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Montado management effects on the abundance and conservation of reptiles in Alentejo, Southern Portugal

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Abstract This study was carried out in the Iberian-Mediterranean region of Alentejo (Southern Portugal) to discover which 'montado' management practices significantly affected reptile variables (abundance, richness). Field surveys on 30 sampling plots allowed us to identify 370 individuals distributed among 12 terrestrial reptile species (six lizards, one amphisbaenid and five colubrid snakes). The lizard *Psammodromus algirus* was the dominant species ($n = 297$ individuals). The highest species richness was comprised of five species, whilst two or three species were recorded in two-thirds of the sampling plots. Principal component analysis over management variables accounted for 71.8% of the total variance and subsequently helped to reveal four agrosilvopastoral types. Among them, the highest reptile abundance largely overlapped the cork oak montado, while higher cattle stocking rates were estimated (trampling index) to occur in the holm oak areas, affecting significantly the reptiles. Regression models also showed that both reptile abundance and richness were significantly related to montado areas, where the shrub layer is well preserved and cattle are either absent or present at low stocking rates. Adequate management of montado, preserving the shrub patchwork, is crucial for the conservation of reptiles. Livestock stocking rates should also be maintained at a sustainable level of 0.2–0.4 cattle/ha.

Keywords Montado management · Reptile abundance · Cattle trampling

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Introduction

The transformation of large woodland areas in some Mediterranean native ecosystems by human activity over thousands of years has lead to a savannah-like landscape that is predominant in southern Portugal, the so-called 'montado', which is the equivalent of the Spanish 'dehesa' (Blondel and Aronson 1999; Joffre et al. 1999; Vicente and Fernández Alés 2006; Surová and Pinto-Correia 2008). It consists of scattered evergreen oak trees, mainly cork oak (*Quercus suber*) and holm oak (*Quercus* [*ilex*] *rotundifolia*), over a matrix of extensive grasslands or shrublands (Costa et al. 2009). With nearly 2.2 million hectares (some authors have estimated up to 4.0 million hectares), 'montado/dehesa' is an agroforestry system that occupies much of the western half of the Iberian Peninsula,

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mainly in the southwest and west: province of Salamanca, foothills of the Central System, Extremadura, Sierra Norte of Seville and the provinces of Huelva and Córdoba in Spain, and the province of Alentejo and the Algarve in Portugal (López-Sáez et al. 2007). Cattle breeding at low stocking rates (beef), sheep (lamb), Iberian pig (ham) and cork production have traditionally been the most economically important activities in the montado. Such agrosilvopastoral land uses mimic putative natural ecosystems that may sustain high levels of biodiversity, both within and between habitat/biotype scales, and thus are to be preserved under the EU Habitats Directive (Plieninger and Wilbrand 2001; Ramírez and Díaz, 2008).

However, not all montados can be considered as good examples of sustainable management and either abandonment or intensification may seriously endanger the functioning of the ecosystem (Pinto-Correia and Mascarenhas 1999; Gaspar et al. 2007; Plieninger 2007). Rural depopulation and long-term abandonment of traditional agricultural activities allowed large amounts of shrub cover to develop, while lack of regeneration of the wooded layer due to mechanized agriculture and increased stocking rates converted montado into open grassland. In light of the recent Common Agriculture Policy (CAP), the montado farms with higher livestock rates or a high level of Iberian pig production are the most profitable (Gaspar et al. 2007) and thus the montado is becoming a mainly silvopastoral system (Surová and Pinto-Correia 2008). The chronic lack of natural tree regeneration results in habitat loss and fragmentation, negatively affecting the ability of the montado to support rich biodiversity (Tucker and Evans 1997; Plieninger 2006; Ramírez and Díaz 2008; Tárrega et al. 2009).

Besides economic and social circumstances, ecological conditions also play a determinant role in the montado ecosystem. At a regional scale, Joffre et al. (1999) found an association between tree density and mean annual precipitation that suggests ‘an optimal functional equilibrium based on the hydrological equilibrium hypothesis’. These authors also pointed out the edaphic control of tree density. Tree distribution creates two distinct microclimates: one beneath and the other outside the tree canopy (Huber-Sannwald and Jackson 2001; Hussain et al. 2009). This heterogeneity produces environmental gradients that induce different animal responses and thus community diversity across the landscape.

