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Hotspots of species richness, threat and endemism for terrestrial vertebrates in SW Europe

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ABSTRACT

The Mediterranean basin, and the Iberian Peninsula in particular, represent an outstanding "hotspot" of biological diversity with a long history of integration between natural ecosystems and human activities. Using deductive distribution models, and considering both Spain and Portugal, we downscaled traditional range maps for terrestrial vertebrates (amphibians, breeding birds, mammals and reptiles) to the finest possible resolution with the data at hand, and we identified hotspots based on three criteria: i) species richness; ii) vulnerability, and iii) endemism. We also provided a first evaluation of the conservation status of biodiversity hotspots based on these three criteria considering both existing and proposed protected areas (i.e., Natura 2000). For the identification of hotspots, we used a method based on the cumulative distribution functions of species richness values. We found no clear surrogacy among the different types of hotspots in the Iberian Peninsula. The most important hotspots (considering all criteria) are located in the western and southwestern portions of the study area, in the Mediterranean biogeographical region. Existing protected areas are not specifically concentrated in areas of high species richness, with only 5.2% of the hotspots of total richness being currently protected. The Natura 2000 network can potentially constitute an important baseline for protecting vertebrate diversity in the Iberian Peninsula although further improvements are needed. We suggest taking a step forward in conservation planning in the Mediterranean basin, explicitly considering the history of the region as well as its present environmental context. This would allow moving from traditional reserve networks (conservation focused on "patterns") to considerations about the "processes" that generated present biodiversity.

1. Introduction

The current biodiversity crisis clearly calls for the identification of biodiversity hotspots, usually defined as the most threatened areas among those of exceptionally high biodiversity and/or rates of endemism (Myers, 1988; Mittermeier et al., 1998; Reid, 1998; Brooks et al., 2002). Myers (1988) originally identified 18 hotpots, located in the tropics and in the Mediterranean bioclimatic regions. The Mediterranean basin is one of these hotspots, being at the same time one of the "hottest hotspots" (Shi et al., 2005), one of the most significantly altered (Myers et al., 2000), and in fact a climate change hotspot (Maiorano et al., 2011). The entire region represents only 1.6% of the Earth's surface, but it hosts 10% of the world's higher plants and almost 800 species of terrestrial vertebrates excluding fishes (Blondel, 1995). Considering the European subcontinent, the Mediterranean basin is by far the most important area for conservation. In fact, Mediterranean Europe hosts nearly 82% of the 419 European breeding birds (with 10% of the species being endemic; Voous, 1960), more than 69% of the 217 European terrestrial mammals (overall 5.6% of them are endemic; IUCN, 2006a; Schipper et al., 2008), more than 88% of the 94 European amphibian species (33% of them are endemic; IUCN, 2006b), and almost 74% of the 118 European species of terrestrial reptiles (28% are endemic; Gasc et al., 2004).

The Mediterranean basin is not only an outstanding "hotspot" of biological diversity but is also exceptional because of its long history of integration between natural ecosystems and human activities (Blondel et al., 2010). Topography, climate, and disturbance mechanisms modeled the structure and the spatial patterns of the landscapes that we currently observe (Blondel, 1995; Rundel et al., 1998; Farina et al., 2003), but human presence is by far the most important factor that have affected the entire basin. As

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a result, only 4.7% of its primary vegetation remains, and the traditional agricultural lands, the evergreen woodlands and the *maquis* that dominate the region today are the result of anthropogenic disturbance dating back to the beginning of the Holocene (Farina et al., 2003). All this resulted in a high spatial heterogeneity that has been proposed, together with the huge latitudinal and elevation gradients and with refugia effects (Taberlet and Cheddadi, 2002; Rey-Benayas and de la Montaña, 2003; López-López et al., 2008; Blondel et al., 2010) as one of the main determinants of the high vertebrate species richness in the region (Kerr and Packer, 1997; Atauri and de Lucio, 2001).

