Estudios

Space use, distribution and conservation of the Spanish pond turtle (*Mauremys leprosa* Schewigger, 1812). A review (Chordata, Geoemydidae)

Uso del espacio, distribución y conservación del galápago leproso (*Mauremys leprosa* Schweigger, 1812). Una revisión.

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Abstract

The Spanish pond turtle (*Mauremys leprosa* Schweigger, 1812) is an ibero-magrebian species; some scarce populations are found in south France, and small introduced populations in Italy and Balearic Islands. In general terms, the species shows important population decline in many areas, albeit an increment has been reported in northeastern Spain, and is relatively abundant in northern Africa. Although the knowledge on its geographical distribution has increased, especially during the last years, we can still find knowledge gaps and controversial aspects on its relationships with the environment. The aim of this work was to update the knowledge of the space use by the Spanish pond turtle at general, regional and local level, and contribute to the bases of future research and management recommendations. According to the available knowledge, the species shows preference for deep-water bodies, with high vegetation covers, rocky beds, high solar radiation and sloping banks. It has suffered high stress by habitat alterations. In Portugal, the species is more abundant in the southern half of the country. In Spain, it tends to be absent or relict in some central and northwestern zones. The French populations are small and isolated. In Africa, it is cited in the Maghreb. The species is protected in Europe, and included as Vulnerable in the Red List of European Reptiles. In Africa, it is relatively protected only in Algeria and Morocco. The revision shows a fast-growing knowledge in the last years, though with important gaps, and the need of new studies and conservation measures, to prevent the population decline and provide effective protection for the Spanish pond turtle and its habitat.

Resumen

El galápago leproso (*Mauremys leprosa* Schweigger, 1812) es un elemento ibero-magrebí, salvo por escasas poblaciones en Francia, e introducciones en Italia y las Islas Baleares. Muestra un importante declive poblacional en muchas zonas, si bien ha mostrado incremento poblacional en el noreste español, y se considera relativamente abundante en el norte de África. Aunque el conocimiento sobre su distribución y selección del hábitat ha ido aumentado, especialmente en los últimos años, se aprecian lagunas en la distribución y aspectos discutibles sobre su relación con el medio. El objetivo de este trabajo es la actualización bibliográfica del conocimiento del uso del espacio del galápago leproso a nivel general, regional y local, contribuyendo a las bases de futuras investigaciones y recomendaciones de gestión. De acuerdo con el conocimiento disponible, la especie muestra preferencia por cuerpos de agua profundos con elevada cobertura vegetal, lecho rocoso, alta radiación solar y orillas inclinadas. Ha estado sometida a una gran presión por alteración del hábitat. En Portugal, se concentra en la mitad meridional, mientras que, en España tiende a estar ausente o relicta en algunas áreas centrales y noroccidentales. En Francia las poblaciones son muy escasas y aisladas. En África, está citada en el Magreb. Cuenta con protección legal en Europa y está incluida como Vulnerable en el Libro Rojo de los Reptiles Europeos. En África está relativamente protegida solamente en Argelia y Marruecos. La revisión bibliográfica pone de manifiesto un rápido incremento de la información disponible en los últimos años, aún con importantes lagunas, y la necesidad de estudios y medidas de conservación contra el declive poblacional y para la protección efectiva del galápago leproso y su hábitat.

1. Introduction

The Spanish pond turtle, *Mauremys leprosa* (Schweigger, 1812), is an Ibero-Maghrebian endemic species, with the exception of small populations in southern France (Courmount & de Sousa, 2011). Some small populations in Italy (Panzeri *et al.,* 2014) and Balearic Islands (Pinya *et al*., 2007; González *et al*., 2016), are known to be introduced (Panzeri *et al*., 2014). It is a thermophilic species associated to the subtropical Mediterranean climate (Da Silva 2002; Segurado *et al*., 2005; Sillero *et al*., 2020). In a general view, the revision of the literature shows that its distribution occupies a large part of the Iberian Peninsula, except some central and northwestern zones, being very scarce or absent in northern regions, and scarce in the most extremely semiarid areas in southeastern Spain. Some distribution gaps also stand out since they are located within areas where the species presence is generalized (large areas of the southeastern and central-eastern areas) (Figure 1). The species is also found in northern Africa, from Morocco to Libya (Iverson, 1992; Schleich *et al*., 1996; Fritz *et al*., 2006; Maran, 2010; Trape *et al*., 2012; Schweiger, 2014; Bertolero & Busack, 2017; Escoriza & Ben Hassine, 2017; Backhouche *et al*., 2019).

The Spanish pond turtle is a middle-sized species (carapace length variable among zones; maximum cited 228 cm; Keller, 1997), with a relatively flattened carapace, and grey-brownish or greenish coloured (Figure 2), that is often colonized with algae. This may cause the detachment of dorsal scales, although, on the other hand, it may favour crypsis in dark riverbeds and cloudy waters. The conservation status of the species may vary between different official sources and zones, from vulnerable to least concern. Several studies, however, have been aware of the important population declines over the past four decades (Campo & Ruiz, 1992; Da Silva, 2002; Araújo & Segurado, 2008; Gálvez & Albero, 2017). It is considered vulnerable in the 'Atlas and Red Book of the Reptiles and Amphibians of Spain' (Pleguezuelos *et al*., 2002). In many areas, the Spanish pond turtle is in sympatry with the European Pond Turtle (*Emys orbicularis* Linnaeus 1758) and with alien freshwater turtle species, mainly the red-eared slider (*Trachemys scripta* Schoepff, 1792).

