Thermoregulation, activity and microhabitat selection in the rare and endangered Batuecan Rock Lizard, *Iberolacerta martinezricai* (ARRIBAS, 1996)

(Squamata: Sauria: Lacertidae)

Thermoregulation, Aktivität und Mikrohabitatwahl der seltenen und gefährdeten Felseidechse *Iberolacerta martinezricai* (ARRIBAS, 1996)
(Squamata: Sauria: Lacertidae)

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KURZFASSUNG

Zur Naturgeschichte von *Iberolacerta martinezricai* (ARRIBAS, 1996), der seltensten Reptilienart Kontinentaleuropas, liegen nur wenige Angaben vor. Das zahlenmäßige Geschlechterverhältnis betrug nach Informationen aus der Datenbank des Autors 0,74:1 (Männchen:Weibchen), während im deutlich größeren Datensatz der Feldbeobachtungen (dieser schließt allerdings Beobachtungswiederholungen ein) die Männchen überwogen (1,27:1).

Alle Altersgruppen und Geschlechter zeigten ähnliche, die Morgenstunden betonende Tagesaktivitätszyklen. Nachmittagsaktivität erfolgte gehäuft an schattigen Orten, wobei Sonnenexposition bei hohen Lufttemperaturen vermieden wurde. Zwei Häutungsperioden (eine im April, eine um Ende Juni und Juli) wurden beobachtet. Der Lebensraum war mäßig geneigtes, ausnahmslos von Felstrümmern und großen Blöcken, mit reichlich Moos- und Flechtenbewuchs dominiertes Gelände, was auf erhöhte Feuchte und geologische Hang-Stabilität hinwies. Besondere Vorlieben für einzelne Mikrohabitate waren nicht feststellbar.

Die Körpertemperatur aktiver Individuen war die höchste innerhalb der Gattung *Iberolacerta*: 33.31±0.12 °C (Spannweite 22.8-39.2 °C), ohne signifikanten Geschlechtsunterschied. Im Mittel hatten blaufärbige Männchen eine höhere Körpertemperatur als grüne (33.73±0.19 °C gegenüber 32.8±0.28 °C). Die Aufenthaltsorte adulter Weibchen wiesen eine höhere Lufttemperatur auf (23.77±0.20 °C, Spannweite 13.8-37.1 °C) als die der Jungtiere. Die Substrattemperaturen (30.08±0.31 °C, Spannweite 16.5-52.1 °C) waren an den Aufenthaltsorten der Weibchen höher als an denen der Männchen.

Iberolacerta martinezricai war mäßig thermokonformistisch (Spannweite der Aktivitätstemperatur: 16.4 °C) und ein effektiver und ziemlich präziser Thermoregulator was die Substrattemperatur betrifft ($r = 0.36$, Anstieg 0.14), aber zeigte kein thermoregulatorisches Verhalten hinsichtlich der Lufttemperatur ($r = 0.15$, Anstieg = 0.09). Tigmothermie, Aktivität im Schatten bei hoher Lufttemperatur und Aestivation werden diskutiert.

ABSTRACT

The natural history of *Iberolacerta martinezricai* (ARRIBAS, 1996), the rarest reptile of Continental Europe, is practically unknown. Sex ratio calculated from the author's morphological database was 0.74:1 (males:females), whereas from the clearly higher number of field observations (repetitions included) was (1.27:1), favoring males.

All sexes and ages revealed similar daily activity cycles, skewed toward the morning hours, with the afternoon activities concentrating at shadowy sites with elevated air temperatures and avoiding sun basking.

There were two periods of molting, one around April and another between late June and July. The macrohabitat was strictly rocky (large boulders covered with plentiful mosses and lichens that denote elevated moisture and geological habitat stability) in gentle steeped slopes. Specific microhabitat selection was not observed.

Body temperatures of active lizards were the highest within the genus *Iberolacerta*: 33.31±0.12 °C (range: 22.8-39.2 °C), without significant differences among sexes or ages. On the average, blue males had higher body temperatures than green ones (33.73±0.19 °C versus 32.8±0.28 °C). Ambient air temperatures measured (23.77 ±0.20 °C, range: 13.8-37.1 °C) were higher at sites where adult females than where juveniles were observed. Substrate temperatures (30.08±0.31 °C, range: 16.5-52.1 °C) were higher in places where females than where males were observed.

Iberolacerta martinezricai is a moderate thermoconformist (total temperature range of activity 16.4 °C) and an effective and fairly precise thermoregulator with respect to substrate temperature ($r = 0.36$, slope 0.14), but seemed not to thermoregulate relative to the air temperature ($r = 0.15$, slope = 0.09). Tigmothermy, activity in the shadow with high ambient air temperatures and aestivation are also discussed.

KEY WORDS

Reptilia: Squamata: Sauria: Lacertidae; *Iberolacerta*, *Iberolacerta martinezricai*; microhabitat, body temperatures, skin moults, habitat selection, thermoregulation, activity, ecology, behavior, physiology, Sistema Central, Las Batuecas y Peña de Francia Natural Park, Spain

INTRODUCTION

Iberolacerta martinezricai (Arribas, 1996) was described from the Sierra de Peña de Francia as a subspecies of *Lacerta cyreni* Müller & Hellmich, 1937, coincidental with the raising of this latter to species level (from former *L. monticola cyreni*). The presence of Iberian Rock Lizards (at that time collectively named *Lacerta monticola* Boulenger, 1905) in the Mountain Peña de Francia, Province of Salamanca, Spain, was known from Klemmer (1957) who studied a male collected by A. Epple in 1954.

When this German collector visited the Peña de Francia (2-IX-1954) some days before the annual pilgrimage to the monastery, only a dirt track constructed in 1920 existed. In 1961 the street was asphalted facilitating massive access of motor vehicles, and in the 1970's, the characteristic antenna was installed, well visible from a distance. These landmarks show the increasing human pressure upon the area over the past hundred years.

