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HABITAT CHARACTERIZATION FOR THE CONSERVATION OF *Iberolacerta martinezricai* (ARRIBAS, 1996), THE MOST RESTRICTED MAINLAND EUROPEAN REPTILE SPECIES: NEW CENSUSES AND IMPROVED DISTRIBUTION MODELS (SQUAMATA: SAURIA: LACERTIDAE)

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Iberolacerta martinezricai, the Batuecan lizard, is the reptile species with the most restricted distribution in continental Europe, confined to a few rocky scree habitats in the Sierra de Francia, Spain. During the study period of 2018 (22 days of fieldwork from May to October), a total of 67 localities (30% more than in 2007 censuses) were surveyed. Of these places, 30 (44.77%) were positive for the presence of the species. The mean density of specimens per hectare was 41.44 (53.68 ind./ha, considering only the most favorable places), which gives a total estimation of 4140 specimens for the species (undoubtedly an overestimated value). The screes with presence of the species tend to be larger in surface, located at an higher average altitude (1300 – 1700 m), with a lower slope, greater average stone size, higher moisture and presence of lichens and mosses, and with a greater weight in the connectivity of the network of all the screes in the study area. A modeling analysis of the potential distribution of the species (156 potential sites) was performed. This model indicates the probable presence in 89 (57.05%) and very probable presence in 64 (71.91%) of the 89 remaining places. Of the 64 very probable places, 39 have been sampled in the 2018 census. Of those 39, the species was really present in 27 (69.23%), which would indicate a good fit for the model. The model has allowed the identification of 35 new scree sites where the presence of the species is very probable (25) or probable (10) to be sampled in future.

Keywords: Batuecan lizard; Sierra de Francia; censuses; density; microhabitat; potential distribution; modelling; metapopulations; connectivity; conservation.

INTRODUCTION

The genus *Iberolacerta* Arribas, 1999, is currently composed of eight lizard species from the northern Iberian Peninsula, the Pyrenees, the Eastern Alps, and the northern Dinaric mountains. The genus is particularly well represented on the Iberian Peninsula, where seven species are recognized using external morphology, osteology, karyotype, and genetics as discriminant criteria (Odierna et al., 1996; Arribas, 1997, 1999a, 1999b; Mayer and Arribas, 2003; Arribas and Odierna, 2004; Carranza et al., 2004; Crochet et al., 2004; Arribas and Carranza, 2004, 2007; Arribas et al., 2006; Arnold et al., 2007). The genus seems to be adapted to, and now cornered in the main mountain ranges of the northern and central regions of the Iberian Peninsula, even though there are populations of *I. monticola* (the most eurytopic species as is also less strictly saxicolous) inhabiting similar shady and fresh places at sea level on the coast of Galicia and Asturias (NW Spain) up to more than 2000 m.

All the species use similar habitat types, the specific characteristics of which vary somewhat between sites, mainly regarding the composition of the vegetation and bioclimatic characteristics. Most areas of these lizards' mountainous habitats are formed by bedrock, which, after alteration due to geological and climatic processes, produced landslides of rock boulders (screes, in spanish named "canchal").

Iberolacerta martinezricai (Arribas, 1996), the lizard of the Peña de Francia, also called Batuecan lizard in ref-

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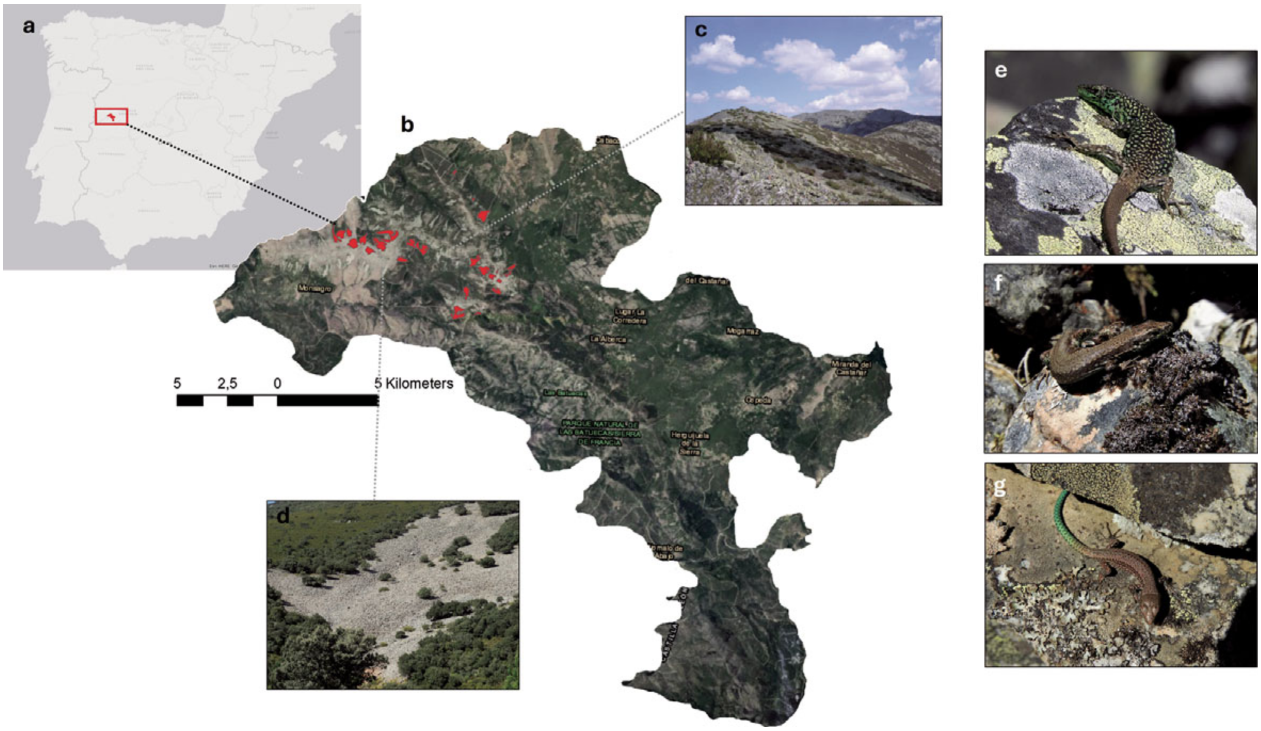

Fig. 1. *a*, Location of the distribution area of *Iberolacerta martinezricai* within the Iberian Peninsula; *b*, natural park of Las Batuecas-Sierra de Francia; *c*, view of Sierra de la Peña de Francia; *d*, typical scree in the Sierra de Francia; *e*, male; *f*, female; *g*, juvenile. Photos by D. Lizana.

erence to the Batuecas valley, is a medium-sized lizard with dark dorsal coloration, fairly variable, as old males can be green, grayish, or bluish ground toned (Fig. 1), with reticulated sides that not infrequently extend to all the dorsal tract. Females are usually duller, generally brown or grayish with a dorsal row of small black dots or two fine juxtaposed lines. Most specimens show between one and three brilliant-blue axillar ocelli; these are more numerous (up to eight) in adult males, and less numerous and small in females, being yellowish in juveniles (Arribas et al., 2008).

This species is endemic to this small mountain massif of Central Spain and is the only lizard species endemic to the region of Castile and León (Fig. 1). Initially, the presence of the species was considered restricted to the summit of the Peña de Francia mountain (between 1600 – 1723 m a.s.l.; Pérez-Mellado, 1982, 1983; Arribas, 1996), its reduced range being the consequence of unsuitable habitat in the surrounding low altitude areas. The overall bioclimatic characteristics of the species habitat are excepcional (nearly extreme) for the *Iberolacerta* usual requirements.

The most optimistic estimates of its abundance, not systematic and calculated extrapolating the observations in the summit of the mountain, were around 45 specimens/ha, with only five to six hectares of adequate habitat available, consisting of bedrock, rock boulders interspersed with grass and broom vegetation (Arribas, 1999a).

Subsequent surveys (Arribas, 2004) revealed the presence of *I. martinezricai* in the nearby Puerto del Portillo slopes (La Alberca, Salamanca), at 1000 – 1400 m, where dense but localized populations were recorded in typically Mediterranean environments (Supramediterranean and Mesomediterranean vegetation belt areas with evergreen oak forest). Additional sightings were made in the nearby Pico de la Hastiala Mountain (1735 m) and on the northern slopes of the Sierra de las Mestas ridge. Thus, the known area occupied by the species covered only two 10 × 10 km UTM grids (29TQE48; 29TQE38) of discontinuous habitat. Accordingly, an estimate of the complete distribution area was only 12 – 15 km^2 (Arribas, 2004).

In 2007 – 2008 a new study found specimens in new localities belonging to the 10 × 10 km UTM 29TQE39 grid, thus increasing their distribution area to 21 UTM 1 × 1 km squares, resulting in approximately a total of 20 km^2 of extremely reduced discontinuous habitat within the limits of the Batuecas-Sierra de Francia Natural Park (Carbonero et al., 2016). The Batuecan lizard is only distributed in three 10 × 10 km UTM grids, which are: 29TQE38, 29TQE48, and 29TQE39 (the latter was provided as new in Carbonero et al., 2016). A total population of less than 1500 adult specimens was estimated, spread in highly small and localized populations.