The Mediterranean basin is also characterized by highly differentiated biogeographical patterns and land-use practices that make it impossible to consider the entire basin as one single hotspot. Médail and Quézel (1999), based on plant endemism and plant species richness, identified 10 separated hotspots distributed in the Mediterranean. Among these hotspots, the Iberian Peninsula (including Spain and Portugal) stands out hosting almost 50% of European plant and terrestrial vertebrate species and with more than 30% of endemic species (Araújo et al., 2007; Maiorano et al., unpublished results).

There has been a number of papers dealing with the distribution of several single taxa in the Iberian Peninsula, including vascular plants (Castro-Parga et al., 1996; Araújo, 1999), lichens (Martínez et al., 2006), invertebrates (Martín-Piera, 2001; Abellán et al., 2005; Zamora et al., 2007; Sánchez-Fernández et al., 2008), and some groups of terrestrial vertebrates (Araújo 1999; Lobo and Araújo, 2003; Nogués-Bravo and Martínez-Rica, 2004; Rey-Benayas et al., 2006). Some papers have also assessed the effectiveness of protected areas in the Iberian Peninsula (Rey-Benayas and de la Montaña, 2003; Traba et al., 2007) and, in particular, Araújo et al. (2007) have considered terrestrial vertebrates, using distribution data with a coarse spatial resolution of 50 km × 50 km. However, such resolution is of limited help if the aim is to map finer-scale hotspots, evaluate conservation status of species and to derive effective conservation guidelines (Hurlbert and Jetz, 2007; Seo et al., 2009), especially in the highly heterogeneous Mediterranean region (Médail and Quézel, 1999; Atauri and de Lucio, 2001). Coarse-grained resolution is potentially linked to important errors of commission, with species that are shown to be present in areas where they are actually absent (Catullo et al., 2008). Not considering these errors can produce a biased view of where biodiversity concentrates (Hurlbert and Jetz, 2007), and can introduce large errors in gap analyses (Rodrigues et al., 2004), with critical differences in results (Harris and Pimm, 2007).

Even though the Iberian Peninsula is a priority for conservation in Europe (http://europa.eu.int/environment/), there have been no explicit efforts to map fine-scale hotspots for terrestrial vertebrates in the region. In this paper, we used land cover and elevation to downscale traditional range maps to the finest possible resolution, and we identified hotspots of terrestrial vertebrates based on three criteria: i) species richness; ii) vulnerability, and iii) endemism. We also provide a first evaluation of the conservation status of biodiversity hotspots based on the abovementioned criteria.

2. Methods

2.1. Study area

Our study area encompassed the entire Iberian Peninsula (Portugal and Spain), also including the Balearic Islands (total surface = 588,246 km^2, Fig. 1). In particular, we considered all islands larger than 0.1 km^2 and all archipelagos located close to the mainland (e.g., Columbretes Archipelago, Medas Islands, Cíes, and all nearby Atlantic Islands, etc.). We excluded the Macaronesic territories (Madeira, Azores and Canary Islands) and the Spanish territories located in Northern Africa (Ceuta, Melilla, Chafarinas Islands, Peñón de Vélez de la Gomera, Peñón de Alhucemas and Alborán) because of their peculiar flora and fauna that clearly is not part of the Mediterranean biogeographical region.

The Iberian Peninsula ranges from sea level to 3478 m a.s.l. and includes three different biogeographical regions: Mediterranean,

