrada El León (30 km^2, 0.04%) and two other units in the process of being legally allocated for conservation purposes by the MBN (Desierto Florido 1 and 2, 1,172 km^2, 1.6%), the Private Protected Wilderness Area Huascoaltinos (ASPP, that would have the status of Private Natural Reserve (RNP), 2,197 km^2, 2.9%), the biological corridor of the National Park Nevado de Tres Cruces, that connects the areas of Laguna del Negro Francisco with Laguna Santa Rosa, proposed by the Corporación Nacional Forestal (CONAF, 223 km^2, 0.3%) and the priority sites defined in the EPAB of the Comisión Nacional del Medio Ambiente (CONAMA, 8,636 km^2, 11.4%). Some of these units (abbreviated under the acronym of ASP) overlap partially or completely, so their surfaces cannot be added directly. Eliminating overlaps, these units represent 12,606 km^2, 16.7% of the regional surface (Squeo *et al.* 2008). For the purposes of this study we have carried out only three divisions, which allows for visualizing the *in situ* conservation conditions in which the regional reptile fauna is found, namely, 1.- RNP Private Protected Wilderness Area Huascoaltinos, 2.- Priority Site and 3.- SNASPE+AMCP (which includes, National System of Protected Areas of the State, Marine Coastal Protected Area, areas allocated for conservation by the Ministerio de Bienes Nacionales and units in the process of being allocated for conservation). Details of all protected units are shown in the Appendix 4 and Fig. 4.