Figure 1. Schematic map of the general distribution of the European pond turtle elaborated after the available information in general studies (SIARE, 2014; Díaz-Paniagua *et al,* 2015; Bertolero & Busack, 2017), and local and regional detailed reports (see text). The map emphasizes the main distribution gaps or with few citations, due to habitat alteration, lower sampling effort or unsuitable habitat.

Before the 90s, few articles about *M. leprosa* were published, and although the number was slightly increasing, it has been in the present century when most of the studies on this species have been published. The main orientation of the articles addressed the geographic distribution and the general characteristic of the habitat, with increasing citations during the last two decades. It has not been until more recently when further attention has been paid on the study of habitat selection, i.e. the variables that determine the presence and abundance of the species in comparison to habitat availability (see Keller, 1997; Rubio & Palacios, 1998; Rubio & González, 2000, Segurado, & Araújo, 2004; Segurado, & Figueiredo, 2007). This kind of information is obviously basic for the species management and conservation.

More recent attention has been paid to the interspecific relations between different freshwater turtle species. This topic includes resource partitioning between *M.*

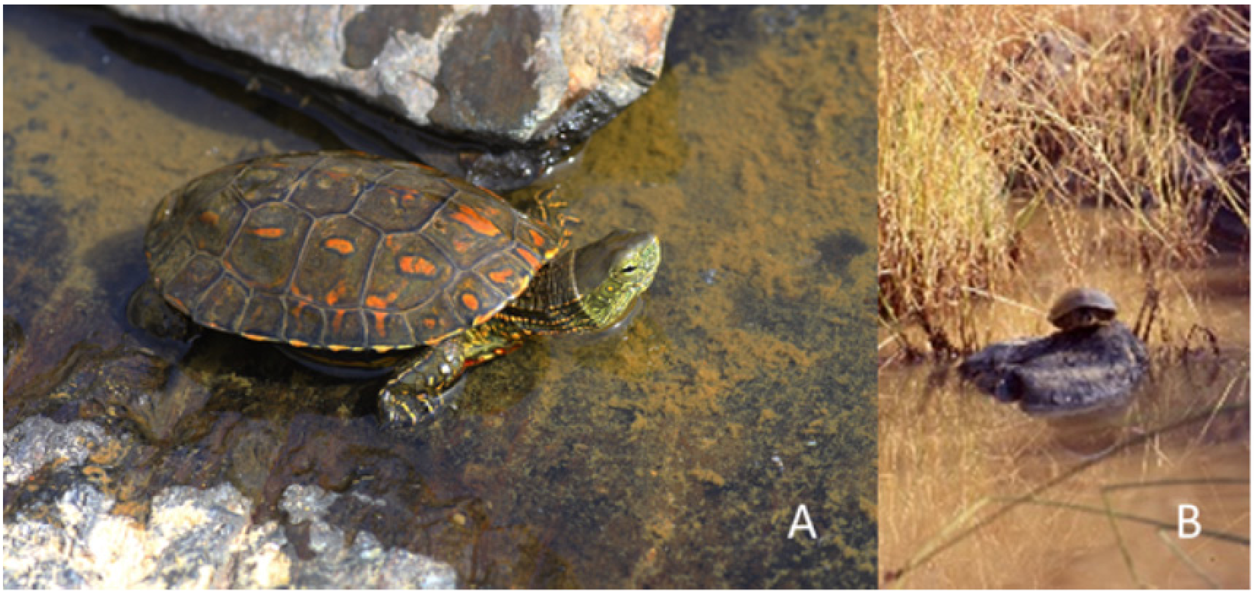

Figure 2. A) Juvenile individual of *Mauremys leprosa* (photograph E. Ruíz). B) Example of preferred basking place: a rock emerging in the waterbody providing quick scape possibility (photograph J. L Rubio, Albacete province, August/2000).

leprosa and *E. orbicularis*, mainly in its spatial dimension, and the interspecific competition and potential impact of the introduced freshwater turtle *Trachemys scripta* on *M. leprosa* populations (Segurado & Araújo, 2004; Segurado & Figueiredo, 2007; Polo-Cavia *et al*., 2010; Poch *et al*.,2020). Both issues are still in discussion and much information is still needed about the presence, abundance and the conservation status of the Spanish pond turtle in many areas. We exhaustively reviewed the bibliography on the use of the space, the geographical scales used and the distribution of the species. Continuing previous general works (Díaz-Paniagua & Andreu, 2014; Díaz-Paniagua *et al*., 2015; Bertolero & Busack, 2017), the aim of this revision was to actualize the available information contributing towards future research and conservation measures of the species. We focused on the studies on the use of the space, and related behaviors (basking and coexistence with other freshwater species), the European and African distributions, and conservation status, threats and protection measures. We emphasize the existence of aspects of space use and interspecific relations in question, distribution gaps, and conservation needs.

