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DISTRIBUTION AND HABITATS OF SCHREIBER'S GREEN LIZARD (*LACERTA SCHREIBERI*) IN PORTUGAL

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We describe the habitats of the endemic Iberian lizard *Lacerta schreiberi* in Portugal and determine those habitat components that best explain the presence of the species. The geographic distribution of *L. schreiberi* in Portugal was also determined through extensive field surveys. The previously known distribution area was enlarged by 150% and new isolated populations were detected. The area occupied by the three previously known southern isolates was delimited and increased by 300%. The species is usually restricted to the margins of rivers and streams. Major habitat characteristics that correlate with the presence of the species are water velocity and quality, dominant species in the tree and shrub strata, streams surrounding the biotopes, and altitude. Nevertheless, the selection patterns that *L. schreiberi* seems to exhibit are only a consequence of its preference for the Atlantic climate. Consequently the presence of the species in a given watercourse seems to be more dependent on the climate of that region than on the intrinsic characteristics of that watercourse.

INTRODUCTION

Habitat destruction and fragmentation have been considered the major factors of species decline and extinction (e.g. Dickman, 1987; Soulé, Alberts & Bolger, 1992). Therefore identification and characterization of species habitats is a fundamental step in any conservation plan. Several methods for evaluating habitats (US Fish and Wildlife Service, 1980) and their suitability (US Fish and Wildlife Service, 1981; Wakeley, 1988) have been developed, as well as ways of integrating them with other ecological information (Wildlife Working Group, 1991).

Schreiber's Green Lizard (*Lacerta schreiberi*, Bedriaga 1878) has been studied in Portugal in order to establish a conservation strategy, in which we plan to incorporate habitat information (Brito *et al*, submitted a). Our aim in this paper is to identify precisely *L. schreiberi* habitats (since it is already known that it inhabits margins of watercourses, e.g. Barbadillo, 1987) and to detect which habitat components correlate most with the presence or absence of the species. Simultaneously we describe the distribution of the species, with detailed comments for the isolated populations, since a previous distribution map has been presented in Brito, Brito-e-Abreu, Paulo, Rosa & Crespo (1996), but on a more general scale.

L. schreiberi is a medium-sized lizard (snout-vent length 117-120 mm) endemic to the Iberian Peninsula, with a markedly Atlantic distribution. In Spain it occurs in Cantábria, Astúrias, Galicia and the Central System mountains, and in Portugal it is present north of the river Tejo. In both countries there are several known isolated populations in the South (Marco & Pollo, 1993; Brito et al., 1996), such as the Sintra, Monchique/Cercal and S. Mamede mountains in Portugal, and the Las Villuercas, Toledo, San Andrés and Morena mountains in Spain. These isolated populations occur in mountains which are "Atlantic islands" surrounded by areas of strong Mediterranean influence. *L. schreiberi* inhabits the margins of streams and rivers, generally in very humid places, being strongly influenced by climatic variables, especially rain and insolation (Brito et al., 1996; submitted b). It is a good climber of stone walls and bushes, and feeds mostly on Coleoptera, Formicidae and Diptera (Marco & Pérez-Mellado, 1988).

METHODOLOGY

DISTRIBUTION

Selection of the sampling area was based on the previously known distribution, assembled from the works of Malkmus (1981; 1995), Barbadillo (1987), De La Riva (1987), Crespo & Oliveira (1989) and Marco & Pollo (1993). Fieldwork was carried out between March and August in the years 1994 to 1996. We sampled 781 watercourses and margins, distributed in 412 UTM 10 x 10 km squares (Fig. 1), which represents 44% of the area of Portugal. We only sampled watercourses and adjacent areas because this is the habitat to which the species is mainly restricted (Malkmus, 1981, 1995; Barbadillo, 1987; De la Riva, 1987; Crespo & Oliveira, 1989). The field sampling took the form of a visual encounter survey lasting about 20 min and/or 100 m of streamside habitat.