Carbonero et al. (2016) characterized its optimal habitat, which seems to consist in slopes located between groves of the Oro, Supra, and to a lesser extent Mesomediterranean vegetation belts, with a certain presence of water and a preference for orientations other than the South, where it is locally abundant. Its presence is more anecdotal on peaks and ridges of the Oromediterranean belt.

The observations of *I. martinezricai* featured a marked Mediterranean character (Arribas, 2004), in contrast to those of other species of *Iberolacerta* found in nearby mountain ranges, such as *Iberolacerta cyreni* (Müller and Hellmich, 1937), which live in high or very high mountain environments (Oro- and Crioromediterranean bioclimatic zones) in the Spanish Central system (mainly in the Sierras de Guadarrama, Gredos and Béjar) (Pérez-Mellado, 1982; Lizana et al., 1991; Arribas, 2010).

Currently, the situation is that *Iberolacerta martinezricai* (Arribas, 1996) is the more restricted and probably the rarest and threatened reptile species in continental Europe. Conversely, is probably the unique mainland European reptile with so fairly accurate estimation of their total species population and area. The previous census for the species confirmed that its distribution area is very small (12 – 15 km^2) inside three 10 × 10 km UTM grid squares (29TQE48; 29TQE38; 29TQE39), with a total occupied area between 20 – 25 km^2 and total estimation of 1200 to 1500 specimens (Carbonero et al., 2016).

The lizard is nowadays considered an endemic of the Sierra de Francia. It is located on the summit of the Peña de Francia (1600 – 1723 m). It is also present in the nearby peak of Hastiala and has also appeared in populations located in the Puerto del Portillo area (La Alberca, Salamanca), between 1400 and 1000 m, descending to at least 840 m in the Batuecas valley. On the other hand, it is also present on the north face of the Sierra de las Mestas (whose culminating point, the Rongiero peak, reaches 1627 m at its summit), at least 800 to 1400 m, from the Pico de Los Robledos area, and the San José Desert (a denomination for an inhabited place) towards the Collado de Valleverde and further west. Very probably it also can inhabit the southern slope, already belonging to the Extremadura Community. Thus, the known area is included in a polygon formed by the Peña de Francia – Hastiala – Rongiero and Peña Orconera. Life history parameters as phenology, molts, thermoregulation, activity, distribution, habitat selection, and other aspects of population dynamics as density or sex-ratio can be found in Arribas (2013). Growth, allometry, sex-dimorphism, maximum longevity, and estimation of predation pressure, in Arribas (2014a). Reproductive biology has been studied by Arribas (2018).

The lizard is considered critically endangered since 2008 (CR b2ab[v]; c2a[ii]) in the IUCN red list (Carbonero et al., 2016; Pérez-Mellado et al., 2009b), due to its reduced distribution, the number of specimens, human influence in part of its vital area and the presumed sensitivity to changes in the microhabitat (fires, climate change and predatory and competing species). The first steps towards a targeted conservation strategy for *I. martinezricai* had to include the assessment of its ecological requirements, mainly concerning its habitat (Primack, 2008); as well as a new estimation of the species numbers, as is done in the present paper.

This study aims to actualize the available data with a new survey ten years after the last one (2007 – 2018). A recent study relating the connectivity with the presence, but not the density of the species, is published in Lizana-Ciudad et al. (2021).

MATERIAL AND METHODS

Period of study. During the year 2018, a total of 22 days of fieldwork have been carried out, from May to October, trying to carry out at least one weekly sampling, except in September and October, which were done only to take data from the dates of the end of autumn activity of the species and population densities based on transects. In 2018, the 43 localities sampled in 2007 (corresponding to summits and hillside places) were visited, as well as another 24 new localities, up to a total of 67 localities sampled in the Sierra de Francia.

Study area. The study has focused mainly on the mountainous areas around the Batuecas-Sierra de Francia Natural Park, where the localized populations of the Batuecan lizard are framed (Arribas, 2005, 2014; Carbonero et al., 2007, 2016) (Fig. 1). Among the existing montane systems in this environment, it is worth highlighting the Sierra de la Peña de Francia whose highest point is Cerro Rongiero (1627 m).

Habitat. The distribution of *I. martinezricai* is framed in the Meso and Supra-Mediterranean bioclimatic belts, reaching the Oromediterranean belt in the peaks of the Sierra de Francia, that is, in La Hastiala and La Peña de Francia. This means that their main area of distribution is between 840 and 1723 m, although our data reveal that they mainly occupy medium and high altitudes, above 1300 m.

The large screes that are found on the Mesomediterranean belt have surrounding arboreal vegetation composed mainly of holm oaks (*Quercus ilex*) and cork oaks (*Quercus suber*). On the Supra-Mediterranean belt the screes are located between groves of rebollo oak or melojo (*Quercus pyrenaica*) and plantations of scots pine (*Pinus sylvestris*). The Oromediterranean belt only appears on the peaks of the mountains and it is known as the “broom belt” where heathers and brooms are mainly observed. In all these areas, the climate is markedly Mediterranean, with very high summer temperatures (Arribas and Carranza, 2004), a priori little or not at all appropriate for the presence of an *Iberolacerta*.

Survey methodology. In the study carried out in 2018 the main objective was the monitoring of the populations located in 2007, considering the possible changes that have occurred in a decade, according to the monitoring plan of the species of the management plan of the Red Natura 2000. Numerous new places have been sampled that had not been previously accessed in 2007.

The characterization of the habitat and microhabitat of the Batuecan lizard has been quite accurate, based both on the 2007 study (Carbonero et al., 2008, 2016) and carried out with multivariate statistical analyses (Carbonero et al., 2016), that has allowed us to know where the species could be found with great accuracy (based on parameters such as rocks size, moisture, altitude, and orientation).

The objectives and action plan in the 2018 survey were:

1) to check the presence or absence of specimens from the 43 screes sampled in 2007 (see Table 1 in Carbonero et al., 2016);

2) to determine the density, abundance, and demographic structure of each of the localized populations;

3) to map at least the 43 screes sampled in 2007.

4) to carry out a comparative analysis with the data obtained in 2007 and assess the evolution of the populations.

Type of samplings. The sampling method was different between the 2007 and the 2018 studies due to differences in the fundamental objectives of each of the studies and the already known distribution data. Comparability for presence/absence purposes is, however, appropriate. The objectives of the study in 2018 maximize knowing the geographical distribution of the species, the densities, and the number of specimens of the populations. Therefore, only linear transects were carried out in 2018, generally around 100 m in length, instead of the plots used in 2007 and the observation with binoculars, since these methods require much more sampling time.

Line transects are a fast and easily repeatable method on different dates or by other teams of researchers in the future, only by providing the exact location. The assumptions of the linear transect are simple and clear: do not stop observing the specimens that are in the zone of the advance of the transect (Krebs, 1999; Magurran, 2003; Sutherland, 2006). The densities were obtained in 2018 using the “DISTANCE 6.0” program with a bandwidth of 300 cm. The distances of the specimens to the transect line were obtained perpendicular to it with a Bosch DLE50 Prof laser distance meter. The linear transect method has generally provided slightly higher densities than the plot method used in 2007. We believe that the transect method is more recommendable for a rapid follow-up (monitoring) of the situation and evolution of the species, both for the current study and for future repetitions of the same.

Modeling of the potential distribution of *I. martinezricai*. From the information obtained in the field samplings, several potential distribution modeling, connectivity analysis, and a series of statistical analyses were carried out to characterize some of the ecological requirements that explain both the presence and the densities showed by *I. martinezricai* in each scree. This modeling shows the potential distribution of the species that constitutes the basis for future fieldwork in the area, the identification of new areas for the species where its presence is probable, but due to its number and access difficulties, a total and real sampling is impossible. In addition, a more realistic estimate of the total population of the species can be made from the potential distribution (although is potential, because it has not been empirically verified in the field). MAXENT version 3.4.1 (http://www.cs.princeton.edu/schapire/maxent) has been used for modeling the potential distribution of the Batuecan lizard. MAXENT enables the modeling of species niches and distributions by applying a machine learning technique called maximum entropy modeling. From a set of environmental variables in grid format (for example, climatic) and georeferenced locations of occurrence, the model expresses a probability distribution that shows the level of suitability that each grid presents for the species based on its ecological requirements (Phillips et al., 2006). In the modeling, the recommended default values were used. The maximum number of iterations was 500. The program automatically selects the appropriate regularization values to reduce the overfitting of the models. The selection of environmental variables for modeling the potential distribution is based on those already identified as important for the species in the study by Carbonero et al. (2016). See statistical modeling of the presence and density of *I. martinezricai* below for more data on the results of this modeling analysis.