2. Space use

2.1. *Basking*

Segurado & Araujo (2004) showed, at regional scale, the association of *M. leprosa* with zones with high solar radiation. Then, Segurado & Figueiredo (2007) found preference of the species for rocky beds for basking. The species prefer partially open places with direct solar incidence: riverbanks, concrete platforms, fallen trunks, but also floating structures like tree branches, solid wastes as plastic drums or wooden boxes (Martínez-Silvestre *et al*., 2011). These authors showed that basking behavior might take place repeatedly in the same site. The turtles would stay in the usual places twice as long as the unusual places, regardless whether the site was previously occupied by other individuals or not. *Mauremys leprosa* shared basking places with other conspecific the 83 % of their observations, and 44 % shared basking places with one or more individuals of *T. scripta*. Polo-Cavia *et al*. (2010) found, in experimental conditions, interspecific competition between *M. leprosa* and *T. scripta* for baking places; the Spanish pond turtle basking time was shorter in the presence of the red-eared slider, predicting a displacement of the former. The introduction of a competitor interfering the thermoregulation behaviour could lead to reduce the nutritional condition and the recession of the native population. On the other hand, Martínez-Silvestre *et al*. (2011) reported the absence of apparent conflict in their field observations. In situations of potential interspecific competition for basking places, the Spanish pond turtle showed a 'dominant attitude' with prosecutions with their mouth open and stretching their necks toward the red-eared slider. The studies on the basking activities of the Spanish pond turtle lead to different conclusions, and in zones of coexistence of both freshwater turtles, the basking activities seems to be influenced by intrinsic specific characteristics, like thermoregulation ability or individual adult size (Polo-Cavia *et al.,*2010).

2.2. Geographical scales

Segurado & Araújo (2004) studied, in Portugal, the habitat preferences of *M. leprosa* when coexisting with the European Pond Turtle, using distribution maps (UTM 10 x 10 Km grid; 435 cells). By analyzing environmental variables (climatic, geomorphologic, socioeconomic, habitat and landscape variables), these authors found preference of the species for high solar radiation zones, high covers of emergent vegetation, and low tree cover in the waterbodies banks. These results coincide largely with previous studies in southeastern Spain (Albacete province) by Rubio & Gonzalez (2000), who found that the species selected localities with emergent rocks suitable for basking, moderate covers of medium size riparian vegetation, organic soils, in relatively well preserved areas; temperature and land use limited its regional distribution. Escoriza (2018) studied the occurrence of four semiaquatic species of reptiles in relation to habitat structural and physicochemical variables and patterns of coexistence in fluvial systems in northeastern Spain (The Spanish pond turtle, the European Pond Turtle, the Mediterranean Grass Snake - *Natrix astreptophora* López-Seoane, 1884 – and the Viperine Snake - *Natrix maura* Linnaeus, 1758). The results showed that *M. leprosa* occupied low sloped and controlled rivers, very regulated, and with low structural complexity. This type of environment houses a high number of exotic species not adapted to the high seasonality of the Mediterranean rivers (Benejam *et al*., 2005; Boix *et al*., 2010). These results may be explained by the peripheral situation of the population studied and the possible negative influence of the altitude (thus thermal gradient); *M. leprosa*, as a heliothermic animal, occupies the most exposed locations, and being opportunistic, benefits from including in its diet the abundant exotic species in this type of habitats.

At a local scale, Segurado & Araújo (2004) studied the space use of the Spanish pond turtle (and the European Pond Turtle), analyzing the abundance of both species in 200 m sections of streams, rivers and dam banks, showing a clear preference of *M. leprosa* for deep waters with high cover of emergent and submerged vegetation. Segurado & Figueiredo (2007) studied the habitat preference in a river section (1.3 km) in Portugal, showing differences related to the age cohorts (preferences of subadult individuals for deep waters, and juveniles for sandy riverbeds and grassy riverbanks relatively far from the usual basking places). These ontogenetic differences in *M. leprosa* highlight the importance of heterogeneity in freshwater ecosystems for the species (Burke *et al*., 2000).

2.3. Coexistence and spatial segregation between the Spanish pond turtle and the European Pond turtle (Emys orbicularis).

The Spanish pond turtle is found in sympatry with the European Pond Turtle in many areas. A few works have studied the coexistence and spatial segregation between both species (Segurado & Araújo, 2004; Segurado & Figueiredo, 2007). The comparison of the correlations of the abundance of both species with microhabitat variables showed that the responses went in opposite directions. This became more evident when comparing the total number of specimens of *M. leprosa* with the adults of *E. orbicularis*, noting a strong spatial segregation. The juveniles' response of *E. orbicularis* was very similar to the specimens response of *M. leprosa*, implying possible interspecific competition for space. Segurado & Araujo (2004), considering that these results were obtained at local scale, and given a limited mobility of the freshwater turtles, consider that this local spatial segregation may became less relevant at a regional scale. The European Pond Turtle seems to be more selective for the microhabitat variables than the Spanish pond turtle, which may be more generalist. While *E. orbicularis* showed preference for temporary sectors, low deep and high cover of emergent vegetation, grassy banks and sandy riverbeds, *M. leprosa* showed preference only for deep waters and rocky riverbeds.

3. Distribution

3.1 Africa

Two subspecies inhabit the African continent: *M. leprosa leprosa* and *M. leprosa saharica* (Fritz *et al.*, 2006, Veríssimo *et al.*, 2016). The first one is found in the north and northeastern areas of Morocco across to the Atlas Range. While, the second one occupies the territories in the south of the Atlas (Maran, 2010). Although it also appears in the north, where the two subspecies coincide. There are no citations from the Western Sahara (Schweiger, 2014).