In the last decades of 20th century, reference was made to the presence of Rock Lizards in the western Spanish Sistema Central, in a paper about the morphology and biology of *L. monticola* (Perez-Mellado 1982) as well in the Atlas of amphibians and reptiles of the Province of Salamanca (Perez-Mellado 1983). There, referring to the seventies, this author recalled attention to the rareness of the Peña de Francia population: "the situation is more serious in Peña de Francia where the number of visitors is growing every year and where a dramatic numerical regression of individuals, which are scarce by themselves, has been produced in the last decade".

It was not until 1996 when Arribas described *Lacerta cyreni martinezricai* in the framework of a wider revision of '*L.*' *monticola* and '*L.*' *cyreni*. After this, the author added new information about the Peña de Francia's population including data from live specimens and again pointed to the scarcity of the lizards and the increasing anthropogenic transformation of the area

(Arribas 1999a). His tentative estimation of the population density in the top region of the mountain (the only known locality of the species) resulted in the theoretical density of 45 individuals/ha or a total number of some thirty individuals.

Fortunately, *I. martinezricai* was later localized in another area in the Batuecas Valley (Arribas 2004), in the framework of genetic, osteological and karyological studies that showed this lizard was not a subspecies of *I. cyreni*, but a valid species, more related to *I. monticola* than to the former (Mayer & Arribas 2003; Crochet et al. 2004; Arribas & Carranza 2004; Arribas & Odierna 2004).

Iberolacerta martinezricai, is the rarest and probably one of the most threatened reptile species from Continental Europe. A recent survey on the habitat and distribution of *I. martinezricai* confirms that its distribution area is very small (12-15 km^2) inside three 10 km x 10 km UTM grid squares (29TQE48; 29TQE38; 29TQE39). The total occupied area is between 20-25 km^2 and the estimation of the total population of the species between 1200 to 1500 individuals (Lizana & Carbonero 2007; Carbonero pers. comm.). Despite the promising find of the species at a lower altitude site, the species has not been found in other such lowland environment or more to the West, as previously expected.

Iberolacerta martinezricai is considered Critically Endangered (CR, B2ab(v); C2a(ii)), because of its small distribution area (< 10 km^2), population comprising less than 250 adults and its decline from various threats (Arribas 2006; Pérez-Mellado et al. 2009). Despite that the entire population occurs inside a protected area, namely the "Parque Natural de las Batuecas y Sierra de Francia", a specific program and management for the recovery of this species is still required.

However, in spite of this high threat category, little is known on this lizard's biology and ecology (see Arribas 2006 for a résumé of our knowledge).

MATERIALS AND METHODS

Study area

Data processed in this study come from the whole altitudinal range of the species; from the Peña de Francia summit to the Puerto del Portillo in the Batuecas Valley (between 886 and 1735 m a.s.l.).

The main area of the species lies in the north of the Natural Park of Las Batuecas, at medium and high altitudes in the mountainous range of the Sierra de Francia. This first area is centered around the peak "Peña de Francia" (1723 m), extending northward to the peak "Pico de los Robledos" (1611 m) and surrounding areas, to the northeast as far as the "Sierra del Guindo" ("Hastiala" Peak, 1735 m; "Alto del Copero", 1560 m), southward to the "Mesa del Francés" (1640 m), and toward the southeast, up to the northern slopes of the "Sierra de la Grajera" ("Rongiero", 1627 m) (ARRIBAS 2006; LIZANA & CARBONERO 2007). In the peaks, records of the species are merely anecdotal, with densities below 10 individuals/ha in the few sites where it was found (densities of 45 individuals/ha estimated in the previous decade, show the marked regression in parallel to increased human activity). In other places of the area, the population can reach up to 60 individuals/ha (LIZANA & CARBONERO 2007).

The second area where the Batuecan Rock Lizard occurs is called "Puerto El Portillo" ("El Portillo Pass", from 840 m to 1400 m a.s.l.), on the southern slope of a mountain range named "Sierra de la Alberca". This mountain-wall drops away from the Meseta Norte to the considerably lower Batuecas Valley. Its population which was only described in 2004 (ARRIBAS 2004) exhibits densities of 25-30 individuals/ha (LIZANA & CARBONERO 2007). The bedrock of the area is mainly of Paleozoic age, with granites, quartzite and slate outcrops.

The relief is generally smooth but shows active geological phenomena of meteorisation, which produced accumulations of large boulders and loose rocks (called "canchales", averaging 80-120 cm in diameter) and deep valleys with fast flowing streams during the winter. The basal granite and quartzite surface in the peaks and crests forms large areas of boulders in the slopes of the valleys, where slates are more common.

In the area, three bioclimatic stages are represented: the Oromediterranean belt (>1600 m a.s.l.), only in the summits of the mountain ranges, with broom shrubs (mainly *Cytisus balansae*); the Supramediterranean belt (approx. 1000-1600 m a.s.l.) originally vegetated by Pyrenean oak (*Quercus pyrenaica*) and a shrub stratum of heath (*Erica arborea* and *E. australis*), as well as some pine stands (*Pinus nigra* and *P. sylvestris*) interspersed. The low altitudes are occupied by the Mesomediterranean belt (400-1000 m a.s.l.) typically constituted by open forests of Evergreen oaks (*Quercus ilex*) and Cork oaks (*Quercus suber*) in the wetter areas. Azonal vegetation includes saxicolous and riverine species in the ravines (ARRIBAS 2004, 2006; LIZANA & CARBONERO 2007).

Rainfall is concentrated during fall and winter and exceeds 1800 mm in the summit areas. Summers are sunny, with high insolation and lack of precipitation; drought is restricted to July-September. In the lizard habitats, annual and daily insolation cycles are relatively short (just a few hours of direct sun per day), due to the relief of the mountains and the orientation and inclination of the slopes. The sun reaches the habitats late in the morning, especially the lowermost portions of the slopes (MARTIN 1998; ARRIBAS unpublished data).

Field data

Localities were visited from 1996 to 2012 at irregular intervals: 1997 (April, July, and August), 2001 (July and August), and in July of 1996, 2002, 2003, 2004, 2005, 2007, 2008, 2011 and 2012. Calculations were based on time, habitat and temperature data gathered from 619 observations of *I. martinezricai*.