Variables used for modeling the ecological niche. Land use: The Spanish Land Occupation Information

System (SIOSE) has been used as a basis. Developed by the National Geographic Institute, it is the land occupation database for all of Spain with a greater degree of detail. Its reference scale is 1:25,000 and it integrates the information available from the Autonomous Communities and the General State Administration. The tiles shown in SIOSE in some cases have been re-mapped for this study.

Altitude. It has been obtained from a digital model of the terrain with a resolution of 5 m, developed by the Spanish National Geographic Institute through interpolation from the terrain class of LIDAR (Light Detection and Ranging of Laser Imaging Detection and Ranging) flights of the Spanish National Map.

Slope. From the same IGN DTM (Digital Terrain Model of the Spanish National Geographic Institute), the mean slopes for each pixel have been obtained using the ArcGIS 10.5 "slope" tool.

Orientation. From the 5-meter resolution DTM using the ArcGis 10.5 "aspect" tool, nine orientations have been defined for the slopes where the screes are located: North, South, East, West, Northeast, Northwest, Southeast, Southwest, and flat (no slope).

Relative moisture. Although climatic data are usually fundamental when configuring spatial distributions, for a species like *I. martinezricai* that lives in such a specific and reduced habitat, it is not possible to use climatic variables on a regional or national scale (type Bioclim, for example). Not even data from nearby moteorologic stations is of interest. However, as already pointed out in Carbonero et al. (2015), the microclimatic characteristics of the screes are essential to understand the factors that influence the presence and density of the species. It seems that the species positively selects those screes in which there is higher moisture, sometimes with underground running water. For this reason, the Topographic Wetness Index (TWI) has been used, which describes the tendency of a "cell" to accumulate surface water (Quinn et al., 1995).

Regarding the distribution of the species, the central point of those transects that yielded a positive result has been used. Other points where Batuecan lizards were found outside the transects have also been included.

The probability of presence for each pixel has been converted into presence/absence maps for the species using two different thresholds, called "Minimum" (we will call them "scree with probable presence") and "10 percentile" ("scree with very probable presence"); that is, we have used two criteria with which to estimate the probability of presence. The difference between these thresholds is that while the first takes a value that gathers all the pixels that are above the minimum value that the model has given for the presence points (it will vary for each species); what the "10 percentile" does is leave out the 10% of the presence points for which the model gives a minimum value. Therefore, the "10 percentile" will define more restricted potential distributions.

Comments about the results of the modeling analysis and the analysis of connectivity for the habitat of *I. martinezricai*, not included here, have been published in Lizana-Ciudad (2021).

RESULTS

During the 2018 samplings, the species was found in 31 1 × 1 km UTM squares and it was absent in 21. In the previous census, in 2007, a total of 43 screes were surveyed, of which 19 were positive for the Batuecan lizard (in addition to 2 possible, that did not appear in the report, since the lizard could not be identified with certainty, although it was probably *Iberolacerta martinezricai*). During these previous samplings, a total of 82 specimens of *I. martinezricai* were observed.

In the 2018 samplings, a total of 67 screes were visited (almost 30% more than in the previous study), including all those from 2007. The total number of specimens observed in 2018 is 154 including adults, subadults,

TABLE 1. Distribution of the Specimens Detected During the Samplings in the Various Months Expressed by Age Classes and Maximum Temperatures Reached

Month	Day	Adults	Subadults	Juveniles	Total	Temperature, °C
May	22	20	9	0	29	19.8
	31	0	0	0	0	13.4
June	13	16	4	2	22	26.1
	14	7	3	2	12	31.2
	20	3	2	4	9	29.3
	21	3	1	1	5	30.5
	28	7	2	0	9	34.7
	29	5	5	0	10	24.6
July	4	7	0	2	9	29.4
	12	4	1	0	5	25.1
	13	4	1	0	5	27.8
	18	0	0	0	0	29.2
	19	2	0	1	3	31.3
August	8	2	2	0	4	27.0
	9	1	0	0	1	29.3
	15	0	0	0	0	35.2
	23	1	0	1	2	30.7
	24	7	1	0	8	30.8
	29	2	0	1	3	39.1
	30	5	1	2	8	27.5
September	12	5	1	3	9	37.4
October	24	0	0	1	1	27.4
Total		101	33	20	154	

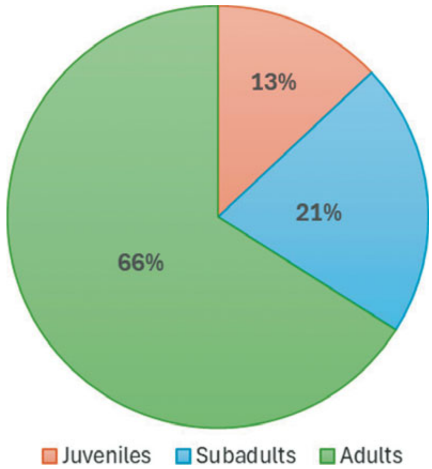

Fig. 2. Pie chart of the age of specimens surveyed.

and juveniles (Table 1; Fig. 2), practically double that in the 2007 study.

There is no significant relationship between the number of specimens observed and the maximum temperature during the samplings (Fig. 3). By sampling the locations in different months, GMT hours, at very different altitudes, orientations, and other biotic and abiotic characteristics of the environment, we mask the logical correlation between temperature and activity of the lizards, being able to indicate that temperatures around 25 degrees are the more appropriate to detect the Batuecan lizard. In general, the specimens are detected when the temperature is not very high (around 22 – 25°C) and in the early hours of the morning. As summer progresses, the activity becomes bimodal, being lizards active in the first and the last hours of the daylight, with a period of inactivity towards noon, in the hottest hours.

Sampled areas. Figure 4 and Table 2 show the screes numbered according to the denomination elaborated in 2018 and a summary of all the data obtained in the 2018 samplings. The localities (screes) have been identified with numbers. The coordinate and average altitude of the scree, its surface, and estimated number of specimens of *I. martinezricai* are indicated (Table 2).

Comparison of 2007 and 2018 results. In the first census (2007), a total of 45 screes were visited, of which 21 were positive (46.66%). During these samplings a total of 82 specimens of *I. martinezricai* were observed.

In the 2018 samplings, a total of 67 localities corresponding to different screes were prospected (almost 30% more than in the previous study). Of these screes, 30 (44.77%) have been positive and 37 negative (55.22%) for the presence of the species. Figure 5 shows a three-dimensional map in which can be seen the positive and negative screes depending on their orientation and altitude, and Figure 6 the 1 × 1 km UTM positive (blue) and negative (red) grids for *I. martinezricai*. The percentage of positive and negative localities is therefore very simi-

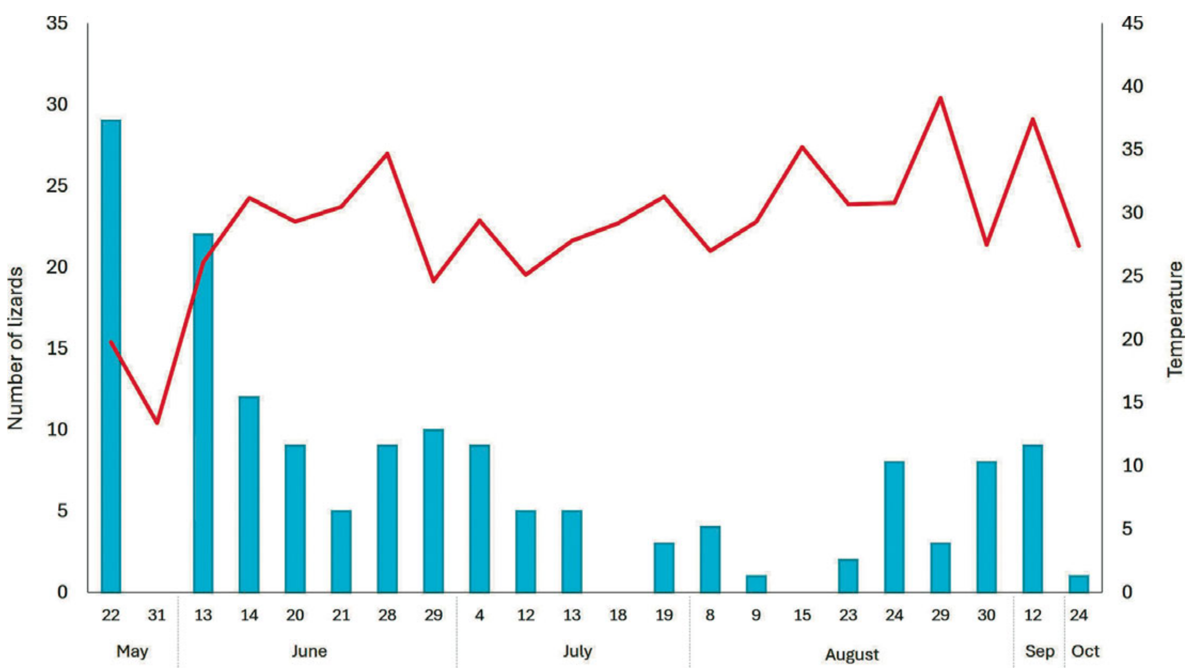

Fig. 3. Relationship between the number of specimens observed and the maximum temperature during the samplings.