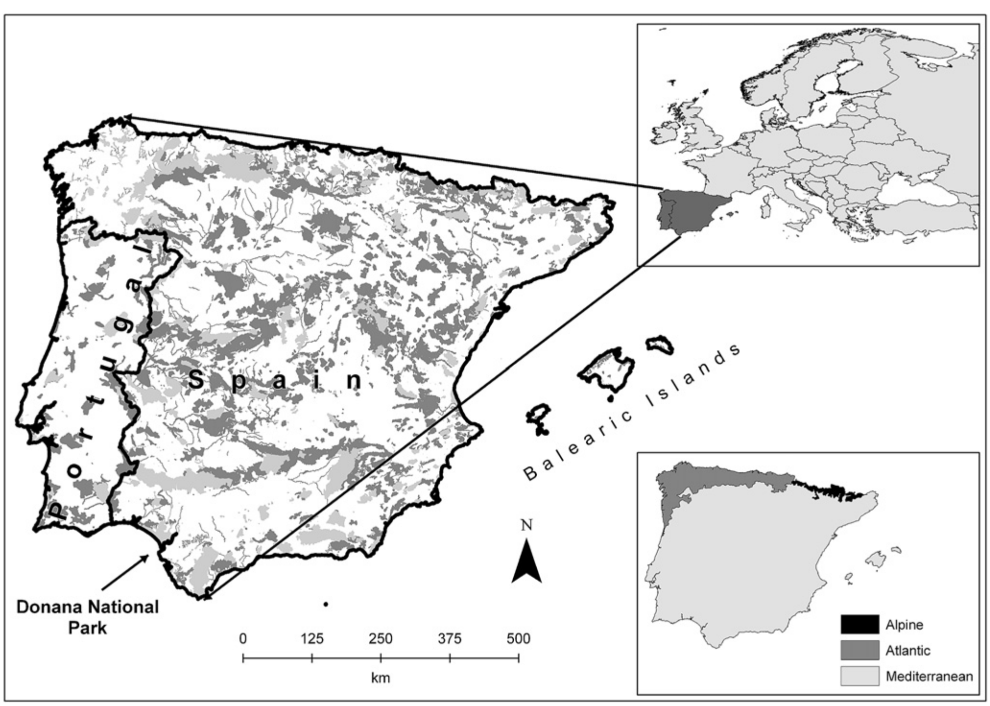

Fig. 1. Biogeographical regions, protected areas (light grey), and Natura 2000 (dark grey) in the Iberian Peninsula.

Atlantic and Alpine (Fig. 1). The Mediterranean region encompasses almost the entire surface of Spain and Portugal (88.1% of the study area), the Atlantic includes territories located along the coastland of Northern Portugal and Northern Spain (10.2%), while the Alpine region (1.7%) encompasses the Pyrenees, at the boundaries between Spain and France (European Environmental Agency, 2005). The Iberian Peninsula is characterized by a high spatial heterogeneity, with two main mountain ranges located in the northern portion of the peninsula (Cantabric Mountain range and the Pyrenees), and some mountain ranges located in the central, eastern and southern portions of the study area (Central System, Ibérico System, Sierra Morena and Penibético System). These structures divide the study area into two large plateaus (the Northern and the Southern Plateau) at an average altitude of 700 m and 600 m above the sea level, respectively. Coastal areas range from the Mediterranean Sea to the Atlantic Ocean influencing the climate of the whole peninsula. Whereas Mediterranean climate encompasses the eastern, southern and central portions of the Iberian Peninsula, the Atlantic climate is present in the western and northern sectors of the study area. The main vegetation types vary from semi-desertic flora, Mediterranean oak forests, steppe-land areas and evergreen pine forests, to deciduous vegetation (including beech trees, oak trees, birches, etc.) and sub-alpine and alpine vegetation. There are also a number of wetlands distributed across the coastline and inner plateaus with high biodiversity (especially breeding bird species), as the study area is included within one of the main corridors for migratory birds in Europe.

2.2. Environmental data and protected areas

We characterized the landscape of the study area using three environmental layers: land cover, elevation, and distance to water. The land cover layer was provided by the CORINE 2000 Land Cover program (http://terrestrial.eionet.eu.int/CLC2000), the digital elevation model (DEM) was obtained from the Shuttle Radar Topography Mission with a resolution of 3-arc seconds (http://srtm.csi.cgiar.org/), and the distance to water was calculated using a hydrologic map of the Iberian Peninsula provided by the Spanish National Cartographic Institute (http://www.ign.es/ign/es/IGN/home.jsp).

CORINE 2000 is divided into 46 land cover classes, grouped into five main categories: artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands, water bodies and courses. The full CORINE land cover legend is available through the European Environmental Agency web site (http://dataservice.eea.eu.int/dataservice/). Using the hydrologic layer, we integrated into the CORINE 2000 small ponds, wetlands, lakes and river courses (distinguishing temporary and permanent waters) that were not represented due to the original resolution of the CORINE dataset.