In Algeria, the subspecies *M. l. saharica* (Fritz *et al.*, 2006) is widely distributed from coastal zones (Bakhouche *et al.*, 2019) to the Sahara, though with a relict character (Schleich *et al.*, 1996), and the taxonomic status is still uncertain in the west and center areas of the country (Fritz *et al.*, 2006). Escoriza & Ben Hassine (2017) do not distinguish between susbspecies considering the knowledge of the species scarce and recent alterations of the aquatic environments occurred in northern Algeria (de Belair & Samraoui, 1994). In Tunisia, *M. l. saharica* is found in large areas mainly in the northwest and some coastal zones in the northeast, also including some Sahara desert margins (Fritz *et al.*, 2006; Escoriza & Ben Hassine, 2017). In Libia, only Iverson (1992) reported a citation of the species, but no more detailed and actualized data are available. Bertolero & Buscak (2017) considered the species extinct in northern Mauritania, and confirmed the presence in the south (regions of Assaba –Kiffa- and Hodh El Gharbi). In Mali, the species is not cited since the second half of the XX century. Some citations in other regions of Africa: southern Niger (Trape *et al.*, 2012) and Gambia (Barnett & Emms, 2005) are considered errors (Bertolero & Busack, 2017).

3.2 Europe

In Spain, *Mauremys leprosa* is widely distributed in the center and the meridional half of the country. In the north, the distribution tends to be dispersed or absent in some provinces (Da Silva, 2002; Díaz-Paniagua & Andreu, 2014). Using the Spanish administrative divisions, autonomous regions, and provinces included, as geographical unites, and starting the distribution description by the northwestern region, Galicia, we find that there are no old citations of the species in this region (López Seoane, 1877). Its origin here is unknown and, even though it is the most cited freshwater turtle at present, it is not considered autochthonous (Ayres & Cordero, 2002; Galán, 2005; Ayres, 2011). However, its presence and reproduction in the south of the region (Minho river) is known for decades (Ayres, 2011, 2018). It is considered absent in central and northern Spain regions, Asturias and Cantabria (Díaz-Paniagua *et al.*, 2015, but see Da Silva, 2002; Diego-Rasilla *et al.*, 2006, local reports in Santoña marshes, and Marquina *et al.,* 2018). Also in the north, in the Basque Country, stable populations have been reported in some ponds, marshes and rivers in different areas of Vizcaya, Guipúzcoa and Álava provinces (Buenetxea & Paz Leiza, 2009; Pérez de Ana, 2014; Egaña-Callejo & Gosá, 2007; Bergerandi & Gosá 1994; Gosá *et al.*, 2010). In Álava, occupation was observed in Charca de Tertanga in 2008 and 2010; a population that may be introduced, but is considered abundant and shows evidences of reproduction (Pérez, 2014). In Navarra**,** scarce populations, probably introduced, are found near urban areas. It is abundant in Arga river and less abundant in Urrobi river and headwaters of the Bidasoa river (Bergerandi & Gosá, 1994). In the north central region, Castilla y León, the species shows an unequal distribution, being scarce in the north of the region (north of the Duero River) but more abundant in the south (Ortiz-Santaliestra, 2011; Alarcos *et al.*, 2013). In central western Spain, Extremadura, the species is common and abundant in most of the northern Badajoz province though in recent years some populations show a declining tendency (Da Silva, 2002; Muñoz del Viejo *et al.*, 2005). In Cáceres province, most of the populations are found in its northeastern zone, with some more isolated populations in central and southwestern areas (Muñoz del Viejo *et al.*, 2005). In the north central region, La Rioja, the scarce citations are considered released animals (Álvarez, 2014; Valdeón *et al.*, 2014). In the central east region, Aragón, the species is also scarce and an important regression of the populations has been reported (Campo & Ruiz, 2019). In the Mediterranean coastal areas of Spain, the northern coastal region, Cataluña**,** has been exhaustively studied for decades, showing an expansion of the populations from littoral areas, or with high urbanistic pressure, towards forest, semi natural or agricultural areas (Benejam & Saura-Mas, 2009; Franch *et al.*, 2015). In the east-southeastern coastal region, Valencia Region, the species is present in the provinces of Alicante and Castellón (Jiménez & Lacomba, 2002), and more abundant in Valencia province, apparently due to a larger hydrographic network (Lacomba & Sancho, 1999; Jiménez & Lacomba, 2002). However, the area shows an important population decline (Albert & Gómez-Serrano, 2000; Jiménez & Lacomba, 2002; Gálvez & Albero, 2017). In southern Spain, Andalucía, the populations are abundant, especially in the central and western areas (Keller, 1997; González de la Vega, 1988; Da Silva, 2002; Rodríguez-Rodríguez *et al*. 2015), but it tends to be scarcer towards the eastern zones, where the climate becomes increasingly arid (Díaz-Paniagua *et al*., 2015). In southeastern Spain, Murcia Region, the populations concentrate in the northwest, where traditional agriculture, and well-preserved environments, have been maintained (Egea *et al*., 2004), Thus, is very scarce in the southern areas of the region, with only some small population associated to seasonal streams (Sánchez-Balibrea *et al*., 2010). In the south-central region of the country, Castilla La Mancha, the Spanish pond turtle is very scarce or absent in Guadalajara, Cuenca and Albacete (Astudillo *et al*., 1993; Barberá *et al*., 1999; Rubio & González, 2000), and mainly associated to Cabriel, Turia, Tagus and Henares rivers. In the southeast of the region, Albacete province, excepting in some lagoons in the central area (Tarancón, 2003), the populations tend to be concentrated in the southwest of the province, around the mountains (Rubio & González, 2000). However, in the rest of the region, Toledo and Ciudad Real provinces, the species is widely distributed (Rubio & Palacios, 1998; Vento *et al*., 2000; Ayllón *et al*., 2003; Hernández, 2010). In the center of Spain, Madrid region, the species is also widely distributed (SIARE, 2014). It is more abundant in the western area and scarcer in the nothern zones (García-Paris *et al*. 1989). In the Balearic archipelago, two populations are reported from Mallorca Island whose origins is reported to be peninsular (Pinya *et al*., 2007); in Menorca, just one introduced specimen was found (González *et al*. 2016). The species is present in the Spanish 'Autonomous Cities' of Ceuta and Melilla, in the northern African coast (Fahd *et al*., 2002; Mateo *et al*., 2003).