Economic, social and ecological montado constraints have a strong influence on ecosystem functioning, affecting the basic habitat components of wildlife such as food, cover and water. Compared to mammals and birds, reptiles have lower mobility and their survival may depend on a particular habitat structure that provides escape from predators (Milne and Bull 2000; Amo et al. 2007). Reptiles also have specific thermal requirements which make them dependent on sunny places for basking (Díaz et al. 2000; Martín and López 2002; Sabo 2003). Assessment of montado management effects on wildlife diversity has mainly focused on bird and mammal populations (Díaz and Pulido 1995; Díaz et al. 1996, 1997; Rosalino et al. 2009), despite the high number of reptile species endemic to the Iberian Peninsula (Pleguezuelos et al. 2002; Cox et al. 2006; Loureiro et al. 2008) and the importance of some of them as key prey in Mediterranean ecosystems (Jaksić et al. 1982, Jaksić and Delibes 1987; Martín and López 1996). The effects of montado management on reptiles have been rarely analysed, although the results of one study showed that some traditional management practices may negatively affect lizard populations, specifically the prevention of regular shrub management and non-natural regeneration of oak trees by managers to favour grazing by domestic animals (Martín and López 2002).

This study was carried out in the Iberian-Mediterranean region of Alentejo (Southern Portugal) aiming to answer the following three questions: (1) What species represent the reptile community in the study area? (2) Are there significant differences in both reptile abundance and richness across different agrosilvopastoral types? (3) What habitat descriptors and management practices significantly affect reptile abundance? Finally, we discuss the implications of results towards reptile conservation under a sustainable way for montado management.

Materials and methods

Study area

The study was conducted in a 6116 ha agrosilvopastoral area near the southern slopes of Serra d’Ossa—a residual horst-mountain (maximal altitude 653 m) that ranges 40 km from the west eastwards—in the Alentejo region of southern Portugal (Fig. 1). The climate is

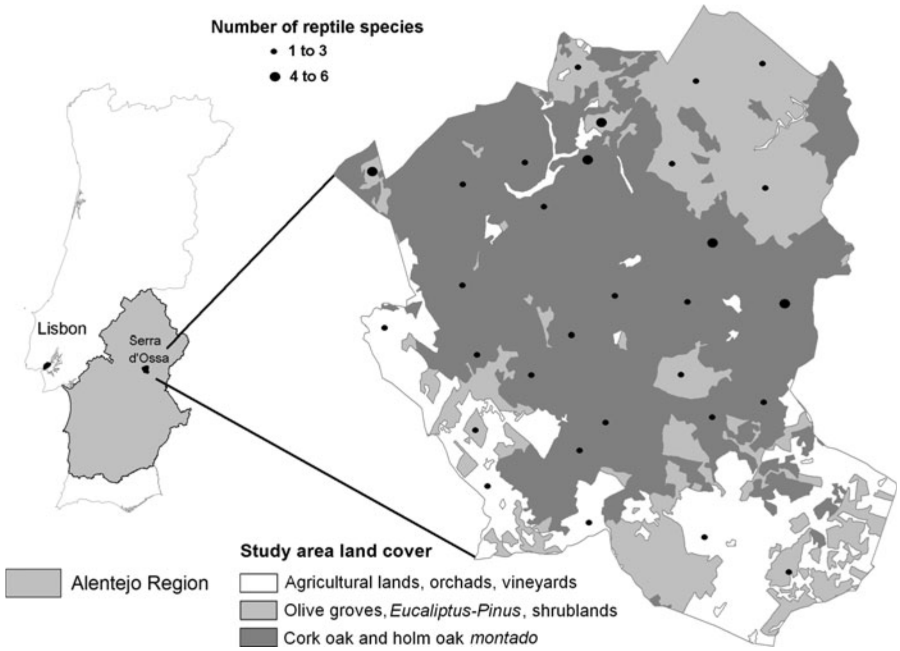

Fig. 1 Main types of land coverage in the study area. *Dots* represent the accumulative richness (number of reptile species) in each sampling plot