We obtained geographical data on the existing protected areas (PAs) and on the Natura 2000 network in Spain from the biodiversity database of the Spanish Ministry of Environment (http://www.mma.es/portal/secciones/biodiversidad/banco_datos/). We extracted PAs for Portugal from the World Database on Protected Areas (http://sea.unep-wcmc.org/wdbpa/), and we obtained a map of the Portuguese Natura 2000 network from the Portuguese Institute for Nature Conservation (http://portal.icn.pt/ICNPortal/vPT/). Natura 2000 is a program established by the European Commission (2000) for the conservation of natural resources. It is regulated mainly by two directives (the 1979 Bird Directive and the 1992 Habitat Directive) that identify endangered species, subspecies and habitats for which each member state is required to identify conservation areas. The Bird Directive is aimed at the protection of bird species and calls for the designation of special protection areas (SPAs). The Habitat Directive aims to protect animals (other than birds), plants, and habitats for which each member state is required to identify sites of community importance (SCIs). The SCIs and SPAs make up the Natura 2000 network, whose aim is to conserve habitat types and wildlife species throughout Europe (European Commission, 2000).

All vector layers were transformed to raster with a pixel size of 100 m (the finest resolution suggested for the CORINE Land Cover map by the European Environmental Agency, http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster); the DEM, already in raster format (original pixel size of roughly 90 m), was re-sampled to obtain a pixel size of 100 m using the resample algorithm (bilinear interpolation) available in ArcGIS 9.2 (ESRI©).

2.3. Species distribution

We collected data on the distribution of 398 vertebrate species in the form of extent of occurrence (hereafter EOO; *sensu* Gaston and Fuller, 2009): 84 mammals (72 species from Schipper et al., 2008; 12 species whose distribution was uncertain in Schipper et al., 2008 from Palomo and Gisbert, 2002), 242 regularly breeding birds (226 species from Hagemeijer and Blair, 1997; 16 species whose distribution was uncertain in Hagemeijer and Blair, 1997 from Martí and Del Moral, 2003), 28 amphibians from IUCN (2006b), and 44 reptiles (31 species from the Global Reptile Assessment, courtesy of S. Stuart; 12 species from Gasc et al. (2004); one from Pleguezuelos et al. (2004)). All 398 species are native to the Iberian Peninsula or have been introduced in historical times and are now naturalized (e.g., *Genetta genetta*, *Herpestes ichneumon*, *Testudo graeca*). Given our focus on conservation, we did not include in the analyses all introduced and exotic species (e.g., *Psittacula krameri*, *Myiopsitta monachus*, *Ovis gmelini*, *Mustela vison*); we also excluded freshwater fishes, for which no information on ecology and distribution was readily available from the entire study area. We included only regularly breeding bird species, because wintering birds are usually present in habitats different from those where they breed, then making complex to create accurate distribution models without increasing commission error. Moreover, we did not consider three bird species (*Phralacrocorax aristotelis*, *Aythia fuligula*, *Pandion haliaetus*) whose breeding distribution in Portugal was unknown. The complete species list is available in the Appendix I.

For each of the 398 species we collected data on elevation range (maximum range of presence), relationship with water, and species–habitat relationships. These data are based on expert knowledge as compiled in the Spanish National Vertebrates Atlases of mammals (Palomo and Gisbert, 2002), birds (Martí and Del Moral, 2003), and amphibians and reptiles (Pleguezuelos et al., 2004). In particular, we classified each of the 46 CORINE 2000 land cover classes into two categories: habitat (land cover types where the species can be found with stable populations) and non-habitat (land cover types where the species cannot be found with stable populations). Moreover, we classified each species in two classes depending on their relationships with water: species with no particular relationship to water in their life cycles, and water-related species (i.e., species that are related to the presence of water courses and/or water bodies). For each water-related species (mainly amphibians and aquatic birds) we collected distance to temporary and/or permanent waters (based on Palomo and Gisbert, 2002; Martí and Del Moral, 2003; Pleguezuelos et al., 2004; and adapted from Maiorano et al., 2006).