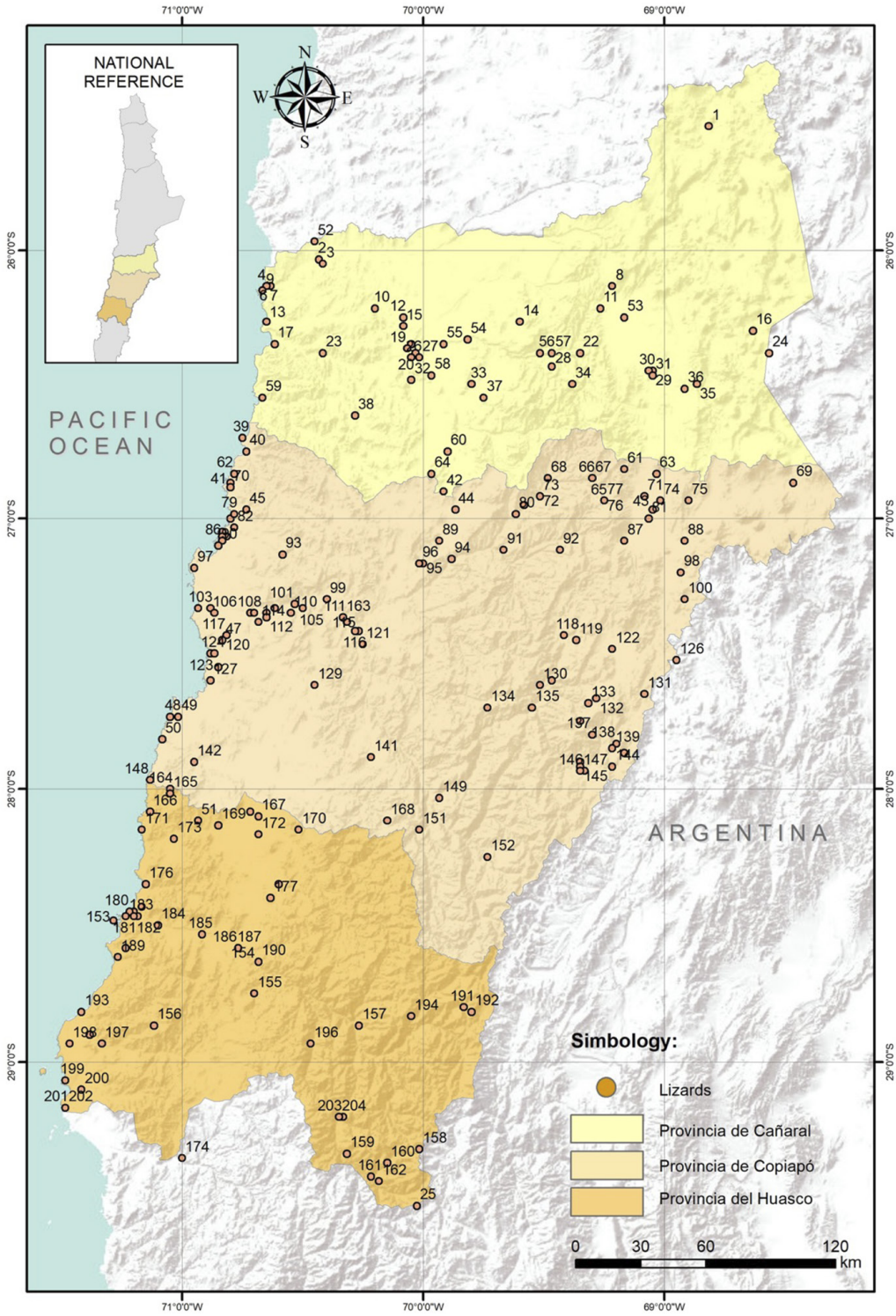

Figure 1. Map of Atacama Region, showing marked points by provinces. Brown dots: localities cited in this text (following the numbering in Appendix 1). / Mapa de la Región de Atacama, mostrando los puntos de registro por provincias (siguiendo la numeración en Apéndice 1). Puntos marrones: localidades citadas en el texto.

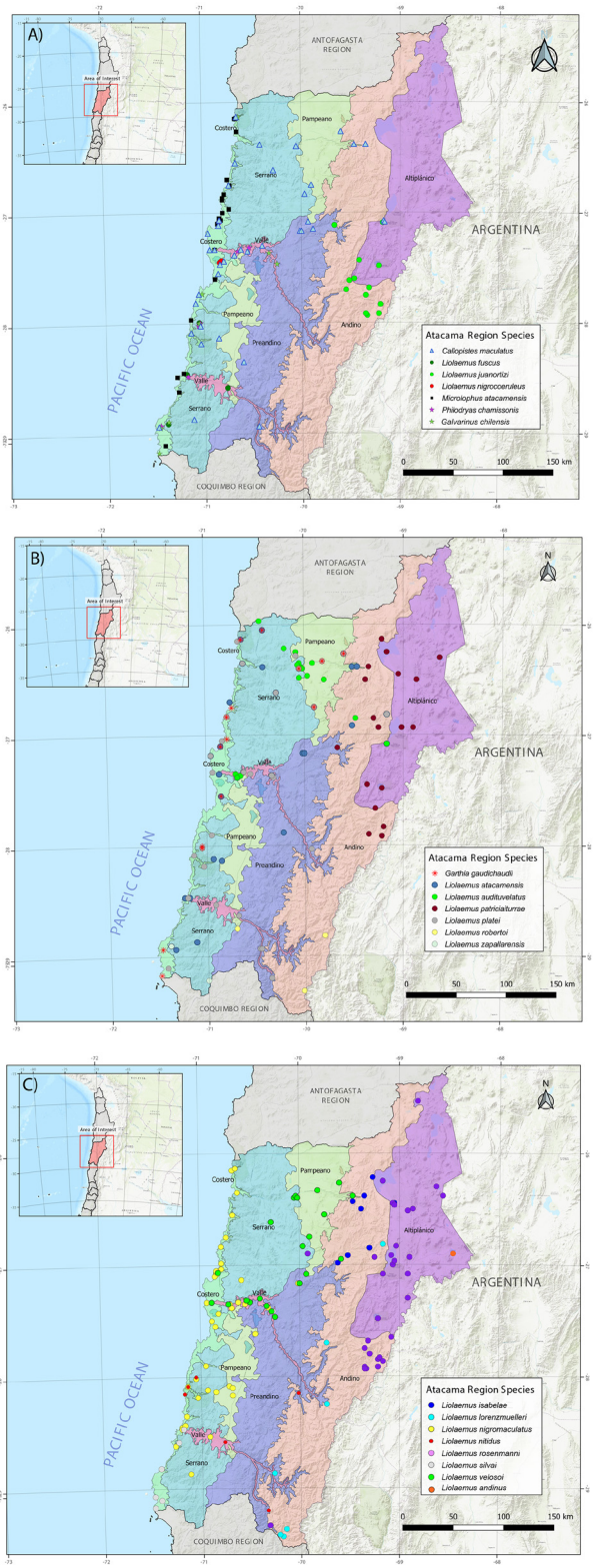

Figure 2. Map of Atacama Region, showing marked points of the species of reptiles present in Ecogeographic Landscapes (Novoa *et al.* 2008). / Mapa de la Región de Atacama, mostrando los puntos de registro de las especies de reptiles presentes en los Paisajes Ecogeográficos (Novoa *et al.* 2008)