All information was compiled in a database and represented as occurrence points in UTM 10 x 10 km squares. For the isolated populations we used a more precise scale - UTM 1 x 1 km. For Sintra mountain we also used information collected by Marques, Paulo & Crespo (1995), while establishing a conservation plan for the herpetofauna of that area.

HABITAT

In every sampled watercourse we also gathered information on variables that characterized the habitat. In Table 1 we present the thirteen variables used and lev-

TABLE 1. Variables and levels used for characterization of the watercourses.

Variable	Levels
Altitude	Metres above sea level
Orientation	N, W (includes NW and SW), S and E (includes NE and SE)
Average width	0.0-1.0, 1.0-2.5, 2.5-5.0, 5.0-7.5 and >7.5 m
Depth	0.00-0.25, 0.25-0.50, 0.50-0.75, 0.75-1.00, >1.00 m
Water velocity	Zero, medium, fast and very fast
Water quality	Dry, clear, inorganic turbidity, organic turbidity, polluted and very polluted
Margin substratum	Sand, soil, stone, soil and stone, rock piles, stone walls and others (clay and cement)
Dominant species in tree strata	Narrow-leaf ash (*Fraxinus angustifolia*), pine (*Pinus pinaster*), Mediterranean trees (*Quercus faginea, Q. rotundifolia, Q. suber, Ceratonia siliqua* and *Nerium oleander*), poplars (*Populus* sp.), exotic species (*Eucalyptus* sp., *Cupressus* sp. and *Acacia* sp.), orchards, marsh species (*Arundo donax* and *Phragmites* sp.), willows (*Salix* sp.) and Atlantic trees (*Alnus glutinosa, Betula pubescens, Castanea sativa, Quercus robur* and *Q. pyrenaica*).
Dominant species in shrub strata	Mediterranean species (*Quercus coccifera, Pistacia lentiscus, Tamarix africana* and some plants from families Cistaceae and Ericaceae), brambles (*Rubus* sp.), marsh species (*Juncus* sp., *Phragmites* sp. and *Scirpus* sp.), Atlantic species (*Alnus glutinosa* and some plants from families Cistaceae and Ericaceae), gramineous (unidentified plants) and other species (exotics, *Crataegus monogyna, Smilax aspersa* and *Cytisus* sp.)
Percent cover of tree + shrub stratum	0-20, 20-40, 40-60, 60-80 and 80-100%
Surrounding biotope	Olive cultures, shrubby areas, pinewoods (*Pinus pinaster*), diverse pinewoods (*P. pinaster* with dense undergrowth, or other less represented species), cork and holm oak groves (*Q. suber* and *Q. rotundifolia*) groves, *Eucalyptus* sp. forests, urban areas (villages or towns), irrigated and arid agricultural systems, English (*Quercus robur*) and Pyrenean (*Q. pyrenaica*) oak forests, and distinct montane agricultural valleys with and without pine woods.
Intensity of human activities	No human activities or abandoned agricultural areas, leisure areas, agricultural areas with few houses, orchards, vineyards, apiculture or pastures; previous level with tarred roads or more houses; small villages; towns, cities or any other human activities, that completely destroy the surrounding area.

els considered. Altitude was only used as a variable for the isolated populations because in other works at a national scale (Brito *et al*., 1996; submitted b) it does not explain the presence of the species. The variables water velocity, water quality and percentage of cover of each stratum were locally estimated through visual evaluation.

According to Brito *et al*. (1996; submitted b), climate, particularly precipitation and insolation, is strongly correlated with the presence of *L. schreiberi*. Therefore it is difficult to separate habitat selection from presence/absence due to climate constraints. In the northern region climate is relatively constant and suitable for the presence of *L. schreiberi*, while the isolated populations appear in less favourable climatic regions (Brito *et al*., 1996; submitted b). Therefore we analysed separately data from the northern region and from the isolated populations.

For the three regions considered - North of the river Tejo, Monchique/Cercal and S. Mamede - the statistical treatment was identical. In all variables we used Chi-squared tests (Seigel & Castellan, 1988) to test if the relation between the different levels of variables and the presence or absence of the species is significant or if it is only due to different sampling efforts. For each class of a given variable, the difference between observed and expected frequencies of presence of the species indicates the preference or avoidance for that class.