In Portugal, the species is widely distributed mainly in the southern half of the country; its presence south of the Tagus River is continuous. In the coastal zone, there are dispersed populations mainly in the north of Lisbon. In the northern half of the country, the species is present in interior areas adjacent to Spain (Zamora province) and in the Minho River (Díaz-Paniagua *et al*., 2015); in the area of Trás-Os-Montes, the populations from the inner zones of Beiras are prominent. The species is distributed from the sea level to 930 masl (Araújo & Segurado, 2008).

Mauremys leprosa in France is scarcely found in the southeastern region of Languedoc-Rousillon, Eastern Pyrenees, apart from some citations from other areas (Courmount & de Sousa, 2011) attributed to introductions (Palacios *et al*., 2015).

In Italy, some individuals were cited in south of La Toscana, that, according to Panzeri *et al*. (2014), came from introduced individuals from an old chelonian rescue center; the finding of a dead juvenile suggests reproduction. Interestingly, fossils of the genus *Mauremys* are reported from Italy: from Miocene, Pliocene (in Tuscany) and Pleistocene (Collareta *et al*., 2020, and references therein).

3.3 Predicted vs presence UTM cells. River basins and provinces

In a general view at the distribution of *M. leprosa*, a relation can be observed with general temperatures and mountain ranges position. Considering the river basins as geographical units in the Iberian Peninsula (where distribution atlases, with UTM 10x10 km grid, are available; SIARE, 2020; Diaz-Paniagua *et al*., 2015), we can compare in more detail the number of UTM cells with cited presence of the species and the number of cells predicted in proportion to the river basins surface area. In Spain, we found significant differences (Chi square = 752;

Figure 3. Distribution of *Mauremys leprosa* in peninsular Spain (presence cells, UTM 10 x 10 km; SIARE, 2014) overlapping the river basins map (Centro Nacional de Información Geográfica, 2020). River basins: Miño-Limia- Atlantic Galicia (1), Cantabrian (2), Douro (3), Ebro (4), Llobregat-Ter (5), Tagus (6), Guadiana (7), South-Segura-Jucar- Turia (8), Guadalquivir (9).

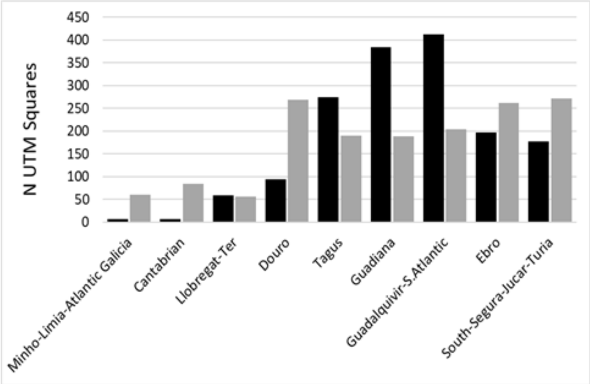

Figure 4. Number of cells with presence of *Mauremys leprosa* (black bars) vs predicted (grey bars) by the river basins surface area in Spain.

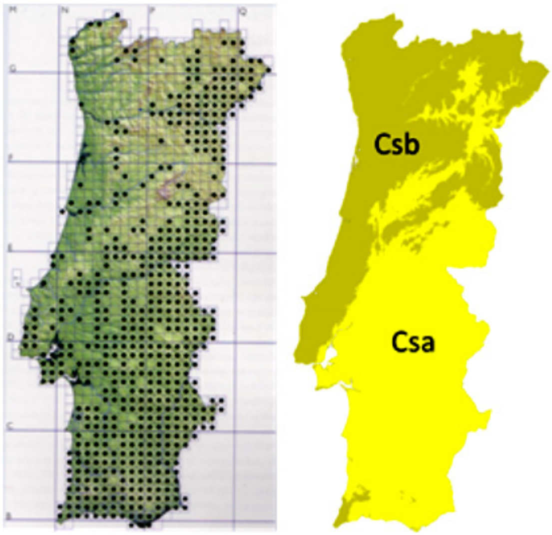

Figure 5. A) Distribution of *Mauremys leprosa* in Portugal (Atlas with UTM cells 10x10 km; Araujo & Segurado, 2008), and B) Climate map; Köpen classification: Csb: warm-summer Mediterranean, Csa: hot-summer Mediterranean; isotherm separating climates: -3°C; (modified from Peterson, 2016, after WorldClim.org).