From each specimen found active, the following data was taken:
- Date and time of the day (GMT).
- Activity: [inactive, basking, and active]. Temperature data (see below) were taken from active specimens only. Activity

was quantified by counting the observation events of active individuals, irrespective of the duration of the observation time.

- S e x [coding: 1 - male, 2 - female, and 3 - adult of undetermined sex]. Those specimens of undetermined sex were used for global adult comparisons with young individuals only.

- A p p r o x i m a t e   a g e [adult (coding: 1 - males, 2 - females, 3 - specimens of undetermined sex), subadults (later also called young, juvenile or immature specimens and hatchlings)]. Subadults were classified in calendar-year age classes (coded "40" if of undetermined age). Hatchlings of the year are in their "first calendar year" (1CY; coded "41"). After their first hibernation they are in their "second calendar year" (2CY; "42"); after their second hibernation they are in their "third calendar year" (3CY; "43"), etc. In total, 40 specimens were studied from: 1st CY, 11 from 2nd CY, 20 from 3rd CY, 4 from 4th CY and 1 young of undetermined age.

- H a b i t a t   s t r u c t u r e s (in percent): In a 2-meter radius around the spot of first localization of the animals, a visual estimate of the percent cover of rocks, stones, bare ground, shrubs and grass was assessed by means of visual estimation scales (PRODON & LEBRETON 1981; EMBERGER 1983).

- S l o p e   i n c l i n a t i o n was measured with a clinometer in discrete categories: 0°-10°, 10°-20°, 20°-40°, 40°-50°, 50°-70°, 70°-80°, 80°-90°).

- T e m p e r a t u r e s were taken (from active specimens only) with Schultheis-type thermometers (Wesco®, 0 °C-50 °C, precision: ± 0.1 °C) from the cloaca (body temperature, BT) within 20 seconds of the lizards' first spotting, and ambient air (AT) in the shadow, 20 cm above the ground. Substrate temperatures (ST) were taken with a TFA® infrared thermometer. Mercury and electronic thermometers were inadequate instruments to obtain reliable temperatures from a surface, as the contact area with the measured object is not two-dimensional but punctual, whereas infrared thermometers measure temperature from a circular surface area and were most suitable for measuring substrate temperatures (but totally unsuitable to take animal body temperatures; see ARRIBAS 2009).

Four parameters were used to define the thermoregulatory behavior:

Mean Body temperature: The average of temperatures at which the lizards were found active.

Thermoconformity: The larger the range of the body temperature, the more pronounced is the thermoconformity. Its standard deviation or standard error of the mean are significant measures and resistant to outliers, but are not available from other studies for comparison.

Efficiency of thermoregulation: Degree of deviation from the perfect poikilothermy (the slope in a diagram of body versus ambient temperatures is equal to 1). This measures the capacity of the lizards to deviate from the environmental temperatures.

Precision of thermoregulation: Measured as Pearson's correlation between body and ambient air temperatures or body and substrate temperatures.

- H a b i t a t   a v a i l a b i l i t y was calculated by photointerpretation, overlaying a grid and calculating the percent covers of rocks, stones, bare ground, shrubs and grass in the different squares.

Availability and use of resources (Table 1) were compared by testing the null hypothesis of random selectivity, using a *Chi*-square log-likelihood statistics (G-test; $p < 0.05$). Selection or avoidance of habitats was quantified by means of an electivity index, a normalized forage ratio: $w_i = o_i / p_i$; where w_i = forage ratio for the habitat category i; o_i = proportion or percent of the habitat category i used; p_i = proportion or percent of the habitat category i available in the environment (KREBS 1989, 1999). Electivity indexes are presented as standardized ratios, which sum up to 1.0 for all habitat categories. Standardized ratios of 1/ (number of resources) (in our case 1/7 = 0.14) point to an indifferent situation (neither preference nor avoidance); values below this indicate relative avoidance, and above relative preference (calculations are after KREBS 1989, 1999). Only deviations greater than 5 % ($p < 0.05$) were considered and discussed in the text.

Total counts differ among variables and age-classes, as they were not consistently available for each observation. For instance, data from an adult of unknown sex

or juvenile of unknown age were not included under males, females, or the definite age categories, but in the collective comparisons of adults against juveniles.

Statistical study

In general, statistical calculations were made using the NCSS-2002® software package (HINTZE 2001). Univariate comparisons among categories were done by ANOVA with subsequent Tukey-Kramer post-hoc multiple comparison tests. At $p < 0.05$, results were considered significant, at $p < 0.01$ highly significant. Concrete p values were given only in the case of significance or near significance, otherwise only

NS (not significant) was stated. Diversity measurements and selection indexes were calculated with the program Ecological Methodology® 6.1.1 (KREBS 1999). The following comparisons between categories were done:

- Separately for all sex and age categories (see under field data above): ("sex and ages") (Tables 1 and 2).
- Adult males versus adult females versus juveniles.
- Adults versus subadults: Adults category included adult individuals of undetermined sex.
- Differences in the temperatures between the green and blue color morphs (ARRIBAS et al 2008).

RESULTS AND DISCUSSION

Sex ratio

Sex ratio of natural populations was calculated from specimens of the author's morphological database, and from specimens observed in the field during transect surveys (certainly with specimens repetition). Results of both approaches are quite different.

In specimens from field observations (usually July - August), the sex ratio was 1.27:1 (260 observations of male versus 204 of female individuals). The difference in the proportion of sexes was significant (Multinomial test: $Chi^2 = 6.75$, $P = 0.009$). The male biased counts may be due to the timing of the fieldwork, which was mainly done in the first week of July, and in some years coincided with the gravid period for females which makes them more stealthy and less detectable. This is probably also the reason for the generally increased abundance of male observations in this study.

In the specimens of the morphological database (captured from from April to August), the sex ratio was 0.74:1 (29 males and 39 females determined); which does not differ significantly from 1:1 (Multinomial test: $Chi^2 = 1.47$, NS).