Mediterranean mesothermic with hot summers (Aug 31–32°C Tmax) and mild winters (Jan 6–7°C Tmin) and total precipitation approximately 600–750 mm per year, with the rain mainly falling during autumn/winter and early spring (IMP 2008). The area belongs to the Mediterranean Ibero-Atlantic province (Rivas-Martínez and Loidi 1999). Almost 50% of the vegetation cover is the so-called montado, the agroforestry system based on transformed Mediterranean oak forests that comprises a northern part of cork oak (29.7%) and a southern part of holm oak (25.0%) in the study area (Fig. 1). Agricultural lands, olive groves and vineyards occupy 28.2%. *Eucalyptus*, pine (*Pinus pinaster*) stands and shrublands occupy 16.5%. Finally, water courses, uncultivated fields and social areas occupy a relatively small part of the study area (0.6%). Beef cattle production at moderate to high stocking rates (less than 2–3 cattle/ha) constitutes the main activity in many local farms, whereas several large estates are devoted to more extensive production systems where earnings from hunting, firewood and honey reach considerable economic importance

Reptile sampling

Reptile sampling was conducted from May to June 2006, a period when reptiles are particularly active due to it being their mating season (Malkmus 2004, Loureiro et al. 2008). Each sampling survey was started by 9 am and finished at midday. Stratified random sampling was used in order to select 30 sampling plots representing the different vegetation cover types occurring in the study area (e.g. forest, shrubs, agricultural land). Each sampling plot comprised a circular area with a radius of 250 m (19.5 ha) and GPS was used to locate the centre point. Reptiles were exhaustively surveyed by two observers within each plot during time-constrained searches of 1.5 h. A couple of field methods such as zigzag walking transects and surveys of coarse woody/rocky debris were combined (Corn and Bury 1990). Each circular plot was visited twice throughout the sampling period. The best scores were recorded (number of individuals or indirect signs of presence, e.g. snake skins) for each species that had been found in the two replicas. These scores were used to determine the relative abundance of each species.

Agrosilvopastoral types

The following variables were quantified for each sampling plot: percentage of each type of land use and percentage of cover and average height of shrubs. Vegetation coverage was quantified using GIS land cover maps. These maps were based on photo interpretation of digital orthophotographs (date 2005; scale

1:10.000) which were validated with field observations carried out in June 2006. For the average height of shrubs, five height categories (in meters) were used: 1. null, 2. <0.6 m, 3. 0.6–1.0 m, 4. 1.0–2.0 m and 5. 2.0–4.0 m. The stoniness of the soil surface and rocky outcrops was quantified using a similar procedure with percentage classes of soil coverage by stones and rocky outcrops. Pruning, firewood cutting and stone clearance were determined by qualitative analysis in the field. Livestock (cattle) presence in the sampling plot was previously confirmed by direct observation of animals grazing or indirectly when recent excrements were found. The effect of livestock on reptile abundance was only quantified in the sampling plots, where an index of livestock trampling was defined: average number of cattle footprints per m^2; ten plots of 1.0 m^2 were randomly selected in each sampling plot in order to obtain this index. Footprints were detected where the clay component had softened the soil or on the dust layer of paths and open patches.