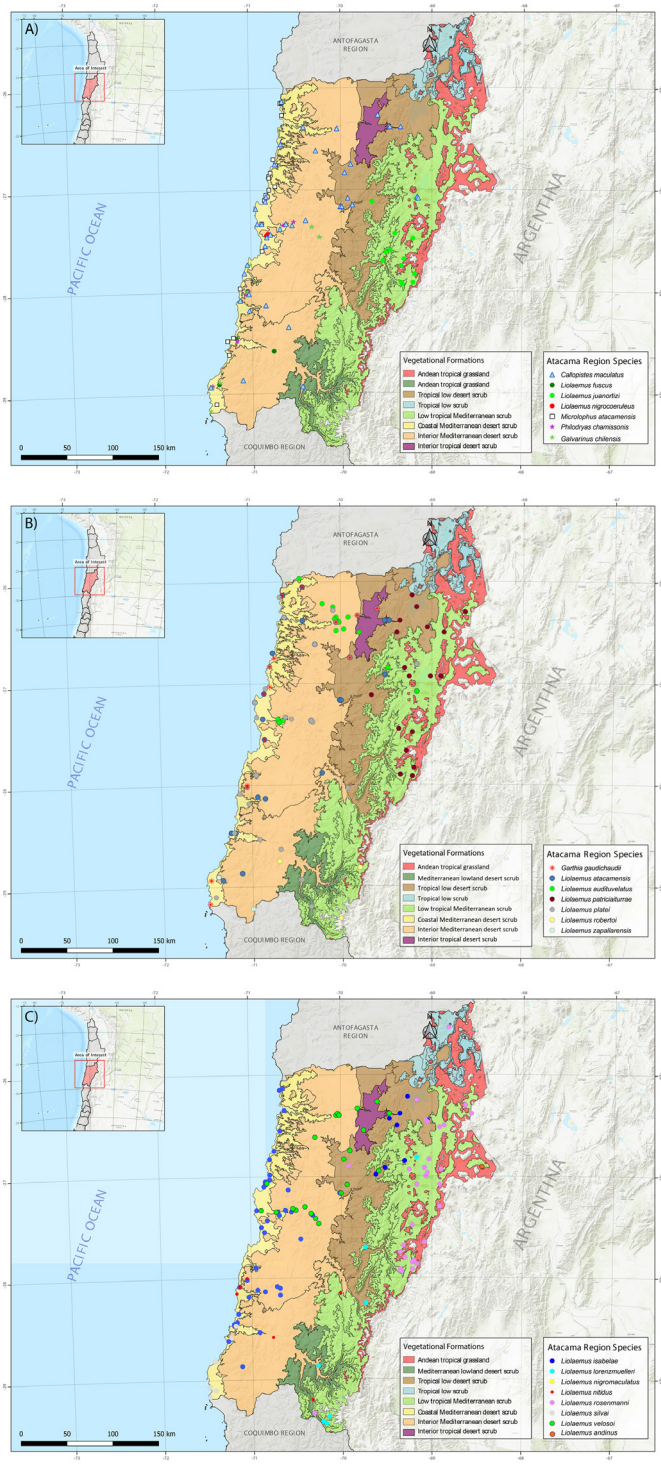

Figure 3. Map of Atacama Region, showing marked points of the species of reptiles present in vegetational formations (Luebert & Pliscoff 2017). / Mapa de la Región de Atacama, mostrando los puntos de registro de las especies de reptiles presentes en las formaciones vegetacionales (Luebert & Pliscoff 2017).