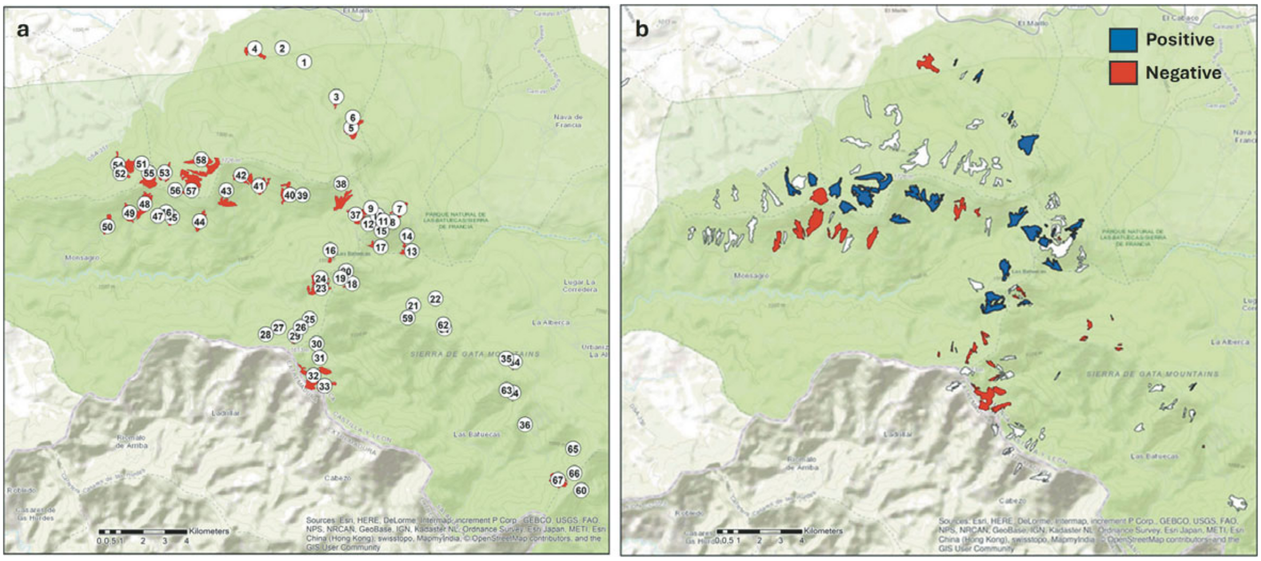

Fig. 4. *a*, Places sampled during the 2018 study. Numbering in Table 2; *b*, positive (blue) and negative (red) presence in of *I. martinezricai*.

lar, despite having notably increased the number of sampled localities. This means that a good part of the scree prospects in the Sierra de Francia do not have the appropriate conditions for the species and would reflect that we are probably facing a natural process of local extinctions due to global warming since the Pleistocene. The Batuecan lizard is the unique *Iberolacerta* that lives in Mediterranean conditions and in mountains with a relatively low top (maximum altitude).

The total number of specimens observed in 2018 was 154, including adults, sub-adults and juveniles, practically double that of the 2007 study. It should be noted that the Portillo 1, 2, and 3 sites have shown negative results in 2018, while Portillo 1 was positive in 2007. There are several possible explanations for this fact: a) that the population of Portillo 1, a scree with a very small surface area, had disappeared since it is a peripheral population with a greater probability of extinction; b) that the environmental conditions of the sampling in 2018 were not appropiated and therefore it had not been detected in it. We are inclined towards this second possibility, since only one sampling was done in 2018. Access to the

TABLE 2. Sampled Localities, Positive and Negative in the 2007 and 2018 Samplings*

Scree ID	Name	UTM *X*	UTM *Y*	Altitude, m	Area, ha	Presence 2007	Presence 2018	Density 2018, ind/ha
1	Maillo 1	229566	4494003	1178	2.36	—	1	20.86
2	Maillo 2	228962	4494399	1200	0.50	—	1	21.4
3	Maillo 3	230389	4492868	1280	1.54	—	1	36.18
4	Maillo 4	228211	4494390	1200	11.73	—	0	
5	Robledo 1	230810	4492169	1311	15.71	1	1	30.08
6	Robledo 2	230829	4492471	1289	0.58	0	0	
7	Fuente Paterno	232019	4489868	1446	6.99	1	1	93.91
8	Viacrucis	231822	4489595	1582	1.44	1	1	
9	Fuente Buitrera	231235	4489960	1559	0.31	1	1	73.92
10	Peña de Francia 1	231416	4489756	1672	1.01	1	1	53.36
11	Peña de Francia 2	231575	4489603	1664	0.50	0	1	51.51
12	Peña de Francia 3	231175	4489532	1610	5.18	1	1	35.95
13	Peña de Francia 4	230576	44937016	1321	4.71	0	0	
14	Peña de Francia 5	231043	44939794	1340	0.14	0	0	
15	Monasterio	231501	4489337	1621	2.48	1	1	
16	Lobos 1	230084	4488854	1365	8.49	1	1	7.9

TABLE 2 (continued)

Scree ID	Name	UTM *X*	UTM *Y*	Altitude, m	Area, ha	Presence 2007	Presence 2018	Density 2018, ind/ha
17	Sur Peña 1	231389	4488903	1370	6.66	—	1	
18	Sur Peña 2	230578	4487926	1403	2.36	—	1	75.01
19	Sur Peña 3	230347	4488091	1497	0.81	—	0	
20	Sur Peña 4	230494	4488237	1510	1.93	—	0	
21	Sur Peña 5	232303	4487279	1272	1.95	—	0	
22	Sur Peña 6	232913	4487431	1192	0.31	—	0	
23	Lobos Sur 1	229710	4487835	1375	11.09	—	1	39.9
24	Lobos Sur 2	229740	4488105	1509	7.65	—	1	10.67
25	Rongiero 1	229479	4487031	1267	3.16	0	0	
26	Rongiero 2	229197	4486767	1297	2.11	0	0	
27	Rongiero 3	228594	4486802	1284	0.61	1	0	
28	Rongiero 4	228229	4486631	1337	0.54	0	0	
29	Rongiero 5	229032	4486552	1397	2.12	—	0	
30	Valle Batuecas 1	229623	4486325	1331	1.77	—	0	
31	Valle Batuecas 2	229690	4485943	1280	1.48	—	0	
32	Valle Batuecas 3	229512	4485462	1350	21.96	—	0	
33	Valle Batuecas 4	229835	4485164	1289	5.38	—	0	
34	Mirador Portillo 1	235021	4485515	1273	0.42	—	1	7.19
35	Mirador Portillo 2	234790	4485735	1298	0.17	—	0	
36	Bajada Batuecas	235244	4483915	894	0.24	—	0	
37	Monsagro 1	230851	4489800	1410	12.69	1	1	91.7
38	Monsagro 2	230451	4490204	1300	11.48	1	1	43.63
39	Monsagro 3	229406	4490381	1369	1.51	1	0	
40	Monsagro 4	228923	4490501	1327	8.29	0	0	
41	Monsagro 5	228193	4490739	1299	13.38	0	1	49.34
42	Monsagro 5B	227713	4490963	1417	8.17	—	1	9.43
43	Monsagro 6	227293	4490261	1384	6.87	1	1	10.98
44	Monsagro 7	226553	4489801	1321	7.82	0	0	
45	Monsagro 8	225786	4489906	1226	4.69	0	0	
46	Monsagro 9	225626	4490042	1246	3.66	0	0	
47	Monsagro 10	225399	4489968	1175	0.89	0	0	
48	Monsagro 11	225042	4490303	1269	17.07	0	0	
49	Monsagro 12	224601	4490074	1196	8.02	0	0	
50	Monsagro 13	224010	4489792	1138	6.43	0	0	
51	Copero 1	225006	4491412	1352	5.72	1	1	57.52
52	Copero 2	224418	4491266	1305	7.98	1	1	99.39
53	Copero	225626	4491126	1391	8.97	1	1	27.96
54	Copero 3	224650	4491361	1342	9.42	—	1	63.54
55	Copero-Hastiala 1	225192	4490955	1519	13.30	1	1	49.58
56	Copero-Hastiala 2	225890	4490646	1541	7.62	1	1	20.22
57	Hastiala 1	226350	4490915	1436	17.31	1	1	6.61
58	Hastiala 2	226738	4491305	1536	21.41	1	1	31.05
59	Leras 1	232134	4486913	1466	1.34	0	0	
60	Herguijuela 1	236719	4482077	1126	1.23	0	0	
61	Peña Carbonera 1	233061	4486606	1476	0.97	0	0	
62	Peña Carbonera 2	233103	4486716	1429	0.32	0	0	
63	Batuecas 1	234966	4484792	1137	2.46	0	0	
64	Batuecas 2	234771	4484830	1133	0.88	0	0	
65	Portillo 1	236537	4483229	1053	1.51	1	0	
66	Portillo 2	236545	4482547	1172	3.10	0	0	
67	Portillo 3	236108	4482381	1019	10.68	0	0	

* Density values and potential number of specimens estimated in the localities.