Data analyses

To determine the agrosilvopastoral typologies and their relationships with reptile abundance and accumulative richness (number of species), a statistical approach based on four steps was used. Before statistical procedures were applied, reptile abundance and richness data were normalized by a log (x + 1) mathematical transformation. The angular transformation (arcsine $\sqrt{x}$) was used to normalize the proportional independent variable data to obtain homogeneity of variances (Zar 1996; Maroco 2003). Statistical analysis started with a principal component analysis (PCA) to reduce the 13 land uses and montado management variables into a smaller number of independent components reflecting habitat characteristics (Díaz et al. 2006). We only considered the determinant variables for each principal component loading with values of at least >0.5 (Maroco 2003). Subsequently, a cluster analysis was performed using the k-means method on the PCA scores with eigenvalues >1.0, using Euclidian distance (squared) as a measure of similarity (Zar 1996). For agrosilvopastorial classification, each large hierarchical cluster was considered a different type. Therefore, we applied tests of hypotheses to determine whether there were significant differences among sampling plots between the two reptile variables and the agrosilvopastorial types (one-way ANOVA) or between reptiles and presence/absence of cattle trampling (t-test). Finally, a stepwise multiple regression analysis was performed to examine the relationships between each reptile dependent variable (abundance, richness) and the PCA (independent) components as quantitative explanatory variables, obtaining a predictive model for reptile abundance and richness, thereby eliminating co-linearity problems (Martín and Salvador 1995; Zar 1996). To determine which of the studied independent variables significantly correlated with reptile abundance, the statistical test values of the partial regression coefficients (null hypothesis H_0: $\beta_i = 0$) were analysed. All statistical analyses were performed using SPSS v.16 (Maroco 2003), except for the cluster analysis where STATISTICA v.6.0 was used. Digital mapping and record plotting were performed using ArcView 3.2. Spatial interpolation through the IDW module of ArcView 3.2., Inverse Distance Weighted, was also applied to investigate spatial distribution of livestock (cattle) trampling index *vs* reptile abundance.

Results

Reptile community

Field surveys allowed us to identify 370 individuals distributed among 12 terrestrial reptile species: six lizards comprising four lacertids *Psammodromus algirus* ($n = 297$), *P. hispanicus* ($n = 1$), *Podarcis hispanica* ($n = 10$) and *Timon lepidus* ($n = 5$); two skinks *Chalcides striatus* ($n = 10$) and *C. bedriagai* ($n = 1$); the amphisbaenid *Blanus cinereus* ($n = 16$); five colubrid snakes *Malpolon monspessulanus* ($n = 19$), *Hemorrhois hippocrepis* ($n = 4$), *Rhinechis scalaris* ($n = 3$), *Macroprotodon brevis* ($n = 3$) and *Coronella girondica* ($n = 1$). The taxonomic nomenclature used is in accordance with the latest review (Carretero et al. 2009).

Psammodromus algirus was recorded in all 30 sampling plots and the data were particularly abundant among oak patches with a shrub layer (Fig. 1). The Iberian three-toed skink *C. striatus* was found in 10 plots scattered across the study area, but always within the herbaceous layer, as expected for its habitat. The eyed lizard *T. lepidus* and the Iberian wall lizard *P. hispanica* were present in 4–5 plots, predominantly in cork oaklands, with a preference for

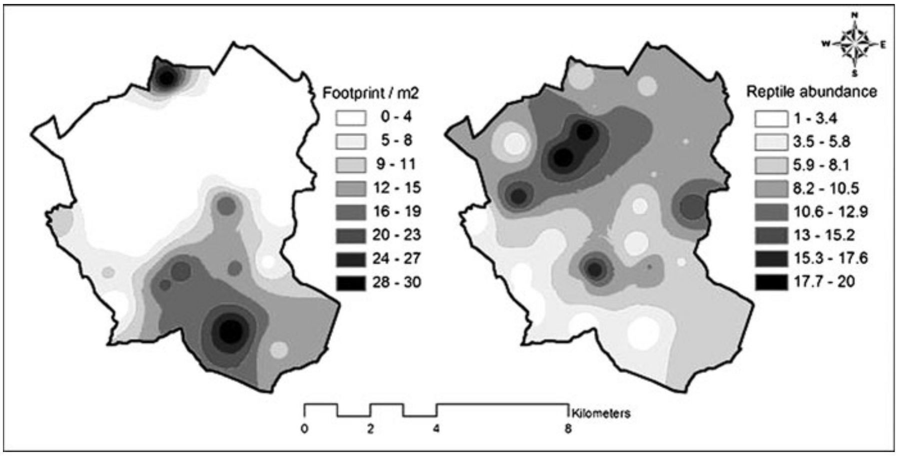

Fig. 2 Spatial distribution of livestock (cattle) trampling index versus reptile abundance using spatial interpolation through the IDW module of ArcView 3.2.—inverse distance weighted