RESULTS

DISTRIBUTION

Fig. 2 shows the distribution of *L. schreiberi* in Portugal, with an increase of 150% relative to the previously known range. Of the total area of the Portuguese distribution, 61% of the squares correspond to

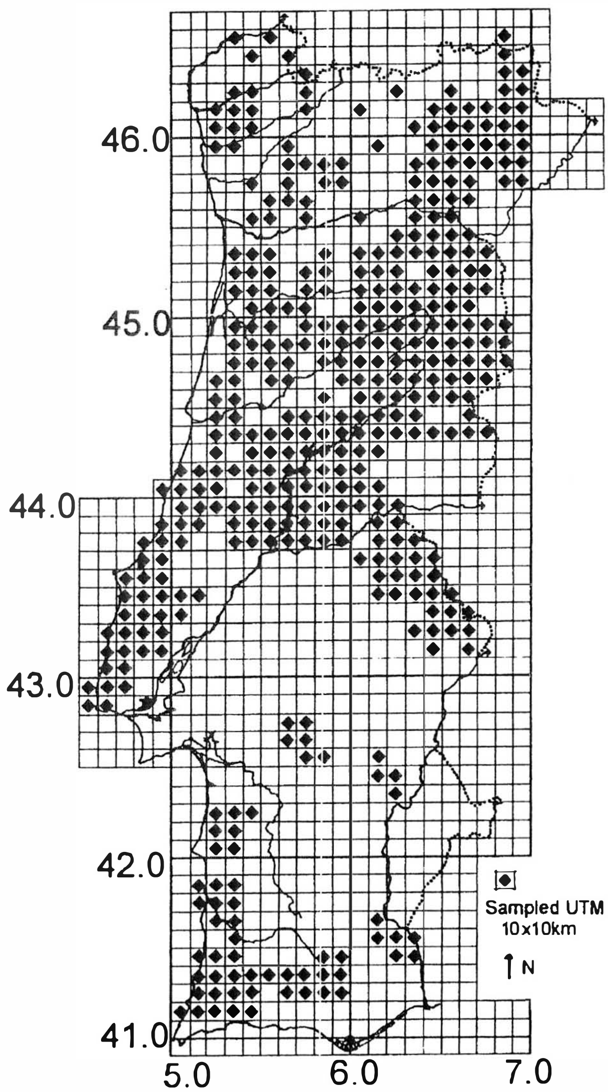

FIG. 1. Sampled area between 1994 and 1996.

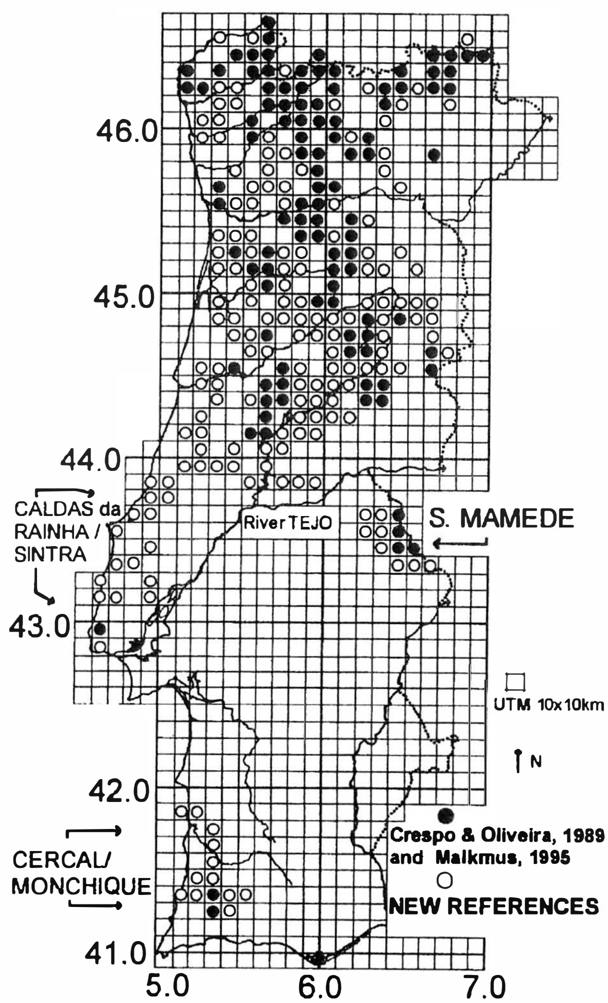

FIG. 2. Distribution area of *L. schreiberi* in Portugal.