A previously published sex ratio for *I. martinezricai* (males:females = 0.78:1 in

ARRIBAS & CARRANZA 2004 and ARRIBAS 2007), based on a smaller number of 50 database records, was similar to the current one. In *Iberolacerta aranica* (ARRIBAS, 1993), the proportion of sexes in adults was different from 1:1 (0.55:1), favoring females (however, hatchlings' sex ratio in the laboratory was the contrary (1.8:1); this shift may be explained by temperature-depending sex determination; see ARRIBAS 1997). In *I. cyreni* more females than males (0.69:1) were observed. The usual situation in Rock Lizard species, however, is that the proportion does not differ significantly from 1:1 as in *I. bonnali* (LANTZ, 1927) (0.98:1), *I. aurelioi* (ARRIBAS, 1994) (1.2:1), *I. horvathi* (MÉHELY, 1904) (1.01:1) and *I. monticola* (1.14:1). In this last species however, the females outnumbered the males (0.27:1) in the highest places of the Serra de Estrela, Portugal, where densities are extremely high (all above *Iberolacerta* data from ARRIBAS 1997).

In laboratory-born/bred *I. monticola* and *I. cyreni*, the sex ratio did not differ significantly from 1:1, although, it happened frequently that in lacertids, slightly more males than females were born (1.17:1 in *I. monticola*, 1.21:1 in *I. aurelioi*, 1.8:1 in *I. aranica* [data from BARBADILLO 1985; RÚA & GALÁN 2003; ARRIBAS & GALÁN 2005]). The samples of *I. martinezricai* and *I. bon-*

Table 1: *Iberolacerta martinezricai* (ARRIBAS, 1996). Habitat structures at the sites of first spotting and selection of these structures with respect to their availability. First line: arithmetic mean ± standard error. Second line: in parentheses, minimum and maximum values. Third line: selection index (w, see Materials and Methods). Fourth line: standardized proportions in % . Positive or negative signs indicate selection or avoidance. Only deviations exceeding 5 % ($p < 0.05$; highlighted in bold) are considered and discussed in the text. Habitat category entries in lines three and four, respectively, sum up to 1.0 in each column. In the lower part of the table, G-test values and their probabilities are indicated.

Tab. 1: *Iberolacerta martinezricai* (ARRIBAS, 1996). Habitatstrukturen, jeweils am Ort der ersten Beobachtung und deren Selektion in Bezug zur Verfügbarkeit. Erste Zeile: arithmetisches Mittel ± Standardfehler. Zweite Zeile: in Klammern, Minimum- und Maximumwerte. Dritte Zeile: Selektionsindex (w, siehe Material und Methoden). Vierte Zeile: normalisierte Anteile (%). Positive bzw. negative Vorzeichen bedeuten Selektion bzw. Vermeidung. Nur Abweichungen über 5 % ($p < 0.05$; in Fettschrift) sind berücksichtigt und im Text diskutiert. Die Summe für alle Habitatkategorien je Spalte ergibt für die Einträge in den Zeilen drei und vier jeweils den Wert 1,0. Im unteren Tabellenteil werden G-Werte und ihre Wahrscheinlichkeit angegeben.

Sex and Ages Geschlecht und Alter	Males ($n = 49$) Männchen	Females ($n = 28$) Weibchen	Young ($n = 85$) Junge	Availability in the habitat (%) Verfügbarkeit im Lebensraum
Inclination of habitat (angular degrees) Hangneigung (Grad)	26.87±2.2 (0-90) w = 0.2175 **+ 7.4 %**	24.57±2.6 (0-70) w = 0.1825 + 3.9 %	23.38±1.5) (0-80) w = 0.1074 - 3.5 %	24.5±1.10
% Rocks % Felsen	92.79±2.4 (30-100) w = 0.2057 **+ 6.2 %**	92.5±2.5 (60-100) w = 0.1882 + 4.5 %	86.7±2.6 (0-100) w = 0.1091 - 3.3 %	89.7±1.59
% Stones % Steine	0±0 (0-0) w = 0.0001 **- 14.2 %**	0±0 (0-0) w = 0.0001 **- 14.2 %**	13.96±2.2 (0-70) w = 0.2220 **+ 7.9 %**	0.93±0.57
% Bare Soil % Nackter Boden	0.34±0.3 0-15 w = 0.0620 **- 8.08 %**	0.96±0.9 0-25 w = 0.1607 + 1.7 %	1.64±0.9 0-60 w = 0.1698 + 2.7 %	1.09±0.51
% Shrubs % Gebüsch	1.39±0.8 (0-30) w = 0.1906 + 4.7 %	0.38±0.3 (0-10) w = 0.0478 **- 9.5 %**	1.96±1.0 (0-80) w = 0.1525 + 0.9 %	1.45±0.60
% Grass % Gras	3.37±1.5 (0-40) w = 0.1324 - 1 %	5.76±2.4 (0-40) w = 0.2077 **+ 6.4 %**	5.69±1.3 (0-40) w = 0.1269 - 1.6 %	5.06±0.90
% Moss/Lichens % Moos/Flechten	10.89±2 (0-30) w = 0.1918 + 4.9 %	13.18±3.3 (5-30) w = 0.2130 **+ 7.02 %**	11.25±1.6 (0-30) w = 0.1124 - 3.04 %	11.29±1.15
G-test ($df = 6$) p	2.19 0.9007	2.160 0.9044	0.595 0.9953	

nali are of insufficient size to derive any conclusion in this respect.