sites with some assemblages of shrubs or trees and/or having some spots of rocky outcrops The amphisbaenid *B. cinereus* was recorded in nine plots covering both cork and holm oak areas in the eastern half of the study area (Fig. 1). The Montpellier snake *M. monspessulanus* appeared in 12 diverse plots. The ladder snake *R. scalaris* and the false smooth snake *M. brevis* were only found in three plots for each species, all placed within the north-western part of the area surveyed (Fig. 1). In general, the reptile abundance largely overlapped the cork oak area (the northern part of the study area), whilst the opposite pattern was observed with the index of livestock trampling—Pearson's correlation, $r = -0.474$, $P = 0.009$ (see Fig. 2). The highest reptile richness (six species) was found twice among the plots. Two or three species was often the modal richness value observed in two-thirds of the sampling plots. Three species constituted the maximum richness for both lizards (lacertid) and snakes. Each single observation for *P. hispanicus*, the five-toed skink *C. bedriagai* and the southern smooth snake *C. girondica* was recorded in three different plots situated in the north-western part of the study area.

Land use and agrosilvopastoral management

The PCA for land use and agrosilvopastoral management variables produced four principal components which together account for 71.8% of the total variance (Table 1). We found a positive correlation between PC-1 and the variables shrublands, pine stands, shrub height and shrub cover percentage, and a negative correlation between the same component and grasslands and livestock trampling index. Thus, PC-1 described a gradient from open grazing areas to bushy and forest areas occupied by shrubs, thick pine formations or by a combination of both these covers. PC-2 showed a positive correlation with Cork oak montado, while PC-2 had negative correlations with rocky outcrops, stoniness of soil surface and livestock trampling index. This component clearly separated fertile soil where cork oak trees can thrive from poor shallow soil deficient in humus and nutrients. PC-3 was positively correlated with Holm oak montado and streams, but negatively correlated with grasslands: in areas where the degree of tree cover was high, pasture tended to be scarce. PC-4 was positively correlated with eucalyptus stands and olive groves, but negatively correlated with shrublands. This component unveiled a gradient from relatively undisturbed natural areas to exotic eucalyptus stands in shallow soil areas, and to olive groves in small areas where montado is a non-profit land use system. The cluster analysis on the 30 sampling plots revealed four major hierarchical clusters, which thereafter were considered as being the main agrosilvopastoral types found in the study area (Fig. 3). Significant differences were found in PC scores across all agrosilvopastoril types, namely in PC-1 (ANOVA: $F = 17.34$, $P = 0.000$), PC-2 (ANOVA: $F = 27.99$, $P = 0.000$) and PC-3 (ANOVA: $F = 16.86$, $P = 0.000$), but not in PC-4 scores (ANOVA: $F = 1.76$; $P = 0.180$). Multiple comparisons (Tukey tests) showed that PC-1 scores were different only between types I and II ($P = 0.005$) and IV ($P = 0.008$), and between types II and III ($P < 0.001$) and IV ($P < 0.001$). PC-2 scores differed between types I and II, III and IV ($P < 0.001$). Finally, the PC-3 scores

Table 1 Principal components analysis using land use and agrosilvopastoral management variables

	PC-1	PC-2	PC-3	PC-4
Cork oak montado	0.16	**0.86**	0.04	0.06
Holm oak montado	−0.35	−0.34	**0.66**	−0.15
Eucalyptus stands	0.41	−0.21	−0.27	**0.54**
Pine stands	**0.80**	−0.42	−0.26	−0.04
Olive groves	−0.02	−0.15	0.21	**0.60**
Grasslands	**−0.54**	−0.16	**−0.62**	−0.23
Shrublands	**0.58**	−0.38	−0.16	**−0.51**
Shrub height	**0.83**	0.05	0.11	0.09
% shrub cover	**0.88**	0.10	0.18	0.16
Rocky outcrops	−0.29	**−0.75**	0.07	−0.01
% stoniness of soil surface	0.47	**−0.76**	0.17	−0.07
Streams	−0.11	0.00	**0.77**	−0.11
Livestock trampling index	**−0.59**	**−0.51**	−0.12	0.45
Eigenvalue	**3.71**	**2.67**	**1.71**	**1.25**
% of explained variance	**28.52**	**20.57**	**13.13**	**9.59**