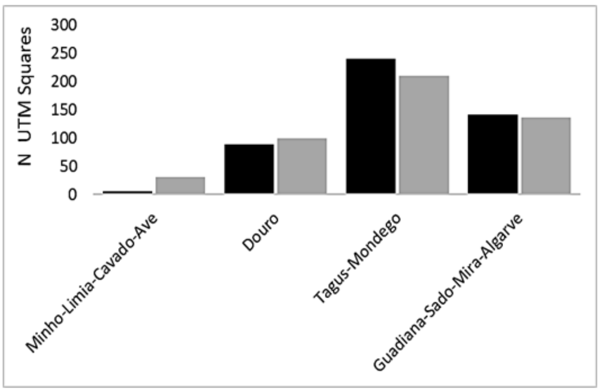

Figure 6. Number of cells with presence of *Mauremys leprosa* (black bars) vs predicted (grey bars) by the river basins extension in Portugal.

d.f. = 8, p<< 0,001); the presence cells density per river basins shows a North-South gradient (Figure 3), indicating the general influence of environmental temperatures that can be expected of a thermophilic semiaquatic reptile, (classified as Mediterranean species; Sillero *et al*., 2012). The northern and northwestern river basin (Cantabrian, Miño-Limia-Atlantic Galicia, and Douro) shows smaller number of presence cells than predicted by its extension, while the southern river basins (Tagus and Guadiana river basins) show the opposite figures. However, there are exceptions. In the northeastern area (Llobregat-Ter rivers basins), the observed presence and predicted cells number do not differ significantly; moreover, a population increment in the last years has been reported in this zone (Franch *et al*., 2015). In contrast, the central-eastern basins (Ebro River) and the southeastern river basins (Segura-Jucar-Turia river), show less citations that predicted, in spite of their southern and/or Mediterranean situation (Figure 4).

In Portugal, the species shows a quite homogeneous distribution, with few gaps, that fits quite closely the temperature maps (Figure 5), interrupted, mainly, by the presence of mountain ranges. Excepting the Minho-Limia-Cavado-Ave river basins, in the most northern zone, with few presence cells, the rest of the river basins, Douro, Tagus and Guadiana rivers basins, show predicted presence-cells numbers (Chi-Square = 6,088; d.f. = 2; p> 0,35; Figure 6).

In a deeper level in Spain, the same analysis (number of presence vs predicted cells, by provinces within regions ('Comunidades Autónomas'), helps to highlight the distributions gaps and needs of new data to be provided or further sampling effort (Table I). The Northern provinces, in Galicia, Cantabria, Navarra, La Rioja and Basque Country (except Vicaya province), all have less presence cells than expected by their surface areas alone, which is consistent, among other factors, with the distribution of temperatures. The main exception in the northern zone is Catalonia (the northeastern region) with positive figures in its provinces due to the influence of the Mediterranean Sea, Barcelona, Girona and Tarragona, except in Lleida. In Castilla y León, the provinces of Burgos, León, Palencia, Segovia, Soria, Valladolid, and Zamora, all of them at relatively high latitude too, also have low numbers, while Salamanca have positive figures, and Ávila shows approximately the expected number. The eastern coastal provinces of Murcia and Valencia regions show expected (Murcia), positive (Valencia), or slightly low figures (Alicante and Castellón). The relatively low figures of the last two provinces, located just in the Mediterranean coast, might be explained mainly by anthropic habitat alterations. While the western provinces of Extremadura region (Cáceres and Badajoz), and Castilla-La Mancha region (Toledo and Ciudad Real), have high numbers, the eastern provinces of this same region (Castilla-La Mancha), Cuenca, Guadalajara and Albacete, show much less presence cells than predicted by their

Table I. Number of UTM cells (10x10 km) with presence of *Mauremys leprosa* in the provinces of peninsular Spain, provinces surface-areas within administrative regions ('Comunidades Autónomas'; source Instituto Geográfico Nacional, 2005), and number of cells predicted in proportion to the provinces surface-area.

Region (Com. Aut.)	Provinces	Province surface area (Km2)	N Presence cells	N expected cells
Andalucía	Almería	8.775	29	39
	Cádiz	7.436	94	33
	Córdoba	13.771	112	61
	Granada	12.647	77	56
	Huelva	10.128	124	45
	Jaén	13.489	99	59
	Málaga	7.308	64	32
	Sevilla	14.036	128	62
Aragón	Huesca	15.626	23	69
	Teruel	14.797	27	65
	Zaragoza	17.274	40	76
Asturias	Asturias	10.604	1	47
Cantabria	Cantabria	5.253	1	23
Castilla León	Ávila	8.050	31	35
	Burgos	14.022	17	62
	León	15.570	2	68
	Palencia	8.052	1	35
	Salamanca	12.349	78	54
	Segovia	6.796	9	30
	Soria	10.303	9	45
	Valladolid	8.110	6	36
	Zamora	10.561	31	46
Castilla-La Mancha	Albacete	14.918	27	66
	Ciudad Real	19.813	147	87
	Cuenca	17.141	17	75
	Guadalajara	12.167	21	53
	Toledo	15.370	121	68
Catalonia	Barcelona	7.728	58	34
	Girona	5.910	47	26
	Lleida	12.150	10	53
	Tarragona	6.303	30	28
Extremadura	Badajoz	21.766	208	96
	Cáceres	19.868	173	87
Galicia	Coruña	7.950	0	35
	Lugo	9.856	1	43
	Orense	7.273	4	32
	Pontevedra	4.495	0	20
La Rioja	La Rioja	5.028	8	22
Madrid	Madrid	8.022	83	35
Murcia Region	Murcia	11.313	50	50
Navarra	Navarra	9.801	14	43
País Vasco	Álava	2.976	9	13
	Guipúzcoa	1.940	5	9
	Vizcaya	2.173	9	10
Valencia	Alicante	5.817	17	26
	Castellón	6.632	24	29
	Valencia	10.806	77	47

surface area. In Madrid, a much-prospected zone, the presence cells are abundant. The species is abundant in all southern provinces, in Andalucía. The exception in the south is Almería province, which low presence-cell number is remarkable since in North Africa the species is abundant in similar climatic conditions (D. Escoriza, pres. comm).