Activity

The circadian activities (expressed by the number of observation events) of the Batuecan Lizard are visualized in Fig. 1. There were no significant differences in the daily activity schedule among all the sex and age categories analyzed ($F_{5,606} = 0.43$, NS; see Table 2 for details of each category), even if they were grouped into only three categories (males, females and juveniles) ($F_{2,600} = 0.14$, NS) [Males: $n = 259$, mean = 1043± 12.93, 742-1705; Females: $n = 201$, mean = 1056±14.71, 756-1722; Juveniles: $n = 143$, mean = 1040±15.26, 726-1653]. Equally, juvenile specimens showed identical patterns to adults ($F_{1,610} = 0.19$, NS
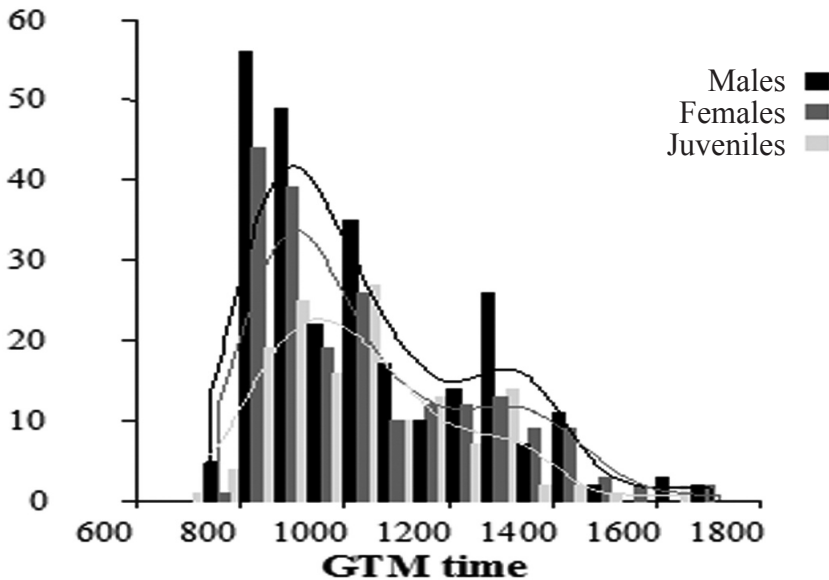
Fig. 1: Bar graph representing the number of active specimens (males, females and juveniles) of *Iberolacerta martinezricai* (ARRIBAS, 1996) as observed during the hours of the day (*n* = 612 observations).

Abb. 1: Balkendiagramm der Anzahl aktiver Individuen (Männchen, Weibchen und Jungtiere) von *Iberolacerta martinezricai* (ARRIBAS, 1996) aufgrund von Beobachtungen im Tagesverlauf (*n* = 612 Beobachtungen).

[Adults: *n* = 469; mean = 1048±9.55; 742-1722; Juveniles: *n* = 143; mean = 1040±15.26; 726-1653).

The magnitude of the mean activity is similar within the three age and sex classes studied, and its period extends over 9 or 10 hours per day. All three classes exhibited activity curves skewed towards the morning hours, whereas the afternoon was usually spent at shadowy places with air temperatures warm enough to allow for activity without sun basking and the risk of overheating. During the morning hours, the animals basked until they reached activity temperatures, appropriate to begin to hunt and display social behavior. During hot weather, the extent of this morning sun basking could be reduced strongly if the air temperature sufficed for being active. At mid-summer, after the end of the reproduction period (mid-July), lizard activity declined, in part due to the excessively hot and dry weather conditions. Then, sun basking, was restricted to the first hours of their total daily activity. As the day proceeded, lizards were seen only when running from crevice to crevice, which makes the author suppose that there exists a certain degree of subterranean and less detectable activity in crevices among the large boulders, that retain fresh air during the hottest hours of the day (ARRIBAS 2004; ARRIBAS & CARRANZA 2004).

Molts

The first molting of the year occurred just shortly after leaving the hibernacula (end of March or early April), perhaps somewhat earlier in males (3 molted and 5 unmolted seen at this moment) than in females (1 molted versus 3 not molted). These proportions are indicative but a sound finding would require further analyses of a larger sample. At the end of April, all individuals observed were molted.

There is no data from May and June so that it is not clear whether or not there is another molt between the first and the next observed molt seen towards the end of June and early July in males, and a little ad-

Table 2: *Iberolacerta martinezricai* (ARRIBAS, 1996). Habitat structures [inclination of slope (°, angular degrees), proportion (%) of rocks, stones, bare soil, shrubs, grass and moss/lichens in the place where the individual was spotted], time of activity (GMT) and temperatures (°C) of body (cloaca, BT), ambient air (AT) and substrate (ST) for all the sexand age classes [2CY, 3 CY - juveniles at their second and third calendar year, respectively] studied. First line: arithmetic mean ± standard error. Second line: minimum and maximum values. The sample named 'Σ Adults' includes males and females plus adults of undetermined sex. Temperatures refer to active specimens only. Sample size as indicated in the column headers unless otherwise noted. --- No data.

Tab. 2: *Iberolacerta martinezricai* (ARRIBAS, 1996). Habitatstrukturen [Geländeneigung (°, Winkelgrade), Anteil (%) an Felsen, Steinen, nacktem Edboden, Gebüsch, Gras und Moos/Flechten am Aufenthaltsort des Individuums], Uhrzeit der Aktivität (GMT) und die Temperaturen (°C) von Körper (Kloakaltemperatur, BT), umgebender Luft (AT) und Substrat (ST) für die untersuchten Geschlechter- und Altersklassen [2CY, 3 CY – Jungtiere in ihrem zweiten und dritten Kalenderjahr]. Erste Zeile: arithmetisches Mittel ± Standardfehler. Zweite Zeile: Minimum- and Maximumwerte. Die Stichprobe 'Σ Adults' umfaßt die Männchen, Weibchen und Erwachsenen unbestimmten Geschlechtes. Temperaturangaben beziehen sich nur auf aktive Individuen. Die Stichprobenumfänge der Spaltenköpfe gelten - falls nicht anders angegeben - für die ganze Spalte. --- Keine Daten.