Correlations greater than 0.50 are in bold

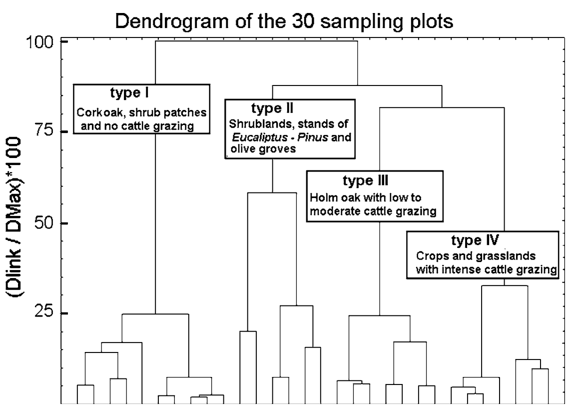

Fig. 3 Dendogram showing four hierarchical clusters of agrosilvopastoril types. K-means cluster method using Euclidean distance as measure of dissimilarity. Minor branches at the bottom represent the 30 sampling plots

showed differences between types I and III ($P = 0.007$) and IV ($P = 0.003$), types II and III ($P < 0.001$), and types III and IV ($P < 0.001$).

Significant differences ($P < 0.05$) in reptile abundance, but not in reptile richness, were found across the different agrosilvopastoral types (Table 2). All multiple comparisons (Tukey tests) showed that reptile abundance was only clearly different between types I and IV ($P < 0.001$). We also found significant differences in reptile abundance, lizard abundance, lizard richness and snake abundance between areas where cattle were present and areas where cattle were absent (Table 2).

Multiple regression analyses showed that reptile abundance was significantly and positively correlated with PC-1, PC-2 and PC-3 ($R^2 = 0.454$, $F = 7.203$, $P = 0.001$, $df = 29$), while reptile richness was significantly and positively correlated only with PC-2 ($R^2 = 0.16$, $F = 5.159$, $P = 0.031$, $df = 1$) (Table 3). Therefore, according to these models, both reptile abundance and richness are significantly related to montado areas, where the shrub layer is well preserved and cattle are absent or present at low stocking rates.

Discussion

Reptile community

All 12 terrestrial species of reptiles found in the study area near Serra d'Ossa were expected in the Alentejo region, according to the national herpetological literature and the sort of habitats present there (Malkmus 2004, Loureiro et al. 2008). Reptile richness in the study area was also similar to other montado areas previously surveyed, not including semi-aquatic species (e.g. Spanish terrapin *Mauremys leprosa*; viperine snake *Natrix maura*) which were not covered by the present sampling scheme, although personal observations had noted their presence in the area (Baptista and Sá-Sousa 2006; Dias 2008). In all three studies lizards were more frequent than snakes, which constitutes a common pattern (Martín and López 2002; Ribeiro et al. 2009), particularly among the lacertid lizards found in these oak forests (*P. algirus*, *P. hispanica* and *T. lepidus*). These lizards did not use habitat at random; *P. hispanica* appeared to prefer rocky patches while *T. lepidus* preferred sites with some vegetation cover and where rocks were present (Castilla and Bauwens 1992; Diego-Rasilla and Pérez-Mellado 2003). Although the problem of detection is not restricted to this species, the abundance of *T. lepidus* might be underestimated in the study area because the probability of sighting the eyed lizards before they retreat into a refuge is largely affected by the transect methods (Díaz et al. 2006). The degree of bias could really only be estimated with marked animals. However, the single observation of *P. hispanicus*

Table 2 Results of one-way ANOVA comparing both reptile abundance and richness (number of species) along agrosilvopastoral types, and of *t*-tests for effects of presence/absence of cattle (based on livestock trampling index)