new information while only 39% correspond to citations from Crespo & Oliveira (1989) and Malkmus (1995). Within the isolated populations there is an increase of 300% in the known occupied area. In Fig. 3 we present the actual total Iberian distribution of *L. schreiberi*.

NORTHERN AREAS IN PORTUGAL

In previous studies, *L. schreiberi* had only been detected in a continuum from the north of Portugal to the region of Ferreira do Zêzere / Coimbra. In the present survey, it has been possible to extend the range of the species almost as far as Sintra mountain. Although it is relatively abundant in the region of Caldas da Rainha / Montejunto, populations are very fragmented, occurring discontinuously between watercourses, due to increasing human intervention with reduction in habitat availability and quality. Fig. 2 may appear to indicate a continuous distribution from Caldas da Rainha up to Sintra Mountain, but this is not the case due to high fragmentation levels as can be seen in Fig. 4. In this area, from a total of 200 1 x 1 km sampled squares, Marques *et al.* (1995) and our own survey only detected the species in 18 of them, which represents 9% of the total sampled area. Sintra mountain is where *L. schreiberi* populations have the greatest risk of extinction, being detected by Marques *et al.* (1995) and our survey, in only five locations: Marmeleiros stream, Urca stream, lagoons of Monserrate, Monserrate Park and Colares stream, distributed within four 1 x 1 km UTM squares (Fig. 4).

S. MAMEDE

Around this mountain there was also an increase in the known distribution area (Fig. 5) especially to the west and south of the mountain. From a total of 79 UTM 1 x 1 km sampled squares, the species was detected in 49, which represents 62% of the sampled area. The species is common above 600 m, descending to 250 m along the streams of Nisa (north-west), Sever (north), Arronches, Xévora and Soverete (south). An isolated population also appears along the Abrilongo stream at the south-eastern extremity of the mountain. The species in this region is strongly associated with the presence of the royal fern (*Osmunda regalis*), an indicator of high humidity.

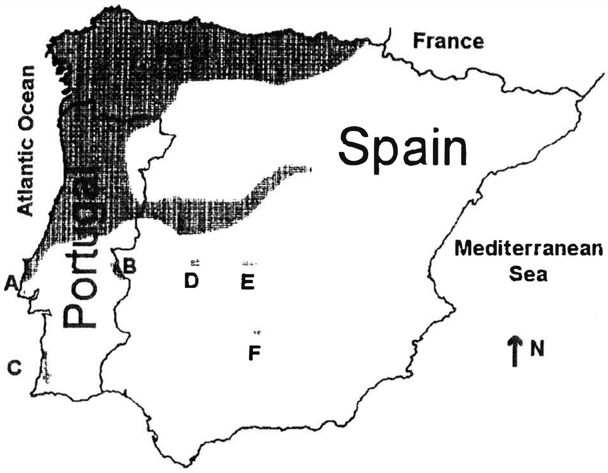

FIG. 3. Iberian distribution area (dark) of *L. schreiberi*. A, Sintra mountain; B, S. Mamede mountain; C, Monchique/Cercal mountains; D, Las Villuercas mountains; E, Montes de Toledo; F, Morena mountain.