Sex and Ages Geschlecht und Alter	Males Männchen (n = 49)	Females Weibchen (n = 28)	Immatures Junge (2CY)(n = 36)	Immatures Junge (3CY)(n = 44)	Σ Adults Σ Adulte (n = 84)	Σ Young Σ Junge (n = 85)
Time of the day (GMT) Tageszeit	1043±12.93 742-1705 (n = 259)	1056±14.71 756-1722 (n = 201)	1043±29.8 726-1653 (n = 36)	1041±18.17 743-1628 (n = 100)	1048±9.55 742-1722 (n = 469)	1040±15.26 726-1653 (n = 143)
Inclination of habitat Geländeneigung (°)	26.87±2.26 0-90	24.57±2.6 0-70	23.14±2.32 0-80	24.04±2.21 0-70	25.78±1.59 0-90	23.38±1.52 0-80
% Rocks % Fels	92.79±2.45 30-100	92.5±2.57 60-100	82.94±4.8 0-100	88.59±3.27 0-100	92.82±1.66 30-100	86.7±2.64 0-100
% Stones % Steine	0±0 0-0	0±0 0-0	3.67±2.5 0-80	0.51±0.51 0-20	0±0 0-0	1.83±1.11 0-80
% Bare Soil % Erdboden	0.34±0.34 0-15	0.96±0.96 0-25	3.82±2.15 0-60	0.52±0.38 0-25	0.52±0.38 0-25	1.64±0.94 0-60
% Shrubs % Gebüsch	1.39±0.85 0-30	0.38±0.38 0-10	1.32±0.77 0-20	2.82±2.07 0-80	0.92±0.5 0-30	1.96±1.07 0-80
%Grass % Gras	3.37±1.5 0-40	5.76±2.41 0-40	6.17±2.23 0-40	5.89±1.87 0-40	4.40±1.22 0-40	5.69±1.33 0-40
% Moss/Lichens % Moos	10.89±2 0-30	13.18±3.32 5-30	7.75±1.79 0-30	15.62±2.65 5-30	11.34±1.62 0-30	11.25±1.65 0-30
BT (°C)	33.52±0.17 25-39.2 (n = 166)	33.00±0.20 22.8-36.8 (n = 115)	--- --- (n = 19)	33.34±0.39 28.3-37.9 (n = 37)	33.31±0.13 22.8-39.2 (n = 281)	33.34±0.39 28.3-37.9 (n = 37)
AT (°C)	23.64±0.28 13.9-34.7	24.7±0.37 13.8-37.1	20.04±0.67 16-26.5	23.47±0.54 13.9-30	24.05±0.22 13.8-37.1	22.58±0.47 13.9-30
ST (°C)	29.35±0.43 18.6-52.1	31.55±0.15 16.5-50.2	24.96±0.97 19.9-32.7	31.36±1.01 16.5-46.1	30.19±0.34 16.5-52.1	29.63±0.84 16.5-46.1

vanced towards the second half of June in females. Early in July, about half of the males and almost all females appeared most recently molted. In the second half of July, all males and of course females had finished molting. In August there were no traces of molting. For September, information on molting activities is lacking. In summary, only two molts were noted during the activity period (April to September): one that is centered around April and another between late June and July.

In other *Iberolacerta* species, differences were found in the molting cycles of males and females. In male *I. aranica* there are two defined periods of molting during the activity period (concentrated around beginning of July and the second week of August, respectively), whereas in females and juveniles there are three (two similar in date to the males' periods, the August molt perhaps slightly earlier, plus a third one towards the second week in September) (ARRIBAS 2007). In *I. horvathi* there are also

Fig. 2: Habitat of *Iberolacerta martinezricai* (ARRIBAS, 1996). The species only occurs at these big, geologically stable, rock boulders (or equivalent old stone walls). Inside this macrohabitat the lizard does not select particular microhabitat characteristics.
Abb. 2: Lebensraum von *Iberolacerta martinezricai* (ARRIBAS, 1996). Die Art kommt nur an diesen großen, geologisch stabilen Felsblöcken (oder vergleichbaren Steinwänden) vor. Innerhalb dieses Lebensraumes bevorzugt die Eidechse bestimmte Mikrohabitatstrukturen nicht deutlich.

Fig. 3: Male blue morph of *Iberolacerta martinezricai* (ARRIBAS, 1996) basking. Peña de Francia (Salamanca, Spain). It is shown that males of the blue morph have slightly higher body temperatures than green morph males.

Abb. 3: Männliche blaue Morphe von *Iberolacerta martinezricai* (ARRIBAS, 1996) beim Sonnen. Peña de Francia (Salamanca, Spanien). Es wird gezeigt, daß Männchen der blauen Morphe eine leicht höhere Körpertemperatur haben als die der grünen Morphe.

three molts, one in spring (first half of May), one in summer (July) and one in autumn (towards end of September or early in October) (LAPINI et al. 1993). In other lacertids there are four or even more molts but during longer activity cycles (for a résumé see ARRIBAS 2007).

Habitat selection

Iberolacerta martinezricai is a strictly saxicolous species. Its presence is narrowly linked to large boulders and talus screes and thus, cannot be found in other habitats (Fig. 2) (ARRIBAS 2004; ARRIBAS & CARRANZA 2004; ARRIBAS 2006; LIZANA & CARBONERO 2007).

Habitat use results, detailed by sex and age are presented in Table 2, and habitat availability and selection tests in Table 1. Regarding habitat preferences, there was a tendency in males towards more stepped slopes, rocky surfaces and avoidance of bare ground and shrubby places; in females towards the increased use of grassy and mossy spots, and avoidance of shrubby and, especially, stony areas; and in juveniles towards these stony habitats. Nonetheless, the null hypothesis (i. e., absence of preferences for any particular habitat types in the categories males, females and juveniles) cannot be rejected, as in all three cases, G-tests were not significant (Table 1). In summary, the species is strictly saxicolous without preferences for particular substructures within this habitat.

None of the ANOVA comparisons among the different habitat categories and factors (males, females and young separately, or adults against juveniles) led to significant results. Significance level was barely approached solely in the use of rocks when adults and juveniles were compared ($F_{1,153}$ = 3.77; P = 0.054), in that rocky habitat was slightly less preferred in the juveniles. This age class occurred more frequently in stony areas (as is typical in lacertids, where juveniles are the pioneer age class).

The species lives in gently stepped slopes where large boulders are dominant, with mosses and lichens growing on their surfaces. These plants indicate comparatively moist conditions and boulder stabili-ty, and would not have developed to such an extent if the rocks were geologically active (i.e., moving). The presence of large rock accumulations is important for the availability of deep crevices which represent shelters containing cool and fresh air, allowing for the lizards' subterranean daytime activities even when external temperatures are too high (ARRIBAS 2004; ARRIBAS & CARRANZA 2004).