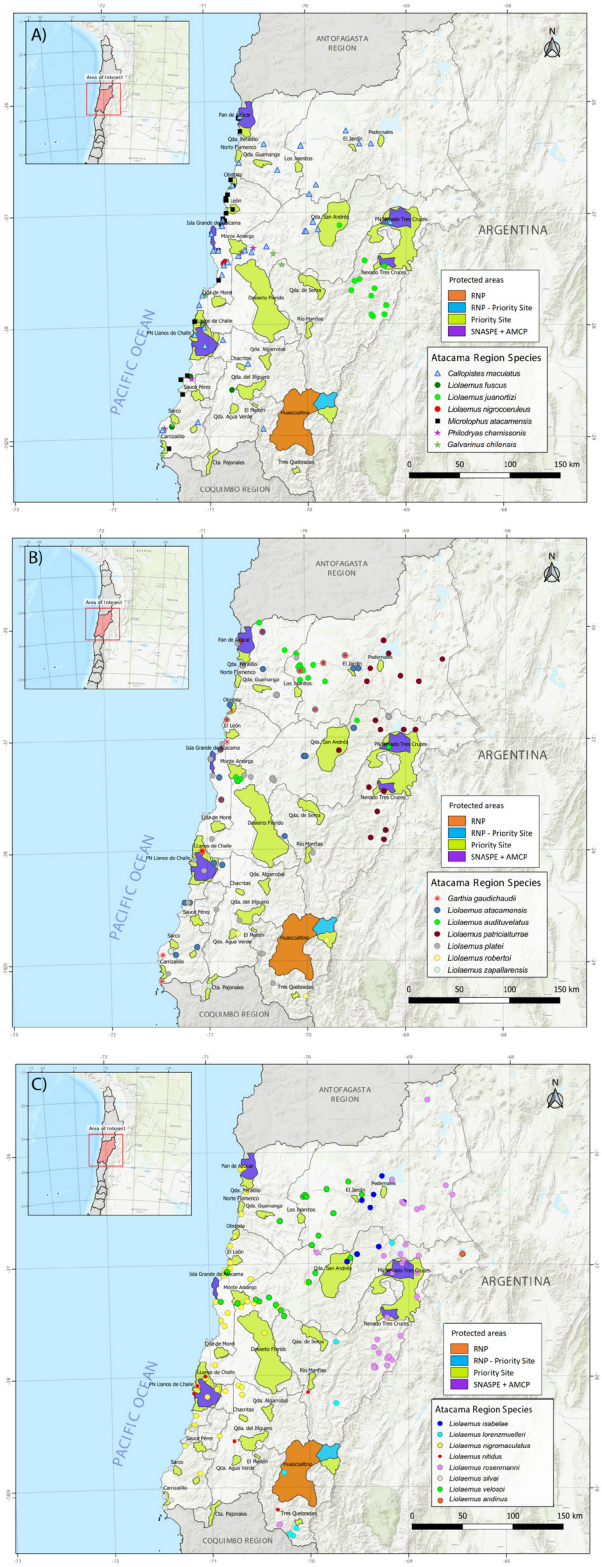

Figure 4. Map of Atacama Region, showing marked points by Protected Areas (Squeo *et al.* 2008) and the species of reptiles present in them. / Mapa de la Región de Atacama, mostrando los puntos por Áreas Protegidas (Squeo *et al.* 2008) y las especies de reptiles presentes en ellas.

RESULTS

A total of 22 reptile species have been recorded in the Atacama Region (Ruiz de Gamboa 2016; Mella 2017) belonging to six genera and five families. In Fig. 1 we pooled sites (localities) of all species for a clearer graphic display (but they are separated in Appendix 1, 2 and 3). By far, *Liolaemus* is the genus with the most species represented in the Region, with more than 77% of species (17 species), while other genera have only one species each. Special mention should be made of *L. melanopleurus*, recently eliminated from the Region (Troncoso-Palacios & Marambio-Alfaro 2021), as it was listed for more than a hundred years.

CHECKLIST

ORDER SQUAMATA
SUBORDER Sauria
Phyllodactylidae
Garthia gaudichaudii (Duméril & Bibron, 1836)

Liolaemidae
Liolaemus andinus Koslowsky 1895
Liolaemus atacamensis Müller & Hellmich, 1933
Liolaemus audituvelatus (Núñez & Yáñez, 1983)
Liolaemus fuscus Boulenger, 1885
Liolaemus isabelae Navarro & Núñez, 1993
Liolaemus juanortizi Young-Downey y Moreno, 1991
Liolaemus lorenzmuelleri Hellmich, 1950
Liolaemus nigrocoeruleus (Marambio-Alfaro & Troncoso-Palacios 2014)
Liolaemus nigromaculatus (Wiegmann, 1835)
Liolaemus nitidus (Wiegmann, 1834)
Liolaemus patriciaiturrae Núñez & Navarro, 1993
Liolaemus platei Werner, 1898
Liolaemus robertoi Pincheira-Donoso & Núñez, 2003
Liolaemus rosenmanni Núñez & Navarro, 1992
Liolaemus silvai Ortiz, 1989
Liolaemus velosoi Ortiz, 1987
Liolaemus zapallarensis Müller & Hellmich, 1933

Tropiduridae
Microlophus atacamensis (Donoso-Barros, 1966)

Teiidae
Callopistes maculatus Gravenhorst 1838

SUBORDEN Serpentes
Dipsadidae
Philodryas chamissonis (Wiegmann, 1835)
Galvarinus chilensis (Schlegel, 1837)

An accurate record of the 22 species of reptiles present in the Atacama Region was obtained in a total of 204 localities (details in Appendix 1, 2 and 3). However, it is included in Figure 1 and Appendix 1 as an effort of a recent species described for the region, *L. andinus*, which according to Abdala *et al.* (2021a) would be found in Laguna Verde, corroborated by the authors (Appendix 5).