MONCHIQUE/CERCAL

Fig. 2 suggests there is a continuum between Cercal and Monchique mountains. Nevertheless there is a high level of fragmentation between the populations (Fig. 6), which are restricted to isolated watercourses and surrounded by unfavorable habitats for dispersion and migration, such as eucalyptus forests or arid agricultural systems. From a total of 121 UTM 1 x 1 km sampled squares the species was detected in 48, which represents 40% of the sampled area. The majority of the observations took place in the higher areas of Monchique mountain (above 400 m), in undisturbed watercourses and sometimes in abandoned agricultural fields. Above 600 m *L. schreiberi* is associated with the presence of Rhododendron (*Rhododendrum ponticum baeticum*), which is a bush associated with an Atlantic climate (Lopez, 1991). There was an extension of the known distribution area to lower areas, along the valleys of Aljezur and Seixe streams. We detected also small isolated populations at the Vale das Amoreiras and Seca streams.

The Cercal mountain populations are more fragmented and are completely isolated from each other, with *L. schreiberi* being detected in only three watercourses: Selas and Godins ravines, and Torgal stream. In these watercourses the surrounding biotope is commonly cork oak groves or arid agricultural systems. Populations are small, with fewer than 3700 individuals (Brito *et al.*, unpublished data), and mostly fragmented, making it very likely that they will become extinct if active conservation measures are not taken.

HABITAT

Due to the agricultural utilization of the river banks, the habitat to which the species is restricted is the margins of the watercourses. However, in high altitude areas, where the surrounding habitat of streams is preserved, it is common to observe the species far from the watercourses at distances up to more than 300 m.

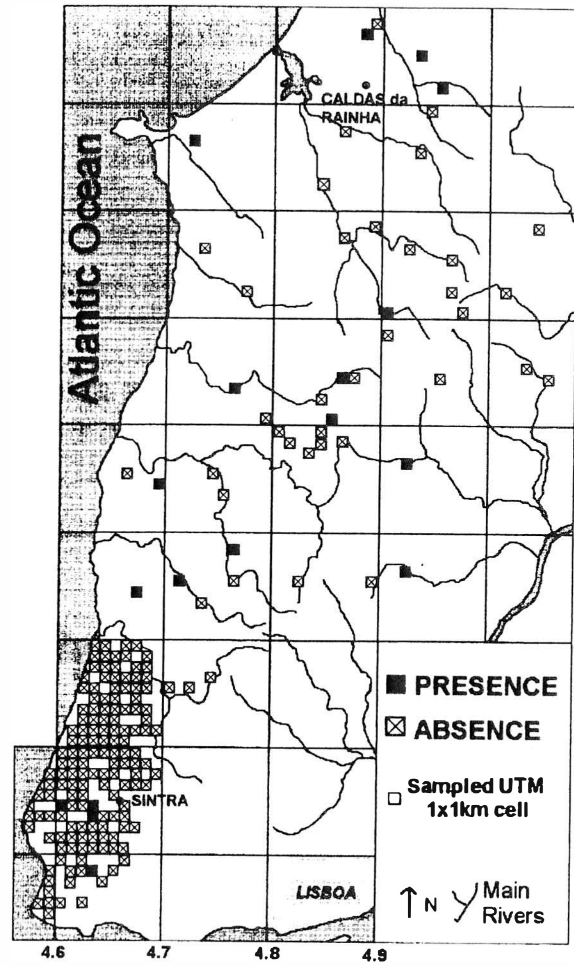

FIG. 4. Distribution area of *L. schreiberi* in the region between Caldas da Rainha and Sintra mountain (Major grid UTM 10 x 10 km).

NORTH OF RIVER TEJO

In Table 2 are presented the five variables in which significant differences ($P<0.01$) were detected.

Water velocity. The species is only absent from watercourses with no running water; i.e. streams which may dry out in summer.

Water quality. This variable partly indicates, as does water velocity, that the watercourses in which *L. schreiberi* does not appear are those that dry out. Nevertheless the species seems to be absent from polluted watercourses but unexpectedly it is apparently indifferent to very polluted watercourses.