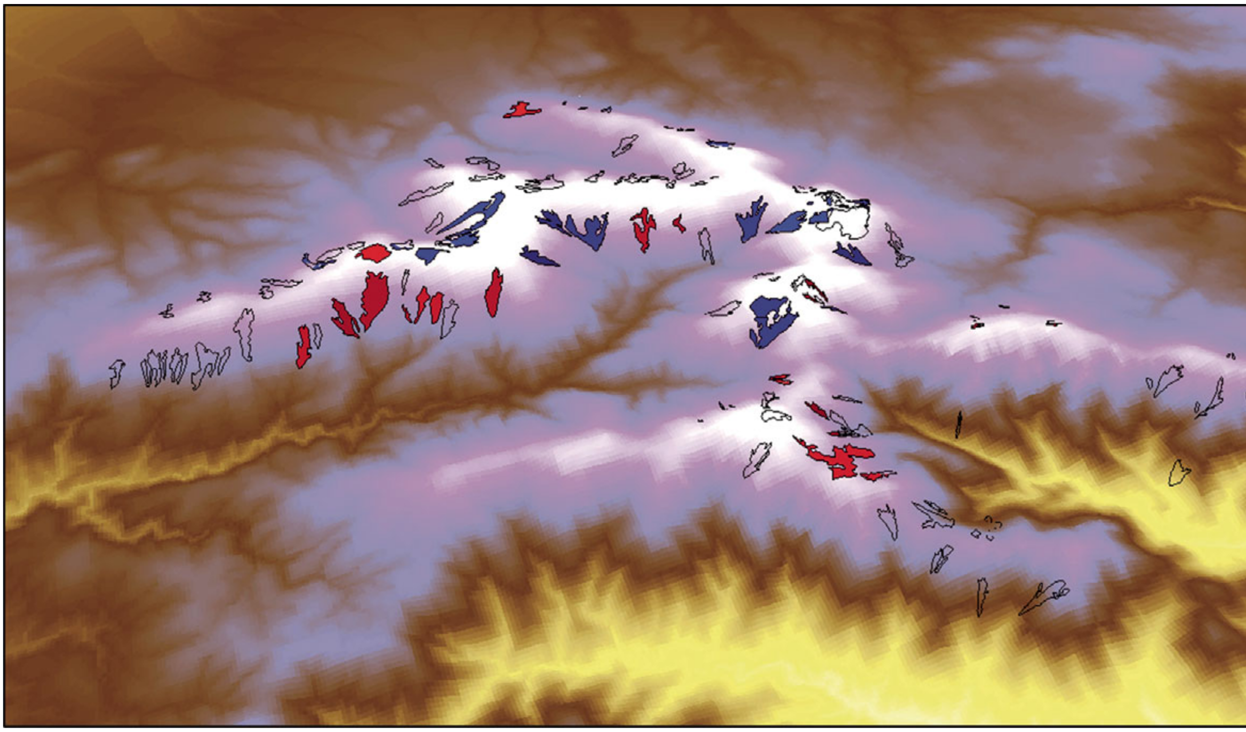

Fig. 5. 3D map in which can be seen the positive and negative screes depending on their orientation and altitude.

Portillo places is difficult and the forest track is normally closed, which makes sampling difficult. Only future prospects in good climatic conditions will allow us to know the situation of this population.

Two localities that were negative in 2007 (Peña de Francia 2 and Monsagro 5) result positive in 2018, while three that were positive in 2007 (Rongiero 3, Monsagro 3, and Portillo 1) have been negative in 2018. This indicates overall stability in the results regarding the presence or absence of the species in the screes, but with some exceptions. The changes are probably due to the low density in these screes and/or the bad weather conditions at the time of sampling that did not allow the species to be detected.

Estimated densities. The total number of specimens observed in 2018 was 154, including adults, sub-adults, and juveniles, practically double that in the 2007 study. It should be noted that Portillo's 1, 2, and 3 screes have shown negative results in 2018, while Portillo 1 was positive in 2007.

The most significant localities due to the higher estimated density (above 20 ind./ha) and the total number of specimens they contain, are shown in the Table 3. The mean density per hectare is 41.44 (calculated only from the set of positive scree for the species). If these results are analyzed in detail, the most important screes for the species are those of medium and large surface, which corroborates the postulates of conservation biology regarding the processes of threat and local extinction in isolated and small localities. Likewise, the most important

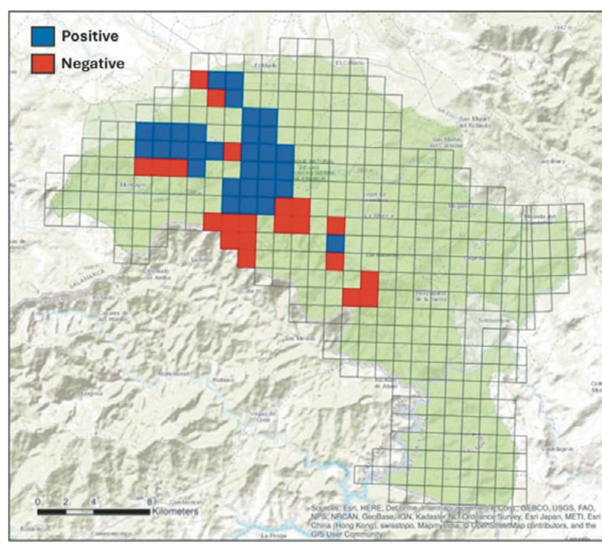

Fig. 6. 1 × 1 km UTM positive (blue) and negative (red) grids for *I. martinezricai*.

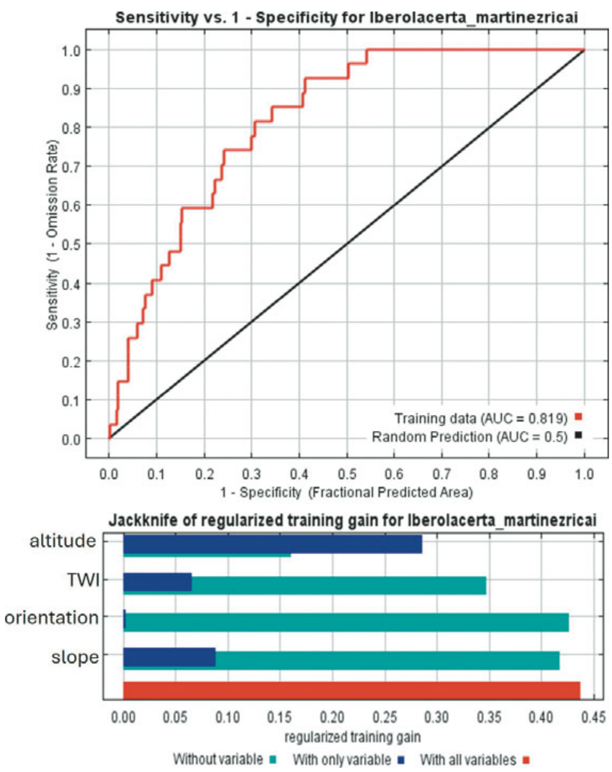

Fig. 7. *a*, area under the curve AUC) for *I. martinezricai* model; *b*, explanatory variables that control the potential distribution of *I. martinezricai* (mainly altitude and to a lesser extent the slope and TWI).

places for the conservation of the species are those located in the highest areas of the sierra, between 1300 and 1700 m of average altitude. The average density of specimens for the set of these screes is 53.68 ind./ha.

Potential distribution model of *I. martinezricai*. In the potential distribution model calculated for *I. martinezricai*, a reduced number of explanatory variables (altitude, orientation, TWI, slope) were used since only these were available for all mapped sites, regardless of whether they were sampled or not. This represents a notable limitation of the models, especially if it is considered that some microhabitat variables such as moisture, the average size of the rocks, or the proportion of moss cover/lichens are important variables in the distribution and abundance of the lizards. For this reason, the Area Under the Curve (AUC) is 0.819, which represents a mean value compared to the results obtained in other potential distribution models for other species (Fig. 7*a*). Regarding the explanatory variables, the potential distribution of *I. martinezricai* is controlled mainly by altitude and to a lesser extent the slope and TWI (Fig. 7*b*).