The comparison in Portugal between the numbers of presence vs expected cells, at the level of the country traditional districts (Table II; Chi square: = 161,4; d.f.: 17; p<< 0.01), shows a clear north-south gradient, though with a few exceptions, consistent with the comparison at the river basins level. Almost all northern districts, including Coimbra, show less presence cells than predicted by their surface area, excepting Bragança, in the northeastern corner of the country. In the central area, Leiria, Santarén, and Lisbon, in the Atlantic coast, show negative figures, while Castelo Branco, Portalegre and Évora in the west, a positive number. All the southern districts show positive figures. These figures are consistent with climate maps (Figure 5); the northeastern provinces with high numbers of cells are located in zones with higher temperatures, and provinces close to the Atlantic central coast, with fewer cells than predicted by their surface, are under the influence of the low temperatures zone shown in the map.

4. Conservation status

The Spanish pond turtle is catalogued as Vulnerable in the Red List of European Reptiles (Cox & Temple, 2009), in the Appendix II of the Bern Convention (European

Table II. Number of UTM cells (10x10 km) with presence of Mauremys leprosa in Portugal districts, traditional districts surface-areas, and number of predicted cells in proportion to the districts surface-area (districts from LÓPEZ-DAVALILLO, 2012).

Districts	Surface area (km2)	N presence cells	N predicted cells
Aveiro	2800	4	18
Beja	10226	105	64
Braga	2706	2	17
Bragança	6599	58	41
Castelo Branco	6627	52	41
Coimbra	3974	12	25
Évora	7392	68	46
Faro	4995	54	31
Guarda	5536	25	35
Leiria	3509	9	22
Lisboa	2801	11	18
Portalegre	6084	60	38
Porto	2332	2	15
Santarém	6723	36	42
Setúbal	5163	34	32
Viana do Castelo	2445	4	15
Vila Real	4309	8	27
Viseu	5011	14	31

Wildlife and Natural Habitats), and in the Annexes II and IV of the European Union's Habitats Directive (92/43/EEC). In Europe, France includes *M. leprosa* in the list of protected species; it is included as endangered of Extinction in the Red National List (UICN, 2009). Given the rarity and population scarcity of the species, it is considered in the country as the most endangered reptile at national level (FRANCK 1998; CHEYLAN & VERNEAU, 2012). In the Iberian Peninsula, the populations are decreasing in most of the territory (ARAÚJO *et al*., 1997; PLEGUEZUELOS *et al*., 2002; ALARCOS *et al*., 2013), excepting Catalonia (the Spanish northeastern region) (FRANCH *et al*., 2015). In Spain, it is included in the Royal Decree 1193/1998, in the Law 42/2007, in the Royal Decree 139/2011 and in the Royal Decree 1015/2013; BOE 2011). It is not an endangered species, but in the Atlas of Spanish reptiles and red book ('Atlas y Libro y Rojo de los Anfibios y Reptiles de España'; PLEGUEZUELOS, 2002) the species is catalogued as Vulnerable. Different recovery programs have been carried out at regional level (the most featured being perhaps the 'Centre de Recupearció d´Anfibis i Reptils de Catalunya – CRARC' -, dedicated to the breeding and reintroduction of the Spanish pond turtle). Portugal includes the species in the Law 316/1989, and in the Law 140/1999, but it is kept as Least Concern in its Red Book (CABRAL *et al*., 2005). In the African continent, only Algeria and Morocco have laws protecting the species. Algeria includes the Spanish pond turtle in its Decree 85-509. Morocco protects the species with the Annual Haunting Decree (Ministerial decree 582-62.3, November 1962 (BERTOLERO & BUSACK, 2017). Overall, a generalized regional-dependent difference of protection status is remarkable.