Dominant species in the tree and shrub strata. *L. schreiberi* prefers watercourses in which the tree stratum has Common Alder (*Alnus glutinosa*), White Birch (*Betula pubescens*) and English Oak (*Q. robur*), and the shrub stratum has young Common Alder, Royal fern (*Osmunda regalis*) and Ivy (*Hedera* sp.). All these species only appear in habitats with an Atlantic climate (Lopez, 1991). On the other hand *L. schreiberi* seems to avoid places with Narrow-leafed Ash (*Fraxinus angustifolia*), Poplar (*Populus* sp.), Holm Oak (*Q. ilex*), Holm-shrub (*Q. coccifera*), Cork Oak (*Q. suber*), Olive (*Olea europaea*), Tamarisk (*Tamarix* sp.), Carob (*Ceratonia siliqua*), Mastic (*Pistacia lentiscus*) and

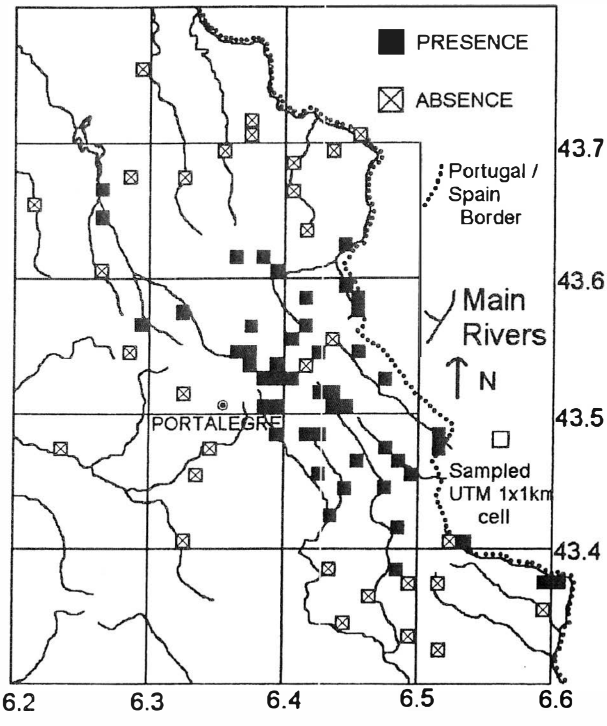

FIG. 5. Distribution area of *L. schreiberi* in the region of S. Mamede mountain (Major grid UTM 10 x 10 km).

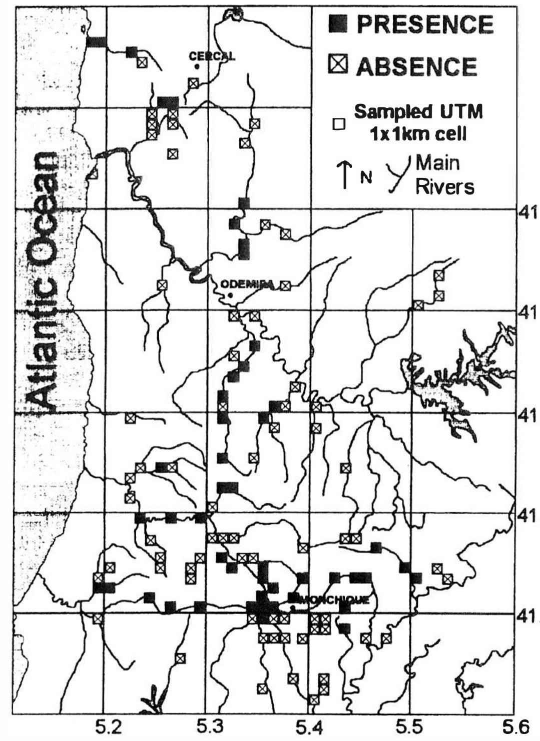

FIG. 6. Distribution area of *L. schreiberi* in the region of Monchique and Cercal mountains (Major grid UTM 10 x 10 km).

Oleander (*Nerium oleander*) in the tree and shrub strata. All these species are typical of Mediterranean ecosystems (Lopez, 1991).

Surrounding biotope. The streams which the species appears to prefer are located in montane agricultural valleys or surrounded by forests of English and Pyrenean oak. The best measure of habitat disturbance, intensity of human activity, was not statistically significant (χ^2 = 6.5, d.f. = 5, P>0.01), which indicates a certain tolerance for human activities with reduced impact on the streams.