In the center of these rock boulders, lizards are less exposed to enemies than in the outer ecotonal areas, although the Weasel (*Mustela nivalis*) and *Vipera latastei* BOSCA, 1878 were seen hunting in sympatry with *I. martinezricai* (*Coronella austriaca* LAURENTI, 1768 was detected but not in the bare center of big rock boulders.). Also flying predators such as kestrels may predate upon lizards in these areas. In the bare rock areas, the trophic resources exploited by lizards constitute what VALVERDE (1957) called "aerial plankton", i. e., Diptera, flying beetles and spiders carried to the rocks largely by air currents, and developed outside the lizard's habitat (ARRIBAS unpublished).

Thermoregulation

Body temperatures (BT).- Details of the body, substrate and air temperatures with regard to sex and age classes are shown in Table 2. The mean cloacal body temperature (BT) in active *I. martinezricai* was 33.31±0.12 °C (range = 22.8-39.2 °C; n = 318 measurements). Body temperature did not differ significantly among sexes and ages ($F_{2,315}$ = 1.83, NS), or ages alone (adults vs. juveniles; $F_{1,316}$ = 0.01, NS).

However, a significant difference was found between the BTs of specimens of the blue and green morphs (T_{248} = 2.68, P = 0.007) [green morph: n = 105, mean = 32.95 ±0.20 °C, range = 25.0-36.4 °C; blue morph: n = 145, mean = 33.73±0.19 °C, range = 22.8-39.2 °C], where the temperature of blue specimens was slightly higher than of green ones. Strictly speaking, this difference arose from the male specimens (T_{163} = -3.31, P = 0.001) [green males: n = 66, mean = 32.8±0.28 °C, range = 25-36.3 °C; blue males: n = 99, mean = 34.00±0.22 °C, range = 29.2-39.2 °C], not from the female temperatures which did not differ among the morphs

Table 3: Comparative thermoregulatory parameters in seven *Iberolacerta* species. -- No data.
Tab. 3: Vergleich thermoregulatorischer Kenngrößen bei sieben Arten der Gattung *Iberolacerta*. --- Keine Daten.

Parameter Taxon	Mean BT (°C)	Max-Min (°C)	Range (°C) Spannweite (°C)	BT-ST Correlation	BT-AT Correlation	BT-ST Slope/Anstieg	BT-AT Slope/Anstieg	Reference Quelle
I. bonnali	28.96	20.8-35.2	14.4	$r = 0.37$	$r = 0.33$	0.14	0.21	ARRIBAS 2009
I. aranica	29.49	22-36.5	14.5	$r = 0.38$	$r = 0.43$	0.11	0.28	ARRIBAS 2010
I. aurelioi	28.13	16.6-34.4	17.8	$r = 0.58$	$r = 0.49$	0.20	0.36	ARRIBAS 2010
I. horvathi	28.69	20-35	15	$r = 0.64$	$r = 0.77$	0.55	0.76	DE LUCA 1992
I. monticola	29.3	20.4-35.4	15	$r = 0.56$	$r = 0.56$	0.30	0.52	ARGUELLO & SALVADOR 1988
I. cyreni	29.4	18.4-35.2	16.8	---	---	---	---	MARTIN & SALVADOR 1993
I. martinezricai	33.3	22.8-39.2	16.4	$r = 0.36$	$r = 0.15$	0.14	0.09	Present paper / diese Arbeit

($T_{83} = 0.03$, NS) [green females: $n = 39$, mean = 33.15±0.26 °C, range = 30.3-36.4 °C; blue females: $n = 46$, mean = 33.13±0.40 °C, range = 22.8-36.8 °C]. As a hypothesis, different BTs of blue and green males could mirror differences in the biological competence and fitness of both color morphs, which merits in depth study (Fig. 3).

Air temperatures (AT).- Ambient air temperatures when lizards were active [$n = 394$, mean = 23.77±0.20 °C, range = 13.8-37.1 °C], differed between adults and juveniles ($F_{1,392} = 7.66$, $P = 0.005$). In particular, this difference arose from the comparison of females (active at higher air temperatures) and juveniles ($F_{2,388} = 6.51$, $P = 0.001$). For details of air temperatures relative to sex and age classes see Table 2. Summer temperatures in the area can reach high values (maximum measured was 37.1 °C, but can probably be higher during thermal waves of African air masses).

Substrate temperatures (ST).- Substrate temperatures at which lizards were active [$n = 393$, mean = 30.08±0.31 °C, range = 16.5-52.1 °C] did not differ between adults and juveniles ($F_{1,391} = 0.47$, NS), but among adults, females were found active at higher substrate temperatures than males ($F_{2,388} = 4.99$, $P = 0.007$). Substrate temperatures according to sex and age classes are summarized in Table 2.

Thermoregulative strategies.- Thermoregulation parameters of the various *Iberolacerta* species are compared in Table 3.

Iberolacerta martinezricai showed the highest mean body temperature (33.3 °C) within the genus (from 28.13 °C in *I. aurelioi* to 29.4 °C in *I. aranica* and *I. cyreni*). This high BT plausibly evolved during a period of adaptation to the Mediterranean climate: this did, however, not happen in other congeneric species. Nonetheless, BT of *I. martinezricai* is most similar to the median temperature calculated from 53 lacertid lizard species (33.8 ºC), mainly not high mountain species (CASTILLA et al. 1999). These authors claimed that within a given species, lizards, if freed from other constraints, frequently show fairly constant mean BTs (thermal rigidity *sensu* VAN DAMME et al. 1989), whereas even among closely related species, body temperatures tend to be different and vary related to the

lizards' biogeographical origins rather than current environmental conditions (BAUWENS et al. 1995). The BTs found in *I. martinezricai* do not comply with this model, in being clearly higher than of other congeners and rather in agreement with the ecological characteristics of the inhabited localities.

The range of observed BTs at which *I. martinezricai* was active (39.2-22.8 = 16.4 °C) was similar as in other low mountain *Iberolacerta*, which all are moderate thermoconformists and able to deploy their activity within a rather wide range of temperatures (for references see Table 3). The maximum body temperature registered (39.2 °C) was exceptional, as already short-termed exposure to BTs above 40 °C is lethal (ARRIBAS 2007 and unpublished) if the lizard is not given the opportunity to hide and cool. Even at substrate temperatures as high as 47.8 °C, the BT of a lizard that had taken refuge under a stone was only 36.5 °C.