To reduce the extensive commission errors that are usually associated with EOOs, we followed Catullo et al. (2008) and Jenkins and Giri (2008) combining the elevation range, the species–habitat relationships, and water preferences to refine the available EOO for 377 species (84 mammals, 226 breeding birds, 27 amphibians, and 40 reptiles). For these species, only the areas inside the EOO with land-cover functioning as habitat, included in the elevation range and respecting the water preferences (if present) were considered in all subsequent analyses (hereafter indicated as *refined EOO*). For 21 species strictly associated with particular microhabitats (not mapped at the scale that we considered) and/or with EOO smaller than 500 km^2 (e.g., *Lacerta aranica*, *Lacerta aurelioi*, *Podarcis atrata*, *Alytes muletensis*,

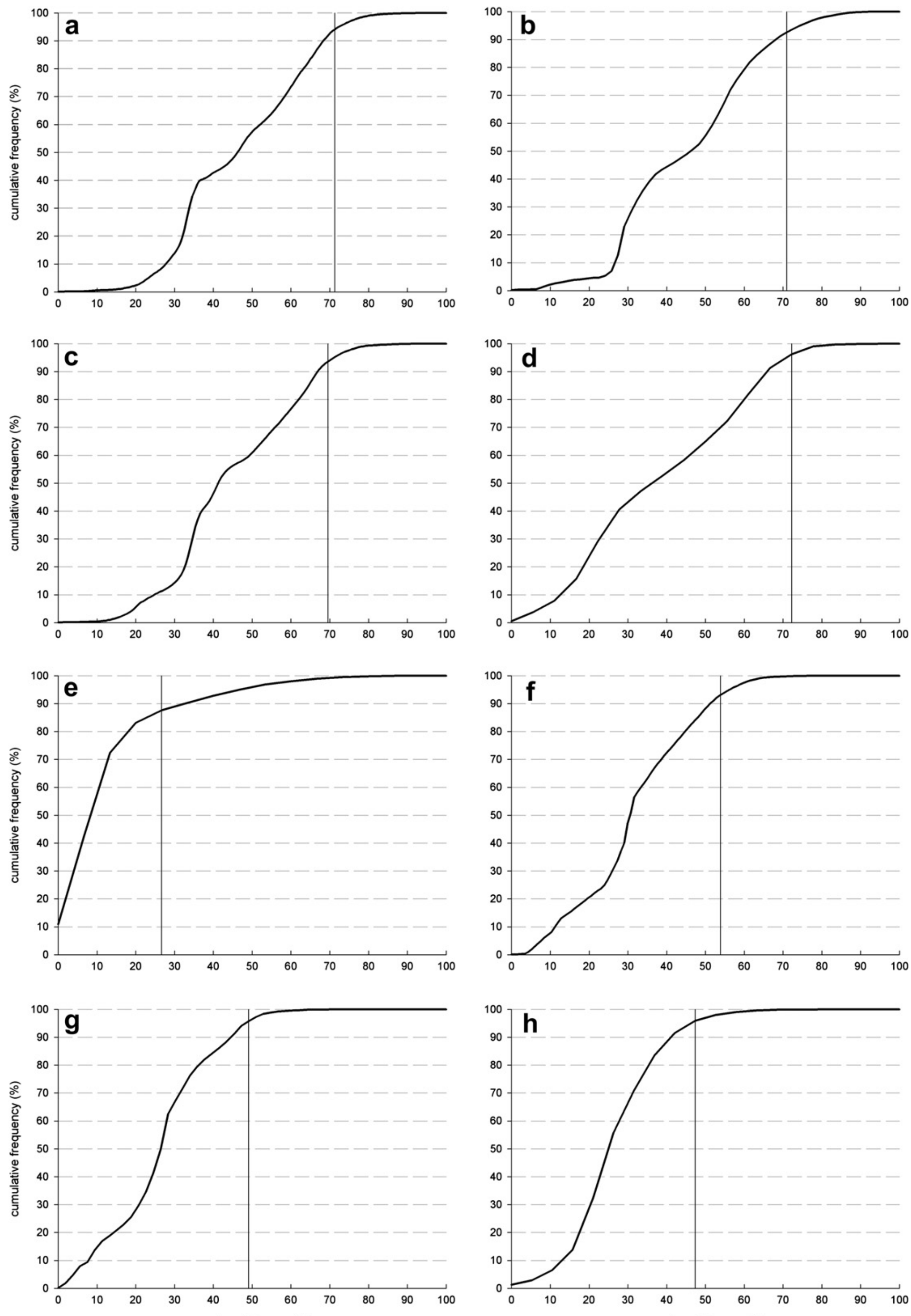

Fig. 2. Cumulative distribution functions of species richness for a) all species, b) mammals, c) breeding birds, d) reptiles, e) amphibians, f) all-IUCN, g) threatened-IUCN, h) endemic species. Vertical line in each graph indicates the species richness threshold value for the identification of the hotpots. More details on the methodology are provided in Methods section.

Puffinus mauretanicus, *Hydrobates pelagicus*, *Falco eleonorae*, *Uria algae*, *Rissa tridactyla*) we considered in the analyses the entire EOO.

No point data was readily available to evaluate the reliability of our refined EOOs. Thus we considered a set of atlases recording species presence in 10 × 10 km squares in Spain (Palomo and Gisbert, 2002; Martí and Del Moral, 2003; Pleguezuelos et al., 2004) for a total of 362 species among those we included in the analyses. If our procedure to refine the available EOO is reliable, we would expect that the *refined EOOs* always have a lower commission error if compared to the original EOOs (Boyce et al., 2002; Hirzel et al., 2006). Therefore, we compared the percentage of habitat inside the 10 × 10 km squares where the species has been found (corresponding to the area inside the EOO where the species is certainly present) with the percentage of habitat inside the entire EOO, which includes also areas where the species is not actually present. If our *refined EOOs* are reliable (i.e., if we were successful in reducing the error of commission), the percentage of habitat where the species is certainly presence should be higher if compared to the percentage of habitat inside the full EOO (Boyce et al., 2002; Hirzel et al., 2006).