	ANOVA: agrosilvopastoral types			*t*-test: presence/absence of cattle		
	F	df	*P* value	*t*	df	*P* value
Reptile abundance	5.913	29	**0.003**	2.201	28	**0.037**
Reptile richness	1.195	29	0.331	1.545	28	0.135
*Lizard abundance	3.258	29	**0.038**	2.230	28	**0.034**
*Lizard richness	0.364	29	0.780	2.413	28	**0.023**
Snake abundance	1.112	29	0.362	2.260	28	**0.032**
Snake richness	1.774	29	0.177	1.570	28	0.128

Significant *P* values <0.05 are in bold

* only lacertid species

Table 3 Models obtained by stepwise multiple regression analyses with land use and agrosilvopastoral management (independent) variables that influence both reptile abundance and richness (dependent variables)

Independent variables	B ± SE	*t*	*P* value
Reptile abundance			
Intercept	3.329 ± 0.162	20.539	0.000
PC-1	0.504 ± 0.162	3.108	0.005
PC-2	0.408 ± 0.162	2.519	0.018
PC-3	0.384 ± 0.162	2.367	0.026
Reptile richness			
Intercept	2.733 ± 0.185	14.814	0.000
PC-2	0.419 ± 0.185	2.271	0.031

B regression coefficients and their standard errors (*SE*) are shown, providing results from *t*-tests (*t*) and associated probability (*P*) values

may reflect the scarce abundance of this diurnal lizard in the study area. Indeed, *P. hispanicus* inhabits dry Mediterranean areas where it is dependent on low vegetation cover (e.g. open, loose soil, especially areas with sparse scrubs such as lavender and thyme) and its population is known to greatly fluctuate between years (Carretero 2008; Pleguezuelos et al. 2008). Among the snakes, *M. monspessulanus* was clearly a generalist species, widespread throughout Mediterranean different habitats, and so it was commonly found throughout the study area (Pleguezuelos 1998). Otherwise, the secretive *Macroprotodon brevis* was hard to find in field surveys and the three individuals observed was a good record of its presence in its favoured habitats. Moreover, this snake has a tendency to be herpetophagous and the amphisbaenid *Blannus cinereus* is one of its favourite preys; this was also frequently found in the study area (Pleguezuelos et al. 1994; Malkmus 2004). The other herpetophagous snake, *Coronella girondica*, was only detected once, despite the relative abundance of its lizard prey (Luiselli et al. 2001).

In the study area, *Psammodromus algirus* contributed most to the reptile surplus in order of abundance, followed by the presence of some widespread Iberian-Mediterranean reptiles, such as *B. cinereus*, *P. hispanica*, *T. lepidus*, *C. striatus* and *M. monspessulanus* (see similar cases in Amo et al. 2007; Ribeiro et al. 2009). As a generalist species, *P. algirus* occupies a wide range of Mediterranean forested and shrubby habitats, even if such habitats are degraded (Carretero et al. 2002). However, this lizard strongly responds to changes in the structure and quality of microhabitats, particularly concerning the shrub layer (Díaz et al. 2000; Santos et al. 2008). In this regard, *P. algirus* might be the best indicator of the effects on reptile abundance driven by montado management practices promoted by farmers near Serra d'Ossa. Indeed, the analyses of variance showed that lizards preferentially used forested areas with shrub layers, avoiding open herbaceous spots in the study area (type I vs. type IV), while lizard abundance increased when the understorey shrub vegetation increased (type I). This seemed to us to correspond to a clear pattern because the Tukey test used for all pairwise comparisons is more conservative, for example, than the SNK (Student–Newman–Keuls) test, controlling the errors of all comparisons simultaneously, while the SNK controls errors among tests of k means (Zar 1996). Thus, the Tukey test is less likely to determine that a given difference is statistically significant.