The slopes of the BT versus ST and AT correlations were significantly different from 1 (if there were no thermoregulatory behavior, the lizards' rhythm of warming up would exactly parallel the heating rhythm of the substrate or air, resulting in a slope of 1). In the relationship between BT and ST, the slope was 0.14 (BT = 28.9225 + 0.1396 ST; R^2 = 0.1324), whereas it was 0.09 in the relationship of BT and AT (BT = 31.0305 + 0.0929 AT; R^2 = 0.0254).

This data shows that *I. martinezricai* is an effective (and fairly precise, see below paragraphs) thermoregulator in respect of substrate temperatures (ST) with the slope of the regression line being clearly different from 1. This thermoregulatory efficiency relative to the substrate temperatures (ST) is equivalent to the corresponding abilities of the high mountain lizards of the sugbenus *Pyrenesaura* (*I. bonnali*, *I. aranica* and *I. aurelioi*) and exceeds that of other low mountain species such as *I. monticola* and *I. horvathi* the slopes of which are closer to 1 (for references see Table 3). In fact, the crucial thermal problem that the high mountain *Pyrenesaura* do face is not the cold, but the overheating of the substrate (ARRIBAS 2007, 2010). Similarly, high STs could be responsible for the increased thermoregulation efficacy of the middle mountain species *I. martinezricai*.

Regarding air temperatures (AT), the slope of the regression line is even more different from 1, but the correlation is so low that there is no indication that the lizard thermoregulates in this respect. In fact they seem to do nothing in particular reaction to increased ambient air temperatures; they hide when ATs rise in parallel to the habitat's increased exposure to the sun, to cool in the crevices and later utilize high ATs to be active without direct sun-basking.

To visualize the precision of thermoregulation in *I. martinezricai*, the body temperatures (BT) and their relationships with both air (AT) and substrate temperatures (ST) are shown in Figs. 4A and 4B. Correlation of BT was higher with ST (r = 0.36; P = 0.0001) than with AT (r = 0.15; P = 0.0000). This difference was still present when the effect of the third variable was extracted (partial correlation BT-ST, effect of AT extracted: r = 0.33; partial correlation BT-AT, effect of ST extracted: r = 0.07). As a result, the species is fairly precise when thermoregulating relative to the substrate temperature (ST) but totally imprecise (or not at all thermoregulating) with air temperature (AT).

Once the BT declined below activity level, warmth gained by tigmothermy (e.g., when lying under a flat stone on top of a warm big rock) may not result in BT rise sufficient to resume activity but to continue digestion for a longer time.

In summer, when ambient morning temperatures rise quickly, activity began almost without any preceding basking, as the animals were able to achieve their activity temperatures without direct sun exposure. Similarly, activity in absence of direct sun (due to orographic conditions) was observed during the afternoon. In general, and as is usual with other mountain lizards (ARRIBAS 2007 and pers. obs. in all the Ibero-Pyrenean species), a moderate wind increased basking time and prolonged the daily activity of the animals. The passage of a cloud produced a drop in air temperature of up to six degrees. And thus in summer, lizards became increasingly active with the lowering of the temperatures after a storm. On cloudy days with mild temperatures, the animals left their shelters at BTs from 29.2 to 33.8 °C (22.7-26.4 °C AT and 26.4-33.1 °C ST).
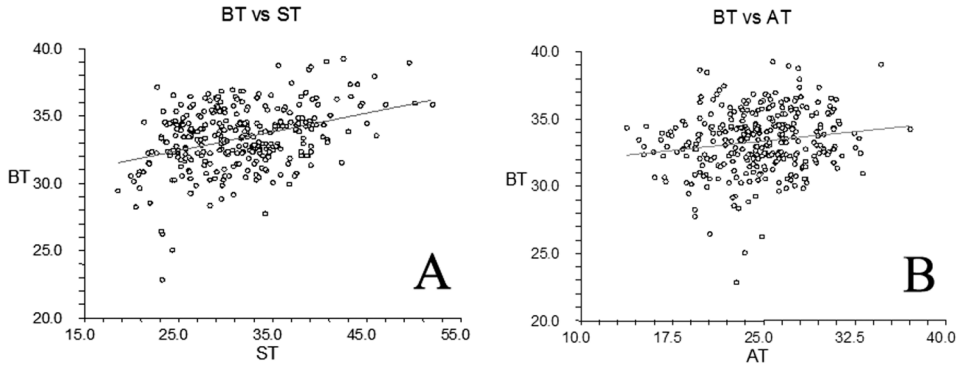
Fig. 4: Scatter plots and regression lines of body temperatures (BT, °C) versus (A) substrate temperatures (ST, °C - left), and (B) ambient air temperatures (AT, °C - right) of *Iberolacerta martinezricai* (ARRIBAS, 1996). Regression line equations and determination coefficients (R^2) are given in the text.

Abb. 4: Streudiagramme und Regressionslinien zur Darstellung der Beziehung zwischen Körpertemperatur (BT, °C) und (A) Substrattemperatur (ST, °C - links) sowie (B) Lufttemperatur (AT, °C - rechts) bei *Iberolacerta martinezricai* (ARRIBAS, 1996). Die Gleichungen der Regressionslinien und die Determinationskoeffizienten (R^2) sind im Text angegeben.

During another meteorological extreme, very dry and hot weather as can occur in the middle of August, there were days when no lizards were seen during day as they did not leave their shelters (aestivation?). The animals sheltered deep in the crevices when the ambient temperature rose excessively. The BT of a burrowed lizard was e.g., 36.6 °C while the rock surface temperature was 47.8 °C. Maximum ST measured on a rock was 61 °C. The highest BT measured (39.2 °C) was detected in a lizard trapped under a culvert without a chance of escape. The animal displayed anomalous behavior, including quick movements and tremors, and probably was close to a critical temperature. At the accidental death of a juvenile, the BT was registered to be 43.6 °C (50 °C ST). Thus, lethality must be expected at body temperatures above 40 °C, similar to other *Iberolacerta* (40.6 °C for *I. aranica*; ARRIBAS 2007).

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