2.4. Vertebrate biodiversity hotspots

We generated eight maps of species richness based on different criteria: total richness, vulnerability, and endemism. In particular, we obtained five maps of total richness, one for each taxonomic group (considering all species belonging to the selected taxon) and one considering all species at the same time. To quantify vulnerability we used the IUCN red list categories defined by the Red Books for Iberian vertebrates (Palomo and Gisbert, 2002; Madroño et al., 2004; Pleguezuelos et al., 2004) when available, and the IUCN red list (IUCN, 2006c) for taxa like *Chiroptera* that were not listed at the national level. We generated two vulnerability maps, one considering 158 species listed from critically endangered to near threatened (hereafter referred to as *all-IUCN*) and one considering only 96 species listed as critically endangered, endangered, or vulnerable (hereafter *threatened-IUCN*). We generated also one map of endemism richness considering only species endemic at the Iberian level, Balearic Islands included, as defined in Hagemeijer and Blair (1997), Palomo and Gisbert (2002), Martí and Del Moral (2003), Gasc et al. (2004), Pleguezuelos et al. (2004), IUCN (2006b), Schipper et al. (2008), and the Global Reptiles Assessment (courtesy of S. Stuart). In order to get comparable results, we divided each richness map by the maximum number of species represented within a single grid cell and multiplied by 100, obtaining a range of values from 0 to 100. To avoid excessive fragmentation and to ensure that all tests could be computed in a reasonable amount of time, following the approach proposed by Waltari et al. (2007), we aggregated the maps of species richness by a factor of 20 using a median aggregation algorithm, obtaining a pixel size of 4 × 4 km.

To test whether coincidence among the different richness maps was better than random, we analyzed the local spatial correlations measuring Moran's I*i* statistic, as implemented in GeoDA (Anselin, 1995, 2003). To test the significance of the local Moran's I*i* we used a conditional permutation procedure with 9999 replications (Anselin, 2003). To limit problems with multiple comparisons, we defined as significant all local Moran's I*i* with $p < 0.0001$ (Anselin, 1995).