Of the three provinces into which the Atacama Region is divided, the one with the highest richness of reptile species is Copiapó, with 19 species, while in the provinces of Chañaral and Huasco 13 species are recorded (Appendix 2, Fig. 1). Seven species have a wide distribution, being recorded in the three provinces (*Garthia gaudichaudii*, *L. atacamensis*, *L. nigromaculatus*, *L. platei*, *Microlophus atacamensis*, *Callopistes maculatus* and *Philodryas chamissonis*), while five other species are recorded in only one province (*L. andinus*, *L. zapallarensis*, *L. nigrocoeruleus*, *L. lorenzmuelleri* and *L. juanortizi*; Appendix 2). The species with the highest number of recorded localities are *L. nigromaculatus* (49 localities), *C. maculatus* (n = 40), *L. rosenmanni* (n = 32), *L. atacamensis* (n = 31) and *L. platei* (n = 30; Appendix 2). At the other extreme, the species with the fewest record locations are *L. andinus*, with only one locality, *L. nigrocoeruleus*, with two localities, followed by *L. zapallarensis* (n = 3), *L. robertoi* and *L. fuscus* (n = 4; Appendix 2).

Considering ecogeographic landscapes (Novoa *et al.* 2008), the coastal is the one with the greatest richness, with 12 species, followed by the Andean (n = 11) and the valley (n = 10), while the landscapes with less richness correspond to the altiplanic and pampean, with seven and six species, respectively (Table 1, Fig. 2). The species present in the largest number of ecogeographic landscapes were *C. maculatus*, present in the seven landscapes; it should be considered that although this species was recorded at the limit of the high Andean landscape, this is an administrative division, so this record should be carefully evaluated. Followed by *L. atacamensis* and *L. platei* (present in six landscapes), while at the other end, *L. andinus*, *L. fuscus*, *L. nigrocoeruleus*, *L. silvai*, *L. zapallarensis* and *M. atacamensis* are only found in one ecogeographic landscape (Table 1, Fig. 2).

Table 1. Species de reptiles listed by Ecogeographic Landscapes according to Novoa *et al.* (2008). *Outliers. / Especies de reptiles por paisajes ecogeográficos, de acuerdo a Novoa *et al.* 2008. *valores atípicos.

TAXA	Ecogeographic landscapes						
	Coastal	Valley	Serrano	Pampean	Preandean	Andean	Altiplano
Garthia gaudichaudii	X	X	X	X			
Liolaemus andinus							X
Liolaemus atacamensis	X	X	X	X	X	X	
Liolaemus audituvelatus		X	X	X		X*	X*
Liolaemus fuscus	X						
Liolaemus isabelae						X	X
Liolaemus juanortizi					X	X	X
Liolaemus lorenzmuelleri					X	X	
Liolaemus nigrocoeruleus	X						
Liolaemus nigromaculatus	X	X	X				
Liolaemus nitidus	X	X	X		X*	X*	
Liolaemus patriciaiturrae					X	X	X
Liolaemus platei	X	X	X	X	X	X*	
Liolaemus robertoi					X	X	
Liolaemus rosenmanni						X	X
Liolaemus silvai	X						
Liolaemus velosoi		X	X	X			
Liolaemus zapallarensis			X				
Microlophus atacamensis	X						
Callopistes maculatus	X	X	X	X	X	X*	X*
Philodryas chamissonis	X	X					
Galvarinus chilensis	X	X					
Number of Species	**12**	**10**	**9**	**6**	**8**	**11**	**7**

*Note: During the printing of this article a new species *Liolaemus carezzae* (Campos-Soto *et al.* 2023) was described in the region, therefore the richness rises to 23 species.