Figure 8 shows the relationship between the presence of the species and the altitude and the slope of each scree. The probability increases with altitude, being practically zero at 800 m and increasing to the highest areas of the sierra (as long as it finds the appropriate habitat, as will be seen later) (Fig. 8a). Regarding the slope (Fig. 8b), it seems that the species selects average slopes, around 20%. This could be related to the average rock size, a parameter that is related to the presence of the species (Carbonero et al., 2015). In percentages of slope greater than 20%, the average rock size will likely be smaller since the larger rocks would tend to roll or move by gravity. The orientation of the screes (and consequently, the degree of insolation or sun exposition) was expected to be an important variable in the model, but the results have not been conclusive. Tests have been made to in-

TABLE 3. Most Significant Localities with the Estimated Density of Specimens and the Total Number of Specimens Estimated

Scree ID	Name	Altitude, m	Area, ha	Density 2018, ind/ha	Estimated number of individuals
7	Fuente Paterno	1446	6.99	93.91	656.4
9	Fuente Buitrera	1559	0.31	73.92	23.2
10	Peña de Francia 1	1672	1.01	53.36	53.8
12	Peña de Francia 3	1610	5.18	35.95	186.2
18	Sur Peña 2	1403	2.36	75.01	177.0
23	Lobos Sur 1	1375	11.09	39.90	442.5
37	Monsagro 1	1410	12.69	91.70	1164.0
38	Monsagro 2	1300	11.48	43.63	500.8
41	Monsagro 5	1299	13.38	49.34	660.1
51	Copero 1	1352	5.72	57.52	329.2
52	Copero 2	1305	7.98	99.39	793.2
53	Copero	1391	8.97	27.96	250.8
54	Copero 3	1342	9.42	63.54	598.3
55	Copero-Hastiala 1	1519	13.30	49.58	659.4
56	Copero-Hastiala 2	1541	7.62	20.22	154.1
58	Hastiala 2	1536	21.41	31.05	664.8

clude it by dividing it into 2, 4, and 8 predominant directions, but we did not detect a clear pattern with this type of analysis. Moisture in the screes is an important explanatory factor for the presence of the species (Carbonero et al., 2015). It seems that the TWI is unable to represent numerically the moisture present in a given scree. Factors on the shape of the base of the scree itself (concave or convex), its depth, etc., contribute to explain the degree of moisture present in the scree and not the TWI itself, that is not able to collect them well. Future studies will look for other indices or other data sources (remote sensing, analysis of the surrounding vegetation, etc.) to obtain more precise quantitative estimators of the moisture present.

As result of the potential distribution model for *I. martinezricai* with MAXENT we obtain the probability of the presence of the species in each scree (Fig. 9).

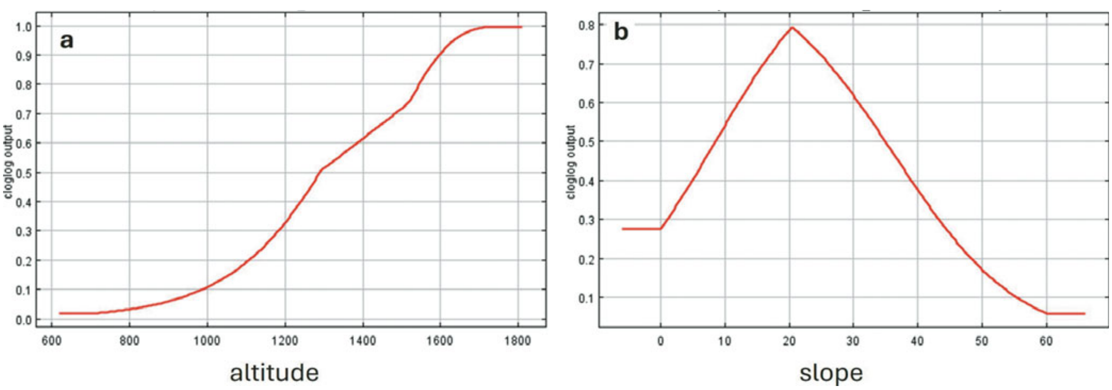

Fig. 8. Relationship between the presence of *I. martinezricai* and altitude (*a*) and slope (*b*).

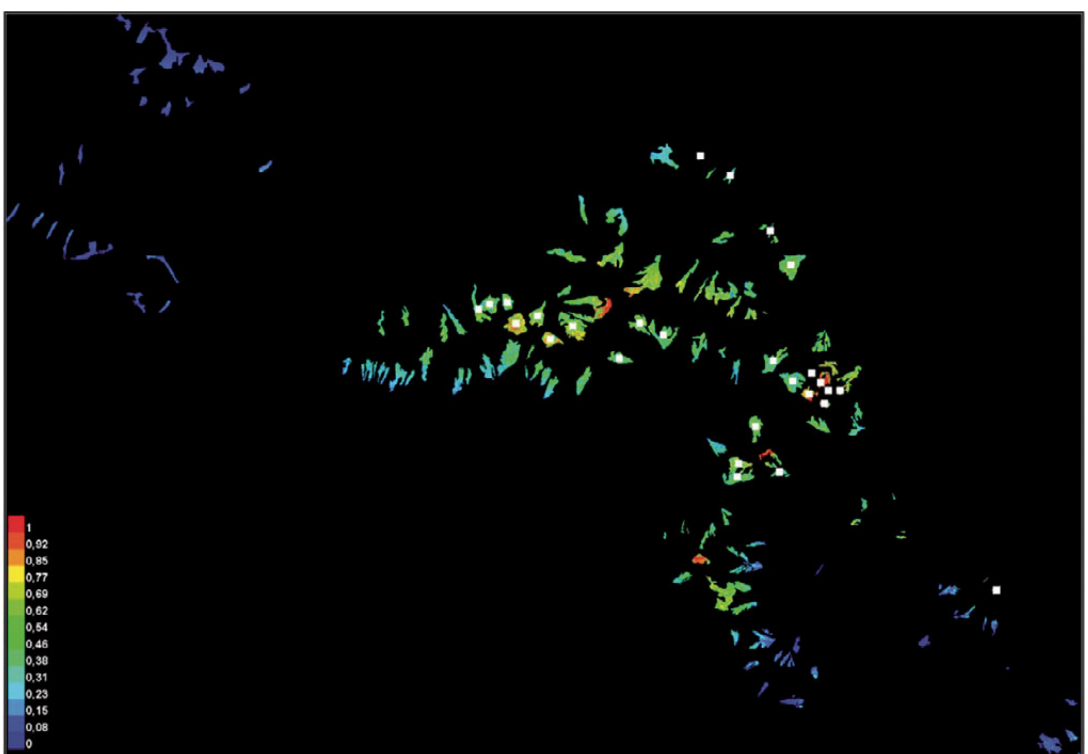

Fig. 9. The color scale represents the probability of the presence of the species in each scree. Ranges from blue (very low probability of occurrence) to red (high probability).

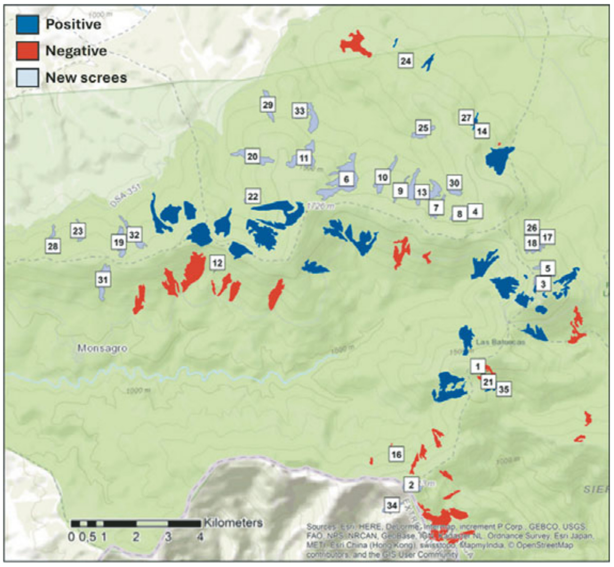

Fig. 10. Unsampled places that should be prospected in the near future with priority depending on the probability of finding *I. martinezricai* derived from our model (in light blue; see the text).

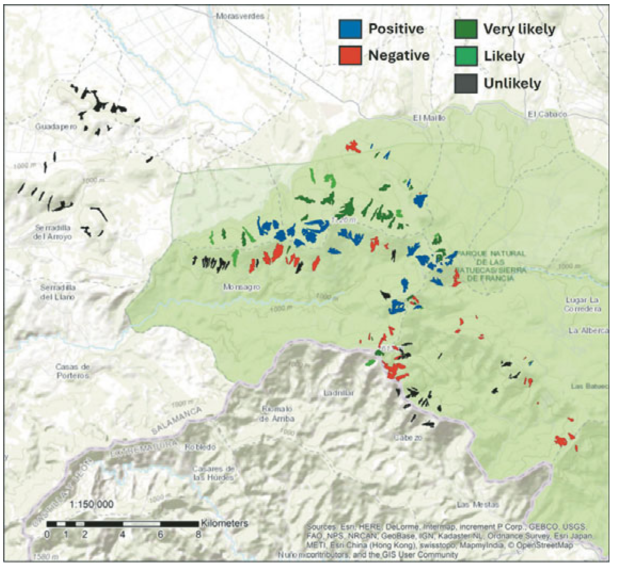

Fig. 11. Screes and their probability to hold *I. martinezricai* populations.