Following Bartolino et al. (2011), we identified hotspots of species richness, vulnerability and endemism using a cumulative relative frequency distribution function for each species richness map. In the upper tail of the cumulative relative frequency distribution, we identified the point for which the slope of the tangent to the cumulative distribution was equal to 1 and we used this value as a global threshold to identify biodiversity hotspots. A threshold identified in this way can help discriminate the areas characterized by the highest values of richness and at the same time by the highest rates of accumulation of richness values (Bartolino et al., 2011).

We produced eight binary hotspots maps (with 1 indicating grid cells above the threshold and 0 indicating grid cells below; Fig. 2), one for each of the richness maps described above. The different types of hotspots were overlaid with the existing protected areas and with the Natura 2000 network in order to identify gaps in their representation. All analyses were performed in ArcGis 9.2 (ESRI©) and GeoDA.

3. Results

3.1. Species distribution and vertebrate biodiversity hotspots

For 330 species (87.5% of all species with a refined EOO and all critically endangered species) the process of EOO refinement was satisfactory, with a minimum of 73.6% for mammals and a maximum of 97.3% for birds (Table 1).

We found a limited amount of surrogacy among the different species groups (Table 2), with a Moran's I*i* of 0.49 measured for the concordance among threatened-IUCN richness and all-IUCN richness, and 0.46 among total richness and mammal richness, and among total richness and bird richness. In particular, looking at the map of local Moran's I*i* (Fig. 3), it is evident that although many areas are consistently indicated as high-richness, the particular pattern is taxon-specific with, for example, mammals concentrated in the northern part of the study area and reptiles and endemic species concentrated in the southern part. However, the area in the Mediterranean biogeographical region at the boundaries between Portugal and Spain (i.e., Extremadura) is almost always indicated as one of the most important from all richness maps.

Table 1
Number of species by taxa and categories of threat evaluated positively. The percentage, calculated over the total number of species per taxon, is shown in brackets (see text for more details).

	Mammals (72 species)	Birds (223 species)	Amphibians (27 species)	Reptiles (40 species)	Total (362 species)
CR	1 (1.39)	3 (1.35)	0 (0.00)	0 (0.00)	4 (1.10)
EN	2 (2.78)	12 (5.38)	1 (3.70)	3 (7.50)	18 (4.97)
VU	12 (16.67)	24 (10.76)	8 (29.63)	3 (7.50)	47 (12.98)
NT	12 (16.67)	25 (11.21)	8 (29.63)	8 (20.00)	53 (14.64)
LC	25 (34.72)	149 (66.82)	7 (25.93)	20 (50.00)	201 (55.52)
DD	1 (1.39)	4 (1.79)	1 (3.70)	1 (2.50)	7 (1.93)
Total (with positive evaluation)	53 (73.61)	217 (97.31)	25 (92.59)	35 (87.50)	330 (91.16)

Table 2
Values of Moran's I*i* calculated over all possible comparisons among maps of species richness.

	All Species	Mammals	Birds	Reptiles	Amphibians	All IUCN	Threatened IUCN	Endemic
All Species	1.0							
Mammals	0.46	1.0						
Birds	0.46	0.39	1.0					
Reptiles	0.37	0.28	0.34	1.0				
Amphibians	0.24	0.22	0.20	0.25	1.0			
All-IUCN	0.41	0.35	0.41	0.31	0.16	1.0		
Threatened-IUCN	0.35	0.26	0.36	0.28	0.11	0.49	1.0	
Endemic	0.26	0.20	0.23	0.38	0.19	0.28	0.28	1.0