Regarding the representation of reptiles in vegetation formations (Luebert & Pliscoff 2017), the one with the greatest richness founded is the coastal Mediterranean desert scrub, with 15 species, followed by the interior Mediterranean desert scrub, with 13 species (Table 2, Fig. 3). On the other hand, the vegetation formations with the lowest species richness was the tropical low scrub, with only one species (Table 2, Fig. 3). The reptile species present in the greatest variety of vegetation formations were *L. platei* and *C. maculatus* (recorded in six formations), while *L. nigrocoeruleus*, *L. silvai* and *M. atacamensis* were recorded in only one type of vegetation formation, followed by *G. gaudichaudii*, *L. andinus*, *L. fuscus*, *L. isabelae*, *L. nigromaculatus*, *L. robertoi*, *L. zapallarensis*, *P. chamissonis* and *G. chilensis*, which were observed in two types of vegetation formations (Table 2, Fig. 3).

Finally, in relation to the representation in the ASP, the priority sites present the highest reptile richness, with 18 species, followed by the SNASPE-AMPC areas, with 11 species, while RNP presents only two species (Table 3, Fig. 4). Two species stand out that would not be protected in any area, namely *L. nigrocoeruleus* and *L. andinus* (Table 3, Fig. 4). *L. nigrocoeruleus* is a coastal species present near the priority sites Monte Amargo and Desierto Florido, while *L. andinus* is an Andean species present only in Laguna Verde.

Table 2. Reptile species listed by Vegetational Formations according to Luebert and Pliscoff (2017). / Especies de reptiles por Formación Vegetacional, de acuerdo a Luebert y Pliscoff (2017). **Abbreviations:** ATG= Andean tropical grassland; MLDS= Mediterranean low desert scrub; TLDS= tropical low desert scrub; TLS= tropical low scrub; LMTS= Low Mediterranean tropical scrub; CMDS= Coastal Mediterranean desert scrub; IMDS= Interior Mediterranean desert scrub; ITDS= Interior tropical desert scrub.

TAXA	Vegetational formations							
	ATG	MLDS	TLDS	TLS	LMTS	CMDS	IMDS	ITDS
Garthia gaudichaudii						X	X	
Liolaemus andinus					X			X
Liolaemus atacamensis	X		X			X	X	
Liolaemus audituvelatus	X				X	X	X	
Liolaemus fuscus						X	X	
Liolaemus isabelae			X		X			
Liolaemus juanortizi			X		X			X
Liolaemus lorenzmuelleri		X	X		X			
Liolaemus nigrocoeruleus						X		
Liolaemus nigromaculatus						X	X	
Liolaemus nitidus		X			X	X	X	
Liolaemus patriciaiturrae			X		X			X
Liolaemus platei	X	X	X		X	X	X	
Liolaemus robertoi					X		X	
Liolaemus rosenmanni			X	X	X			X
Liolaemus silvai						X		
Liolaemus velosoi	X		X			X	X	
Liolaemus zapallarensis						X	X	
Microlophus atacamensis						X		
Callopistes maculatus	X	X	X		X	X	X	
Philodryas chamissonis						X	X	
Galvarinus chilensis						X	X	
Number of species	**5**	**4**	**9**	**1**	**11**	**15**	**13**	**4**

Table 3. Species de reptiles listed by protected areas according Squeo *et al.* (2008). In bold, species not present in any protected area. / Especies de reptiles por Áreas Protegidas, de acuerdo a Squeo *et al.* (2008). En resaltado, especies no presentes en ninguna área protegida.

TAXA	Protected Area		
	RNP	Priority Site	SNASPE+AMPC
Garthia gaudichaudii		X	X
Liolaemus andinus			
Liolaemus atacamensis		X	X
Liolaemus audituvelatus		X	X
Liolaemus fuscus		X	
Liolaemus isabelae		X	
Liolaemus juanortizi		X	X
Liolaemus lorenzmuelleri	X		
Liolaemus nigrocoeruleus			
Liolaemus nigromaculatus		X	X
Liolaemus nitidus		X	X
Liolaemus patriciaiturrae		X	
Liolaemus platei		X	X
Liolaemus robertoi	X		
Liolaemus rosenmanni		X	X
Liolaemus silvai		X	
Liolaemus velosoi		X	X
Liolaemus zapallarensis		X	
Microlophus atacamensis		X	X
Callopistes maculatus		X	X
Philodryas chamissonis		X	
Galvarinus chilensis		X	
Number of species	**2**	**18**	**11**

DISCUSSION

The north of Chile, where the Atacama Desert, the driest in the world, is located, comprises four regions in its different administrative subdivisions (Sayre *et al.* 2000), which together represent the largest number of reptile species, as a percentage of the country. This, although seemingly a contradiction, makes it a space of great interest for researchers, in terms of determining and clarifying the richness of animals present in these apparently unpopulated areas. That is why the Atacama Region, which corresponds to the southernmost section of the desert of the same name, raises the need for evaluation and specific distribution of species.