The model shows an high probability of the presence of the species for the screes that are at higher altitudes and that occupy a central place within the area of presence for the species. The peripheral screes, at a lower altitude, present a very low probability. According to the results, the predominant orientation of the scree seems to have a limited weight in the presence of the species.

If we follow the thresholds defined in the methodology to transform the probability map into a presence/absence map, we will have two potential distributions for the species. The potential distribution that uses the "minimum" value (probable presence) as a threshold, will be broader than using a more restricted threshold such as the "10 percentile" (very probable presence).

Of 156 potential sites, the model indicates the probable presence in 89 (57.05%) and very probable presence in 64 (71.91%) of the 89.

Of the 64 highly probable sites, 39 have been sampled in the 2018 census. Of those 39, the species was present in 27 (69.23%), which would indicate a good fit for the model. The model has served to identify 35 new screes where the presence of the species is very probable (25) or probable (10). Figure 10 shows these 35 places not sampled to date. These localities should be surveyed when possible in the next census since the model indicates that they could have Batuecan lizard populations. Without this information, it is impossible to have a clear idea of the real distribution, connectivity of the populations, and the estimated number of specimens of the species, which will allow it to be better categorized between CR and EN, according to IUCN criteria.

As a summary of all the information discussed, in Fig. 11 we can see the positive and negative sites in the 2018 samplings for the Batuecan lizard. The rest of the sites not sampled but mapped are also included. These places are grouped into three categories according to the probability of presence for the species: very probable, probable, and unlikely. The very probable ones are close to the positive ones, at an altitude similar to these. If they have not been sampled until now (2007 and 2018) it has been because they do not have easy access by roads or tracks and must be sampled by walking, as well as due to the temporal and economic limitations during the sampling of the year 2018.

The probable sites are a little further away from the "core" distribution of the lizard in the Sierra. Finally, the unlikely places for *Iberolacerta* are those located in very low and thermophilic areas (for example those of the Batuecas valley or those at a lower altitude of Monsagro) and those furthest from the nucleus of the distribution, such as those of Gaudapero or Serradilla del Arroyo.

Statistical modeling of the presence and density of *I. martinezricai*. In a first exploratory analysis, the distribution of the variables that have been considered to be relevant when explaining the presence or absence of *I. martinezricai* in a given scree was studied. A comparison of means between the positive and negative places was carried out using the Mann – Whitney *U*-test. The results are shown in the Table 4.

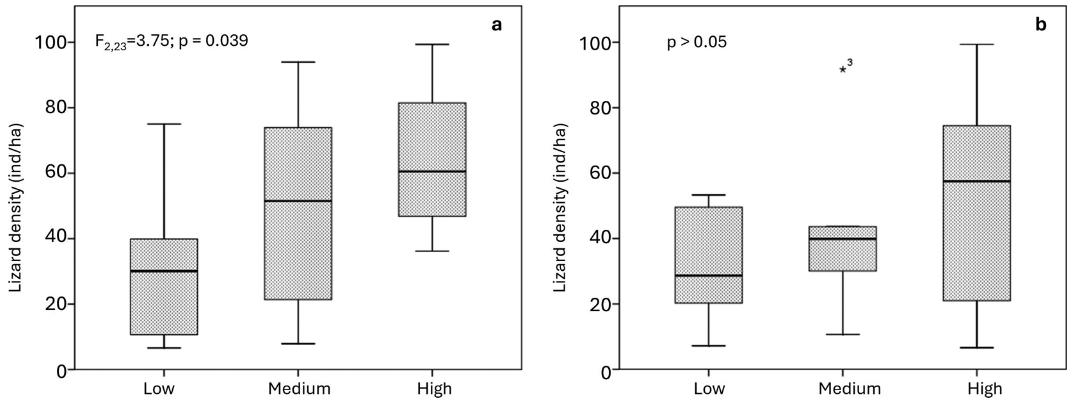

Fig. 12. Densities of lizards regarding: *a*, moss quantity; *b*, moisture.

According to the mean comparison analysis, the positive and negative sites differ in practically all the variables. The screes with the presence of the species are usually larger in terms of surface, located at a higher average altitude, with less slope, greater average stone size, higher moisture (with presence of mosses or lichens), and greater weight in the connectivity of the network of places in the study area (either by means of the PC with different dispersion probabilities and the constituent elements of said connectivity: Cintra, Flux, Connector). However, there are no statistical differences in altitude range, slope orientation, or TWI (Topographic Wetness Index).

Regarding the densities, these seem to depend on the average size of the stone block and the presence of moss, mainly (see Fig. 12*a*). In the case of moisture (Fig. 12*b*), although visually in the boxplot there are differences between groups, these were not statistically significant. For the rest of the variables, no correlation was found ($p > 0.05$). It seems that the density of the species in each scree do not depend on its size, or the degree of connectivity, orientation, or topographic wetness index.

In the multivariate models, only the variables that had shown some relevance in the exploratory analyses were entered. Variables that were autocorrelated had to be eliminated, for example, the size of the scree with the PC index of connectivity probability and also with the components of this same index. The PC was selected as the variable to be introduced in the model because it encompasses the others (size, flow, connector, etc.).

The logistic regression model on presence/absence for the species includes as statistically significant explan-

TABLE 4. Result of the Comparison of Means Between the Positive and Negative Fields Using the Mann – Whitney *U* Test of the Variables that Have Been Considered to be Relevant When Explaining the Presence or Absence of *I. martinezricai* in a Given Scree

Character	Average of absence	Average of presence	Mann – Whitney *U* Test	*Z*	*p*-value
Area	4.028	7.303	319	–2.571	0.010
Slope	26.50	24.77	340	–2.287	0.022
Minimum altitude	1180.5	1330.1	241.5	–3.612	<0.001
Maximum altitude	1344.8	1510.7	189	–4.319	<0.001
Altitude range	164.3	180.7	463	–0.632	0.527
Average altitude	1263.9	1421.6	198	–4.197	<0.001
Orientation	4.15	3.97	478	–0.431	0.667
PC 10000	1.13	2.05	318	–2.583	0.010
PC 1000	1.31	3.46	264	–3.310	0.001
PC 500	1.30	3.61	268	–3.256	0.001
PC 250	1.26	3.43	287	–3.001	0.003
PC 100	1.29	3.39	228	–3.311	0.001
Cintra	0.06	0.13	318	–2.583	0.010
Flux	0.92	2.50	262	–3.336	0.001
Connector	0.32	0.98	327	–2.464	0.014
TWI	9.03	9.41	408	–1.372	0.170

atory variables the slope (in negative, that is, the probability of the presence of the species decreases in the steep slopes, probably because defines the size of the average rock block in the scree), the average altitude, the degree of connectivity between screes, the average size of the rock block and the degree of moisture in the scree (Table 5).

Regarding the GLM for the density of the species, it only included a single variable, the degree of moss cover (Table 6). The rest of the variables were not significant and did not contribute to increasing the explanatory power of the model.

According to the results of the models, it seems that, although for the presence of the species in the screes there are both variables related to the ecology of the landscape and the characteristics of the scree itself, in the case of density this seems only influenced by the microhabitat conditions present in each scree.

CONCLUSIONS

According to the results, the densities obtained from *I. martinezricai* were low (Carbonero et al., 2008, 2015), between 25 and 50 specimens/ha, always compared to other species of the genus *Iberolacerta*. In 2018 the highest densities were found in some very favorable screes for the species, up to 100 ind./ha, descending to 8 ind./ha in the least appropriate areas, the most Mediterranean and lower ones that are Portillo and Batuecas, at 840 –1400 m altitude. The average density in the positive places has been 55.6 ind./ha. There are no other studies of *I. martinezricai* densities with which to compare, but in the following table (Table 7) we can observe densities of other species of the genus *Iberolacerta* in different geographical areas, habitats, and altitudes. As can be seen, the variation in density for each species is very high, being in optimal places up to 10 times the usual or average density of other populations. The density values of specimens per hectare obtained for *I. martinezricai* in 2018 are lower, but close to those of *I. monticola* in Galicia and the Cantabrian Mountains. Data of low average densities are also found in *I. aurelioi* in the Pyrenees (20.8 – 25.8 ind./ha), at high altitude and low productivity. However, in optimal locations they reach values of 145 – 175 ind./ha. The data for *I. cyreni* in Gredos and Guadarrama are much higher (up to 10 times more) than for *I. martinezricai*, perhaps due to the productivity of the. The fundamental difference seems to be that *I. martinezricai* occupies only the screes, while in other areas of the Central System the habitats are more diverse (rocky, prairies, screes, and their ecotonal areas). The known area of distribution of the species has therefore increased due to the greater extension of the samplings, although there are still many areas to be sampled in the Sierra de Francia with promising characteristics for the species. The modeling analysis reveals something already evidenced in 2007: the positive presence of the species and the highest densities are found in the scree areas oriented preferentially towards the north, at medium and high altitudes. Global warming poses a great threat to species of terrestrial vertebrates confined in high mountain areas, as has been proven in numerous studies around the world. This is especially true for massifs whose maximum height is low and where the species cannot escape upwards. The predictions made on the changes in the altitudinal and latitudinal distribution for the herpetofauna in Spain (Nogués et al., 2008; Moreno et al., 2012; Pleguezuelos, 2015; Herrero and Zavala, 2015) support that the ideal habitat for the Batuecan lizard may decline sharply in the near future in a small mountain massif as Mediterranean and low-topped as the Sierra de Francia. In our samplings, we have found several Squamata in the altitudinal distribution of *I. martinezricai* that can compete (*Podarcis guadarramae*, *Psammodromus algirus*, *Lacerta schreiberi*, *Timon lepidus*, *Tarentola mauritanica*, *Chalcides bedriagai*) or prey on it (*Coronella austriaca*, *Vipera latastei*). However, we do not currently have enough data to know what the importance of these processes will be. Even though the area of distribution, the number of positive sites, and the estimated number of specimens is, therefore, greater in 2018 censuses than in 2007, the limited area of distribution in the Sierra de Francia; the low estimated number of specimens of the Batuecan lizard and the threats caused by habitat loss due to climate increasingly warming, support keeping it in the IUCN category critically endangered (CR) and, as