Land use and agrosilvopastoral management

The four agrosilvopastoral types obtained by cluster analysis revealed different practices in the montado management. Type I enhanced homogeneous patches of cork oak that were mainly managed towards cork production, whereas shrub patches promoted a heterogeneous mosaic due to periodic and differential cutting interventions by farmers on shrubs, aimed at fire prevention or soil enrichment through plantations (Acácio et al. 2009). These patches were not usually grazed by cattle as wire fences kept them away. Type II comprised a heterogeneous arboreal layer (pine or eucalyptus stands, olive groves) that covered a more homogeneous shrub layer (e.g. *Cistus ladanifer*) where stones and rocky outcrops were abundant. For this type II, both the poor quality of soil and the higher slopes of land did not facilitated tillable uses and crop planting (Costa et al. 2009). Type III predominantly corresponded to holm oak lands with cattle breeding at low to moderate stocking rates. However, regeneration of holm oaks and associated shrubs often fails when livestock stocking levels increase (Plieninger 2007). In these plots, holm oak trees are periodically pruned of overshadowing and weak branches. Traditionally, this is thought to be beneficial in increasing acorn production and so making extensive rearing of Iberian pigs profitable, as these are efficient acorn consumers (Cañellas et al. 2007). This practice is also thought to favour the hunting of wildlife (Cañellas et al. 2007). Remnant branches are used as timber wood, firewood or to produce charcoal; in the study area, however, they were often put aside in piles on the ground and may have become a form of shelter for reptiles and other small animals (Martín and López 2002; Márquez-Ferrando et al. 2009). Finally, type IV consisted of farms placed on the lower slopes, managed with crops and pastures that have predominantly been maintained in rotation through a ploughed-fallow system. Here, holm oak trees were sparse and constituted much less than 25% of the local land cover, while cattle grazing was more intense and often destructive, creating open patches with highly trampled spots (Gaspar et al. 2007; Plieninger 2007).

Reptile conservation under montado management

The traditional management of cork oak plots allows a scattered tree layer with a mosaic of shrubs that favours lizards and snakes (Díaz et al. 2000; Martín and López 2002). Without permanent management of this kind, these lands would gradually recover to the dense shrublands and closed forests observed after agricultural land abandonment (Moreira and Russo 2007; Acácio et al. 2009). The absence of lizards from densely forested fragments recommends that forest management should be preserved in order to help maintain habitat quality for lizards; land uses such as low livestock grazing or selective tree extraction could improve thermoregulation opportunities for lizards, predator avoidance and foraging success (Vitt et al. 1998; Martín and López 2002; Santos et al. 2008). In contrast, wildfires, severe droughts, intensive livestock grazing and other management practices drastically remove the shrub layer (Moreira and Russo 2007; Acácio et al. 2009). These practices tend to eliminate reptiles because, as ectothermic vertebrates, they need refuges for avoidance of extreme environmental temperatures, concealment from predators and oviposition sites (Woinarski and Ash 2002; Santos et al. 2008; Márquez-Ferrando et al. 2009). Nevertheless, some snakes (*Malpolon*, *Rhinechis*, *Hemorrhois*) occasionally drift into farms, probably attracted by prey such as rodent mammals (field observations; Malkmus 2004; Márquez-Ferrando et al. 2009). In the study area the grasslands and cereal fields were rarely occupied by reptiles, even if holm oak trees were present, apparently because low-lying shrubs were scarce here (type III and type IV). Coincidently, livestock trampling was more intense in these same areas (type IV). Therefore, shrub clearance to favour grass growth or for cereal fields and higher local stocking levels of cattle may be the main factors that negatively affect reptile populations in this area near Serra d'Ossa. For example, the abandonment of extensive agriculture and related traditional practices has caused a large decline in population numbers of the eyed lizard *T. lepidus* in France (Cheylan and Grillet 2005). In Catalonia, it was demonstrated that agricultural land use has the greatest effect on reptile diversity (Ribeiro et al. 2009). Thus, reconciling agriculture and conservation is possible if agricultural practices are developed in sustainable ways (Biaggini et al. 2006; Billeter et al. 2008). In our study area, we can therefore conclude that adequate management of montado to preserve the shrub patchwork is crucial for the conservation of reptiles. Any sort of agricultural intensification should be avoided. Additionally, if farmers leave wood piles on the ground and continue to heap up piles of stones and boulders near the edges of agricultural fields, as was traditionally done, then reptiles would find shelter here and they may be able to recover, demographically, from degraded habitats. Otherwise, we suggest that cattle stocking rates should be maintained at sustainable levels with 0.2–0.4 cattle/ha (Olea and San Miguel-Ayanz 2006).

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