Isolated Populations

In Table 3 we present the five variables, for the isolated population of S. Mamede, in which significant differences (P<0.01) were detected. These variables are nearly identical to those for the northern region, which means that even at a smaller scale these variables are those that best explain the habitat selection of the species. The exception is altitude, with the species apparently absent below 250 m. In the Monchique/Cercal population, the only variable that held significant differences was the dominant species in the tree stratum, with results identical to those for the northern and southern Mamede populations.

DISCUSSION

The distribution of this species in Portugal is clearly Atlantic, occurring in all northwestern and practically all northern and central areas. The species does not cross the river Tejo, due to the climatic transition that occurs in this area, with the rainy climate of the north being replaced by the dry conditions of the south. The potential area of occurrence of *L. schreiberi* according to Brito *et al.* (1996, submitted b) also confirms these results.

The isolated populations of Monchique and S. Mamede have relatively large distribution areas and are not very fragmented. Nevertheless, the populations of Cercal and Sintra mountains are extremely fragmented and have few individuals (Brito *et al.*, unp. data), with Sintra being the most threatened. This population was probably in contact with those in the north until quite recently. However, the post-glacial climatic alterations, combined with increasing human pressure between Sintra and Caldas da Rainha, as all along the Portuguese coast, will have fragmented the populations. Since the population of Sintra does not have the capability to recover by itself, a plan has been established in co-operation with the Sintra-Cascais Natural Park (Marques *et al.*, 1996) to assist its recovery.

Some important habitat characteristics seem to be highly correlated with climate, namely the vegetation type and surrounding biotope. The habitat selection patterns that *L. schreiberi* seems to exhibit appear to be the result of its preference for an Atlantic climate. So the presence of *L. schreiberi* in a given watercourse seems to be more dependent on the climate of that region than on intrinsic characteristics of that watercourse. For example, the species is absent from non-flowing streams and those that are dry. Non-flowing streams will possibly dry out completely in the summer, and this seems to be a restrictive condition for the occurrence of the species.

TABLE 2. Chi-squared results for the variables with significant differences to the north of the river Tejo. *N*, number of samples; Obs, Observed frequency; Exp, Expected frequency; Pre, Preference, which can be positive (+), neutral (0) or negative (-); ** $P<0.01$; *** $P<0.001$.

Variable	*N*	Obs	Exp	Pre
Water velocity **	507			
Zero	128	29	50	-
Medium	136	60	53	+
Fast	217	93	84	+
Very fast	26	14	10	+
*Water quality***	507			
Dry	37	2	14	-
Clear	265	111	102	+
Inorganic turbidity	65	26	25	0
Organic turbidity	71	35	27	+
Polluted	52	14	20	-
Very polluted	17	8	7	0
*Dominant spp. in shrub strata***	490			
Mediterranean species	10	1	4	-
Brambles	340	118	134	-
Other sps and exotics	14	4	6	0
Marsh sps	40	16	16	0
Unidentified gramineous	27	14	11	+
Atlantic spp.	59	40	23	+
*Dominant sps in tree strata****	433			
Narrow-leaf ash	36	5	13	-
Pine	18	1	7	-
Mediterranean trees	30	7	11	-
Poplars	21	5	8	-
Exotic spp.	25	7	9	0
Orchards	19	7	7	0
Marsh spp.	38	20	14	+
Willows	78	38	29	+
Atlantic trees	168	84	62	+
*Surrounding biotope****	503			
Olive cultures	33	0	13	-
Shrubby areas	44	10	17	-
Diverse pinewoods	36	9	14	-
Cork and holm oak groves	6	0	2	0
Eucalyptus forests	20	6	8	0
Pine woods	30	10	12	0
Urban development	47	18	18	0
Irrigated/dry farmland	35	16	14	0
English/Pyrenean oak forest	10	7	4	+
Montane farmed valleys+pine	83	42	32	+
Montane farmed valleys	159	76	61	+

L. schreiberi appears to prefer those places where the vegetation is composed of species associated with an Atlantic climate. Habitats receiving high rainfall therefore seem to be important, and the species evidently avoids places with Mediterranean influences. The surrounding biotope also reflects the influence of climate on the presence of the species, because montane agricultural valleys, and English and Pyrenean oak forests, are typical of the northern mountain regions.