TABLE 5. Logistic Regression Model on the Presence of *I. martinezricai* in the Scree Sites ($R^2 = 0.56$)

Character	*B*	S.E.	Wald	*Df*	Sig.
Slope	–0.623	0.265	5.527	1	0.019
Average altitude	0.018	0.008	5.099	1	0.024
TWI	0.000	0.000	1.100	1	0.294
PC500	0.654	0.284	5.293	1	0.021
Moisture	1.491	0.720	4.292	1	0.038
Rock blocks	0.066	0.024	7.732	1	0.005
Constant	–15.885	7.840	4.105	1	0.043

TABLE 6. GLM for the Density of *I. martinezricai* in the Screes

Character	*B*	S.E.	*B* standardized	*t*	*p*-value
Moss	18.597	6.735	0.491	2.761	0.011
Constant	11.198	12.178		0.920	0.367

has recently been proposed, in the category EN (endangered) in the Spanish Catalog of Threatened Species (CEEA). There are still many unknowns about the biology and distribution of *I. martinezricai*. Until now, the existing data are basic (Arribas, 2014d); There are many unprospected places left and we only superficially know the biology of the species in terms of alimentation, territoriality, competition, predators, etc. For all these reasons, we think that detailed studies should be carried out that will allow us to know in detail the evolutionary responses to current threats, especially massive fires and global warming and the interactions with other species, especially likely predators and competitors.

Future study prospects:

1) Despite the notable sampling effort carried out in 2018, many remote sites remain unsampled in the Sierra de Francia due to their difficult access. Likely, the distribution could thus be expanded in the future, as well as the total number of estimated specimens of the Batuecan lizard.

2) The method of observing specimens in the linear transects without capture is appropriate for the follow-up and periodic monitoring of the Batuecan lizard. For more in-depth studies of demography, reproduction, diet, competition, predation, etc., plotting techniques, mark-recapture, etc. are necessary.

3) The distribution model of the species indicates that 35 scree places not sampled in 2007 and 2018 should

TABLE 7. Comparison Between the Densities Obtained for *I. martinezricai* in This Study, Other Species of *Iberolacerta* and Other Iberian Lacertids*

Species	Region	Lizard density, ind/ha	Habitat	References
I. martinezricai	Sierra de Francia	45 – 60	High areas – very favourable	Carbonero et al., 2008, 2015
I. martinezricai	Sierra de Francia	25 – 30	Low areas – unfavourable	Carbonero et al., 2008, 2015
I. cyreni	Gredos	424		Pérez Mellado et al., 1991
I. cyreni	Guadarrama	220 – 328		Martin and Salvador, 1997
I. monticola	Cabeza Grande de Manzaneda (Galicia)	25 – 125	Screes	Galán et al., 2007
I. monticola	Ancares (Galicia)	52 – 150	Rocky slopes – screes	Galán et al., 2007
I. monticola	Monte Pindo (Galicia)	10 – 103	Rocky areas	Delibes and Salvador, 1986
I. monticola	Cordillera Cantabrica	52 – 150		Moreira et al., 1999
I. monticola	Serra de Estrela – low areas (Portugal)	100		Moreira et al., 1999
I. monticola	Serra de Estrela – peaks (Portugal)	1546		Arribas, 2014
I. aurelioi	Mont-Roig (Pyrenees)	20.8		Arribas, 2014
I. aurelioi	La Pica dEstats (Pyrenees)	25.8		Arribas, 2014
I. aurelioi	Saloria (Pyrenees)	10.3		Arribas, 2014
I. aurelioi	Pyrenees	175		Arribas, 2014
I. aurelioi	Andorra (Pyrenees)	145		Arribas, 2014
I. bonnali	Bigorre (Pyrenees)	380		Arribas, 2014
I. bonnali	Ordesa, Góriz (Pyrenees)	2090	2090 m a.s.l.	Arribas, 2014
I. bonnali	Ordesa (Pyrenees)	4750	2200 m a.s.l.	Arribas, 2014
I. bonnali	Ordesa (Pyrenees)	1550		Arribas, 2014
I. bonnali	Ordesa, Posets (Pyrenees)	175		Arribas, 2014
I. bonnali	Ordesa, Posets (Pyrenees)	200		Arribas, 2014
I. bonnali	Ordesa, Arriel (Pyrenees)	20		Arribas, 2014
I. aranica	Pyrenees	78		Arribas, 2015
		Other lacertids		
Zootoca vivipara		200 – 300		
Podarcis muralis		500		
Podarcis muralis	Insular populations (South of France)	1037 – 1120		
Podarcis carbonelli berlengensis	Berlenga Island (Portugal)	1300 – 1500		

* Summary data collected in Arribas (2014a, 2014b, 2014c, 2014d).

be surveyed as soon as possible in the near future, as they could have populations of the Batuecan lizard. Without this updated information, it is impossible to have a precise knowledge of the real distribution, connectivity of populations and estimated number of specimens of the species, which will allow it to be properly categorized according to the IUCN, in the CR (Critically Endangered) and EN (Endangered).

4) Another important aspect for future studies is to know how climate change, or better current global warming is affecting the species (actually the ecosystem in general), both due to the increase in temperatures in summer and the decrease in the humidity of the lizard sites, a fundamental factor for their survival. Some low-lying sites in Batuecas and El Portillo do not present lizards or have not been found in the 2018 samplings. Possible competition or predation with other reptiles or mammals should be studied in-depth in the future.

5) It would be necessary to carry out a detailed study of the biology of the Batuecan lizard, perhaps through a UE LIFE project, which would clear most of the current unknowns about it.

6) A deep genetic analysis of the species is necessary at the population level that allows knowing the genetic variability in its distribution area and comparing it with the nearby *Iberolacerta* species, in particular *I. cyreni* in the eastern central system, *I. monticola* in the Serra da Estrela in Portugal and *I. galani* in Sanabria and León Mts. Microsatellite study will help to understand the connectivity among screes and the different populations.

7) The sum of all these data on ecology, distribution, habitat, and genetic variability would allow detailed modeling of the distribution of the species, as well as proposals for the management of the species if necessary.

Proposal for a functional connectivity analysis based on genetic analysis and resistance surfaces:

As it is a species with such a reduced distribution, that most likely responds to a classic model of metapopulation dynamics, and its habitat is limited to discontinuous screes, the medium and long-term conservation of *I. martinezricai* must be based on a deep understanding of their dynamics of meta-populations and functional connectivity between localities. Therefore, the connectivity analysis carried out in this study should be complemented and expanded in the near future with a detailed study on functional connectivity for the species (the one presented in this report is based on an indirect estimate of the maximum dispersal capacity for the species), based on genetic analysis and the calculation of resistance to movement concerning the different land uses between the places. Functional connectivity, the degree to which the environment prevents or facilitates the movement of specimens of the same species between patches of favorable habitat (in this case *I. martinezricai* and the screes), is reflected in the genetic structure of the populations (Brown and Kodric-Brown, 1977; Tallmon et al., 2004).

Technical advances in the field have made it possible to carry out studies of landscape genetics with a high level of precision and at a low cost. They are based on the analysis of repetitive marker microsatellites or VNTRs (Variable Number of Tandem Repeats), consisting of short sequences of 1 to 6 nucleotide base pairs that are repeated in tandem a high number of times (SSRs, Short Sequence Repeats). Although microsatellites have been applied for different purposes, in the conservation of *I. martinezricai* they would be used for the analysis of gene flow at a local scale; the determination of paternity and kinship; heterozygosity, drift, and inbreeding; the effective population size (Ne) and the allocation of provenance populations (González, 2003).

Landscape analysis would allow evaluating the relative influence of different factors that act as potential barriers for the dispersal of organisms at different spatial scales, with increasingly fine resolution (Wulder et al., 2004; Greenberg et al., 2005). Genetic data would be linked to different potential variables and the effect of landscape structure, matrix configuration and quality on gene flow and genetic variation would be quantified (Storfer et al., 2007).

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