Regarding the taxonomic validity of the listed species, it should be mentioned that Esquerré *et al.* (2022) consider *L. nigrocoerulerus* to be a junior synonym of *L. velosoi*, while Abdala *et al.* (2021b; pp. 270 and 276) consider both species to be valid. Conservatively, as the controversy remains, in this study we agree with Abdala *et al.* (2021b) on the validity of both species.

This study shows a record of 204 localities for the 22 species of reptiles present in the Atacama Region (Fig. 1, Fig. 5, Fig. 6). The localities indicated can be considered those with positive reptile records, so it is likely that some areas without registration may be evaluated, but without positive records. This has been the first study that shows the detail

of the presence/absence of reptiles in all known localities in the region, which is important for several reasons: first, it shows the level of regional representativeness of the records, both in number and in spatial location; second, it allows knowing which areas do not yet present samplings, or are poorly evaluated (Fig. 1), and therefore, are a future research priority. For example, the areas to the south-west of Copiapó, the areas to the north-east and south of Vallenar have been scarcely evaluated to date, so it is essential to investigate these sectors. On the other hand, the areas east of Chañaral, although they do not show representation, have been studied in depth in three of the four annual seasons (Valdés & Marambio-Alfaro 2018), this due to the extreme conditions prevailing in that part of the high Andes, which

Figure 5. Some of the species of *Liolaemus* from the Atacama Region, Chile: (A) *L. isabelae*, (B) *L. juanortizi*, (C) *L. nigrocoeruleus*, (D) *L. nigromaculatus*, (E) *L. patriciaiturrae*, (F) *L. rosenmanni*. / Algunas especies de *Liolaemus* de la Región de Atacama, Chile.

invites us to re-evaluate the representativeness of reptiles; third, this study lets us know the level of representativeness and the degree of conservation of the reptiles in the ASP, even without having carried out specific samplings within each protected area. (e.g., National Parks of the Region); this is relevant since there are at least two species that are not found in any protected or priority site, being endemic (*L. andinus* and *L. nigrocoeruleus*); fourth, to categorize individuals in the different ecogeographic and vegetation systems and protection areas, allowing to establish well-founded criteria for their conservation, since they complement and do not exclude each other.

Figure 6. Some of the species of reptiles from the Atacama Region, Chile: (A) *Liolaemus zapallarensis*, (B) *Garthia gaudichaudii*, (C) *Microlophus atacamensis*, (D) *Callopistes maculatus*, (E) *Philodryas chamissonis*, (F) *Galvarinus chilensis.* / Algunas de las especies de reptiles de la Región de Atacama, Chile.

With regards to herpetology, the conservation implications of reptile species should take into account these findings and supplement them with the level of recent human activity in some areas. For instance, within the limited geographic distribution of *L. nigrocoeruleus* in the coastal area close to Caldera, there are tourism and real estate development programs being developed (Rodríguez & Rodríguez 2022). Additionally, *L. andinus*, a microendemic species only found on the southern edge of Laguna Verde, is currently undergoing lithium mining surveys (Cabello 2021). In both cases, the presence of these endemic species not just in Chile, but also in the Atacama Region, requires conservation and protection plans in case of potential environmental threats.