TABLE 3. Chi-squared results for the variables with significant differences in the isolated population of S. Mamede. N, number of samples; Obs, Observed frequency; Exp, Expected frequency; Pre, Preference, which can be positive (+), neutral (0) or negative (-); ** $P<0.01$; *** $P<0.001$.

Variable	*N*	Obs	Exp	Pre
*Water velocity****	105			
Zero	36	3	16	-
Medium	23	3	10	-
Fast	29	25	13	+
Very fast	17	15	7	+
*Water quality***	105			
Dry	9	0	4	-
Clear	53	36	23	+
Inorganic+organic turbidity	28	8	12	-
Polluted	15	2	7	-
*Dominant spp. in tree strata****	133			
Narrow-leaf ash	30	1	14	-
Mediterranean trees	7	0	3	-
Poplar	5	0	2	-
Marsh spp.	38	20	19	0
Willows	8	2	4	0
Atlantic trees	45	40	21	+
*Surrounding biotope****	101			
Irrigated/dry farmland	35	8	15	-
Cork oak groves	24	6	10	-
Shrubby areas	11	1	5	-
Olive cultures + pine woods	11	8	5	+
Montane farmed valleys	20	20	9	+
*Altitude (m a.s.l.)****	105			
0 - 250 m	23	0	10	-
250 - 500 m	53	21	23	0
> 500 m	29	25	13	+

Nevertheless, Salvador (1988) and Marco (1994) found variations in substratum and vegetation preferences, but these two studies were carried out in small study areas (maximum: 0.5 ha) when compared to our study. It is therefore to be expected that they found selection at the microhabitat level.

Although the presence/absence of *L. schreiberi* in a watercourse is highly influenced by the climate of that region and far less by any habitat component, it is quite clear that the conservation status of the habitat will play an important role. That is, the streams that are located in climatically favourable regions but in which the habitat is highly degraded or completely altered, will not present conditions for the presence of the species.

Polluted watercourses seem also to be negatively correlated with the presence of the species. The unexpected indifference to very polluted watercourses may be explained by the reduced sampling of this level (less than 3.5%) in relation to the other levels, and not by the unimportance of these highly degraded areas. Pollution, either domestic, industrial or agricultural (arable or pastoral), damages the water quality, and although there has not been any specific study of the effect of polluted water on *L. schreiberi*, it is known that pesticides are easily accumulated in snakes (e.g. Bauerle, Spencer & Wheeler, 1975). Moreover the degradation of water quality reduces insect diversity, which may affect the feeding of lizards (Marco & Pérez-Mellado, 1988). Although *L. schreiberi* normally lives at the margins of watercourses, we observed individuals on top of rocks in the middle of the stream, and even a female under the water (Brito, personal observation). In fact, escape behaviour of this species very commonly involves running to and jumping into the water and seeking shelter among the marginal rocks (Crespo & Oliveira, 1989). So it is to be expected that this lizard may be affected directly by pollution.

The constant presence of water seems to be a crucial factor for this species, for it is usually absent from habitats where there is no running water throughout the year. It is not known at what level the water is important, if it affects the adults physiologically and/or if the development of eggs requires high soil humidity. Physiological studies on the adults and eggs could be made to obtain a better knowledge of this species.

The habitat to which *L. schreiberi* is now mainly confined – the margins of watercourses – is fragile and easily disturbed. Conservation measures for *L. schreiberi* should encompass (1) particular care in every intervention in watercourses especially when destruction of vegetation is involved (regulation of streams, clearing of margins, large dams, etc.); (2) educational campaigns among local communities should be implemented to encourage the preservation of riparian vegetation and the traditional stone walls that surround the watercourses, which are commonly replaced by walls of concrete; and (3) measures to reduce pollution in watercourses should also be implemented.

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