5. THREATS

The main threats for the Spanish pond turtle come mainly from its habitat degradation (DÍAZ-PANIAGUA *et al*., 2015), mainly the destruction of riparian vegetation and extraction of excessive freshwater from the aquifers. This problem is fostering the temporality or desiccation of wetlands in the Iberian Peninsula (ARAÚJO *et al*., 1997; DA SILVA, 2002; ARAÚJO & SEGURADO, 2008), causing the disappearance of many enclaves where the species was present (LIZANA & BARBADILLO, 1997; RUBIO & PALACIOS, 1998; SANCHO 1998; DÍAZ-PANIAGUA & ARAGONÉS, 2015). An emblematic example seems to be Doñana National Park, in southern Spain, where the aquifer overexploitation for intensive agriculture and water supply is considered to cause severe reduction of the number of lagoons and seasonal ponds (CGS, 2008; CUSTODIO *et al*., 2009, DÍAZ-PANIAGUA & ARAGONÉS, 2015). Another important impact of the agricultural activities is the surface water and groundwater pollution due to improper use of plant protection products. They spread through diffuse pollution generating secondary metabolites which impact is higher than that of the original product (DÍAZ *et al*., 1994). The changes of land use for infrastructure construction results in habitat fragmentation and destruction with death of individuals and populations extinctions (RUBIO & PALACIOS, 1998; MATEO *et al*., 2003; STEEN *et al*., 2004; ALARCOS *et al*., 2012). The burning and logging of riparian vegetation in many areas cause partial or total loss of spatial and trophic resources with important impact on the turtles (LIZANA, *et al*., 1991). The presence of alien species, like the red-eared turtle (*Trachemys stricta*), is also considered an important threat (ARAÚJO *et al*., 1997; Da Silva, 2002; Polo-Cavia *et al*., 2010; Campos-Such *et al.,* 2016; Domenech *et al*., 2016). This is not only due to interspecific competition, but also for being a potential source of infection of disease and parasites (Martínez-Silvestre *et al*., 2011; Romero *et al*, 2014; Meyer *et al*., 2015; Domenech *et al*, 2016; Domínguez & Vilarán, 2017), hybridization with different species, and predation of native fauna (Campos-Such *et al*., 2016; Poch *et al.,* 2020; Sancho *et al.,* 2020). The invasion has become a problem very difficult to solve. Pérez-Santigosa *et al*. (2006) studied the freshwater turtle populations in Doñana National Park, in southern Spain, founding that the number of the exotic *T. scripta* individuals doubled that of *M. leprosa*, and was much higher than that of *E. orbicularis*. During the twentieth century, the Spanish pond turtle were illegally captured as pets (Ayres *et al*., 2013), also for human consumption in some zones in southwestern Iberian Peninsula (West Andalucía, Extremadura and Portugal) (Rubio & Palacios, 1998; Ayres *et al*., 2013). Another problem to be highlighted is the habit of fishing red crabs with submerged traps that asphyxiate the turtles (Araújo *et al*., 1997; Da Silva, 2002; Díaz-Paniagua *et al*., 2015). Gutiérrez-Yurita *et al*., (1997) proposed a new model of trap with an emerged part. An ethnoecological problem is also to be considered. Many anglers (data from Salamanca, Ciudad Real and Extremadura areas) kill the turtles attributing to them damage to the fishes (Araújo *et al*., 1997; Da Silva, 2002) or simply because they bit the hook or entered the traps (Lizana & Barbadillo, 1997; Rubio & Palacios, 1998).

The habitat alterations have pressured the Spanish pond turtle to occupy suboptimal habitats (Lloret *et al*., 2002; Pleguezuelos & Feriche, 2003; Polo-Cavia *et al*., 2011), showing, on the other hand, a high tolerance to degraded environments (Martinez-López *et al*., 2017; El Hassani *et al*., 2019). The last authors studied *M. leprosa* populations in the Moroccan Tensifit River, on the outskirts of Marrakech, where urban wastes were damped, finding that the individuals from upstream showed worse body condition, and more abundance than those from the wastes zone. Héritier *et al.* (2017), however, showed physiological stress in populations from downstream of wastewaters treatments plants.

6. Conservation measures

Besides legislation measures, this review emphasizes the need for habitat preservation and restoration measures, as well as control of illegal fishing where the Spanish pond turtle is present (Díaz *et al*., 2015). Different general conservation measures have been proposed (Lizana & Barbadillo, 1997; Rubio & Palacios, 1998; Bertolero & Busack, 2017; Poch *et al*., 2020). Among those concerning *M. leprosa* were effective protection of continental aquatic environments by control and sanction policies in sensitive areas, control of the sale and use of plant protection products and agricultural pesticides, serious environmental impact studies, control of side effects from the construction of new infrastructures so that corrective measures can be implemented. Other proposed measures have been geared towards riverbed cleaning for flood prevention with reduction of heavy machinery.

7. Discussion and conclusions

The preferences of the Spanish pond turtle in respect to the variables studied by different researchers show selection for rocky locations, high solar radiation, deep water bodies, steep banks, and high vegetation cover. Deep locations will keep water during summer droughts. The preference for rocky places may be related with fast thermoregulation advantages. Selection for steep rocky places provides the turtles better opportunities of quick scape (Rubio & Palacios, 1998; Rubio & Gonzalez, 2000). This habitat selection is seen in areas with variety of available resources, but also a high ability to occupy suboptimal environments is observed. This is a point in favour of *M. leprosa* in periurban spaces or environments with a high degree of human intervention with homogenous landscapes or adverse physicochemical parameters, but with a minimum of condition for the presence of the species.

At present, *M. leprosa* populations faces decline in many areas of the Iberian Peninsula (Campo & Ruiz, 1992; Araújo *et al*., 1997; Da Silva, 2002; Jiménez & lacomba, 2002; Pleguezuelos *et al*., 2002; Muñoz del Viejo *et al*., 2005; Alarcos *et al*., 2013; Galvez & Alvero, 2017). Albeit, interesting exception exist like the northeastern areas of the Iberian Peninsula, with extended distribution range in the last years (Franch *et al*., 2015), and unpredicted low presence areas in different zones. The distribution gaps and inconsistencies suggest that additional factors, like regional or local environmental conditions, unsuitable habitat, anthropic impacts, or low sampling effort, must be important, highlighting the need of further sampling programs and habitat studies at different geographical scales in many areas.

In general terms, the decline is the consequence of the sum of all threats the species suffers and jeopardy its future. So new specific plans are needed based on clear knowledge of the space use taking into account the next environmental sceneries, including degraded habitat restoration that foster connectivity between populations. Invasive species populations are growing, while in most cases the actors are unaware of the problem. Maceda-Veiga *et al.* (2019) proposed different measures like aquatic installations biosecurity, species election according to their specific body size and the size of the owner's accommodation capacity, and to prevent the sale of juveniles of large adult body sized species.

Although the knowledge about the geographical distribution of *M. leprosa* increased in the last years, the remaining gaps in many areas, and controversial aspects of space use, make necessary further studies, management measures, and monitoring of the conservation status of different populations. A revision of the legislation adequacy about the species and regional differences is also needed.

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