The distributional bibliographic records (Mella 2017, 2019) are consistent with the frequency records of the species and with their location in ecogeographic landscapes, vegetation formations and presence in protected areas (ASP). Thus, species with wide geographic distribution, such as *G. gaudichaudii*, *L. atacamensis*, *L. nigromaculatus*, *L. platei*, *C. maculatus* and *P. chamissonis*, are found occupying a great variety of ecogeographic landscapes, vegetation formations and are present in several ASP (Moreno *et al.* 2000, 2002). In general, it is agreed that they are rather generalist species, and are distributed in various environments with wide altitudinal ranges (Mella 2017). At the other extreme, species with a more restricted geographical distribution, such as *L. andinus*, *L. nigrocoeruleus*, *L. zapallarensis* and *L. silvai*, are very rare (one or few localities), are found in one ecogeographic landscape, and/or in a vegetation formation, and may not even be represented in any ASP (like *L. nigrocoeruleus* and *L. andinus*) (Marambio-Alfaro & Hiriat-Lamas 2019). This could be explained by the ecological and genetic principles of evolutionary ecology. These have been satisfactorily captured by the theory of adaptive radiation (Shutler 2000; Losos & Ricklefs 2009). This theory indicates that the origin of ecological diversity is essentially due to divergent natural selection acting directly on phenotypic characters linked to ecological activities (Pincheira 2012). This may be a response to the conditions of the Atacama region and its high diversity and endemism of reptiles (Mella 2019). The lack of information on richness and abundance of flora and vegetation species in the Atacama means that the biological matrix provides few elements to the ecosystem and thus contributes to the restricted distribution of species in some cases (Sayre 2000). In general, both the protected areas and the priority sites have been determined by their richness in flora-vegetation and only on some occasions by the fauna biodiversity (Squeo *et al.* 2008). It is relevant to establish that the presence of species in areas with different categories of protection should be classified with different values, due to the presence of a species in a unit such as SNASPE versus AMCP or RNP (e.g., by the difference in the surface amplitudes of each unit or its abundance) (Cruz-Elizalde *et al.* 2018).

In the case of rare species in the records and that are not endemic to the region (e.g., *L. fuscus*, *L. nitidus* and *L. robertoi*), their scarcity of records in Atacama is explained by their marginal distribution in the Region or in extreme places of it. Another group of species with a low presence in ecogeographic landscapes and/or vegetation formations is the case of species with a limited altitudinal distribution (such as coastal species *M. atacamensis* and *L. zapallarensis*) and/or with its highest degree of specialization in intertidal environments (such *M. atacamensis*; Mella 2017; Marambio-Alfaro *et al.* 2021). Another explanatory factor of species with few records corresponds to those species recently described, such as *L. nigrocoeruleus* (Marambio-Alfaro and Troncoso-Palacios *et al.* 2014), which makes its auto-ecology somewhat uncertain. On the other hand, although at least four of the evaluated species present outliers when they are included in the ecogeographic landscapes (Table 1, Fig. 2), this is due to the fact that they have been recorded at the limit of the zones and this can lead to wrong conclusions. However, some of these outliers may represent novel evidence, such as the recent record of *C. maculatus* a 2,940 m a.s.l. (Mella & Jiménez 2022) representing the maximum known altitudinal, and which agrees with its eventual presence in the Andean biogeographic landscape (Table 1).

The results of this analysis, carried out on a more detailed scale, can be compared with other biogeographic studies, analyzed on a more general scale. Thus, Díaz & Lobo (2006) analyze the 83 species of *Liolaemus* of the subgenus chiliensis, and conclude that within this, the nigromaculatus group of the desert of northern Chile (Atacama and Coquimbo Regions, and which includes at least six of the species analyzed in this study) is a sister taxon of the alticolor group (Puna), located further north. On the other hand, Vidal *et al.* (2009), perform a biogeographic analysis of the richness and endemism of Chilean amphibians and reptiles, based on the division of the country into quadrants of 100 km x 100 km, those that partially agree with our analysis: using the non-metric MultiDimensional Scaling (nMDS), the species of the Atacama and Coquimbo Region are mostly associated in clade B, which includes 16 of the 22 species of reptiles registered in our study. In addition, using analysis of Parsimony of endemism (PAE, Vidal *et al.* 2009), they also group in clade D, 17 of the 22 species of the Atacama Region, so that this group forms a homogeneous unit, that is, the Atacama region itself, according to Vidal *et al.*, 2009 and this study would be a unit that concentrates a high degree of endemism. Finally, Vidal and Díaz-Páez (2012), analyzing biogeographic patterns

of reptiles in quadrants of 1° latitude x 1° longitude, show that most of the reptile richness is concentrated in the north-central zone of Chile, and our study area (Atacama) presents a medium richness, with between 6 to 10 species per quadrant.

In summary, this study is considered valuable for providing, summarizing and detailing a wide variety of backgrounds of the reptile species of the Atacama region, and contextualizing the records based on ecogeographic and vegetative zoning, in addition to its conservation implications, which should be replicated in other regions of the country, such as the Metropolitan region, as it is the unit with the second highest degree of endemism and there are no studies on the subject (Mella 2019). Thus, for example, from this analysis arises the need to prioritize the creation and expansion of a protected area, in order to include those species that are not currently in that condition, such as *L. andinus* and *L. nigrocoeruleus* (Ruiz de Gamboa 2016, 2020).

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