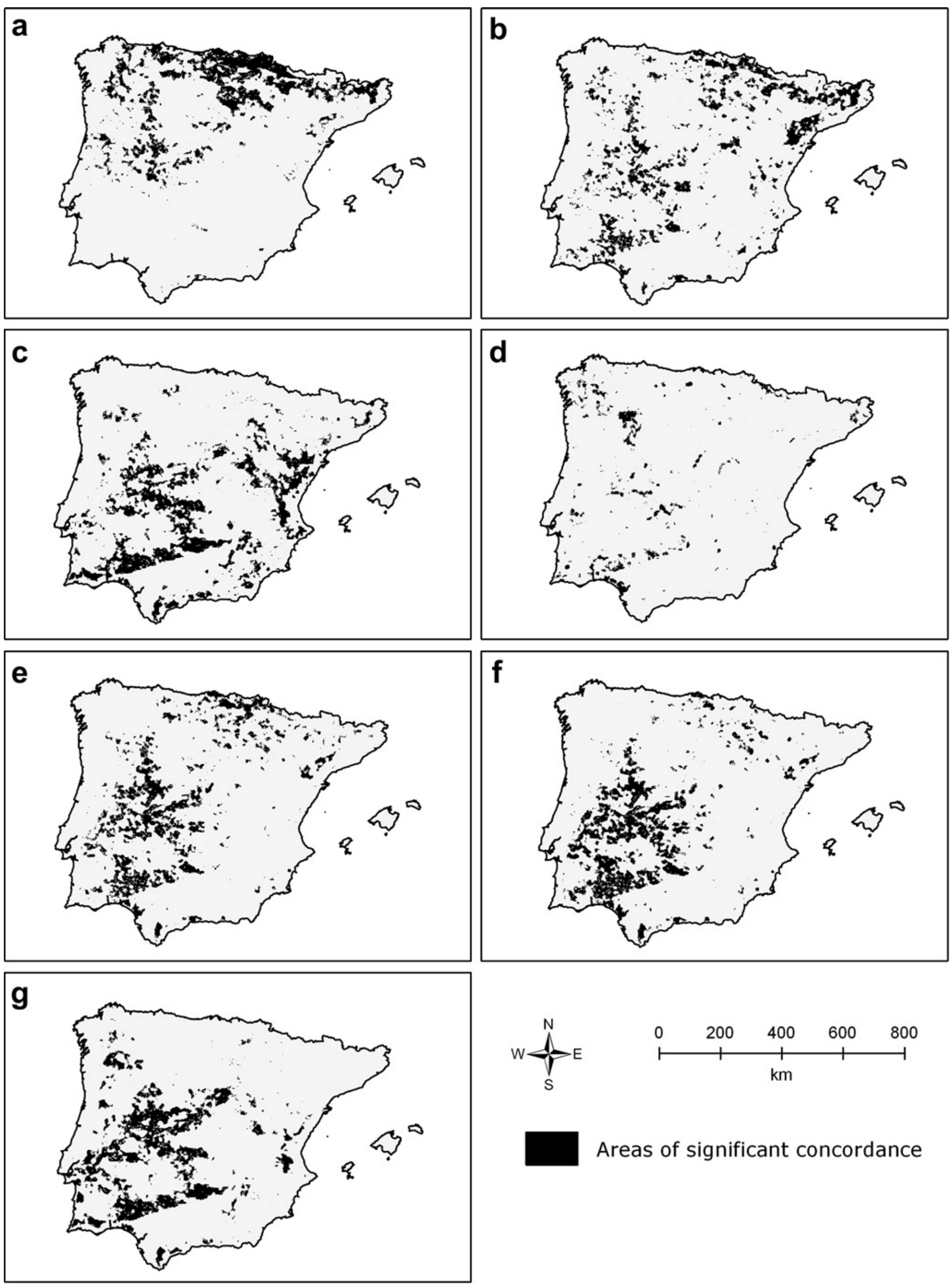

Fig. 3. Areas of significant coincidence (indicated in black and measured as local Moran's I with $p \leq 0.0001$) among high values of total species richness and high values of (a) mammals, (b) breeding birds, (c) reptiles, (d) amphibians, (e) all-IUCN species (critically endangered, endangered, vulnerable, near threatened, data deficient), (f) threatened-IUCN species (critically endangered, endangered and vulnerable species), (g) endemic species. All other possible comparisons have been omitted from the map.

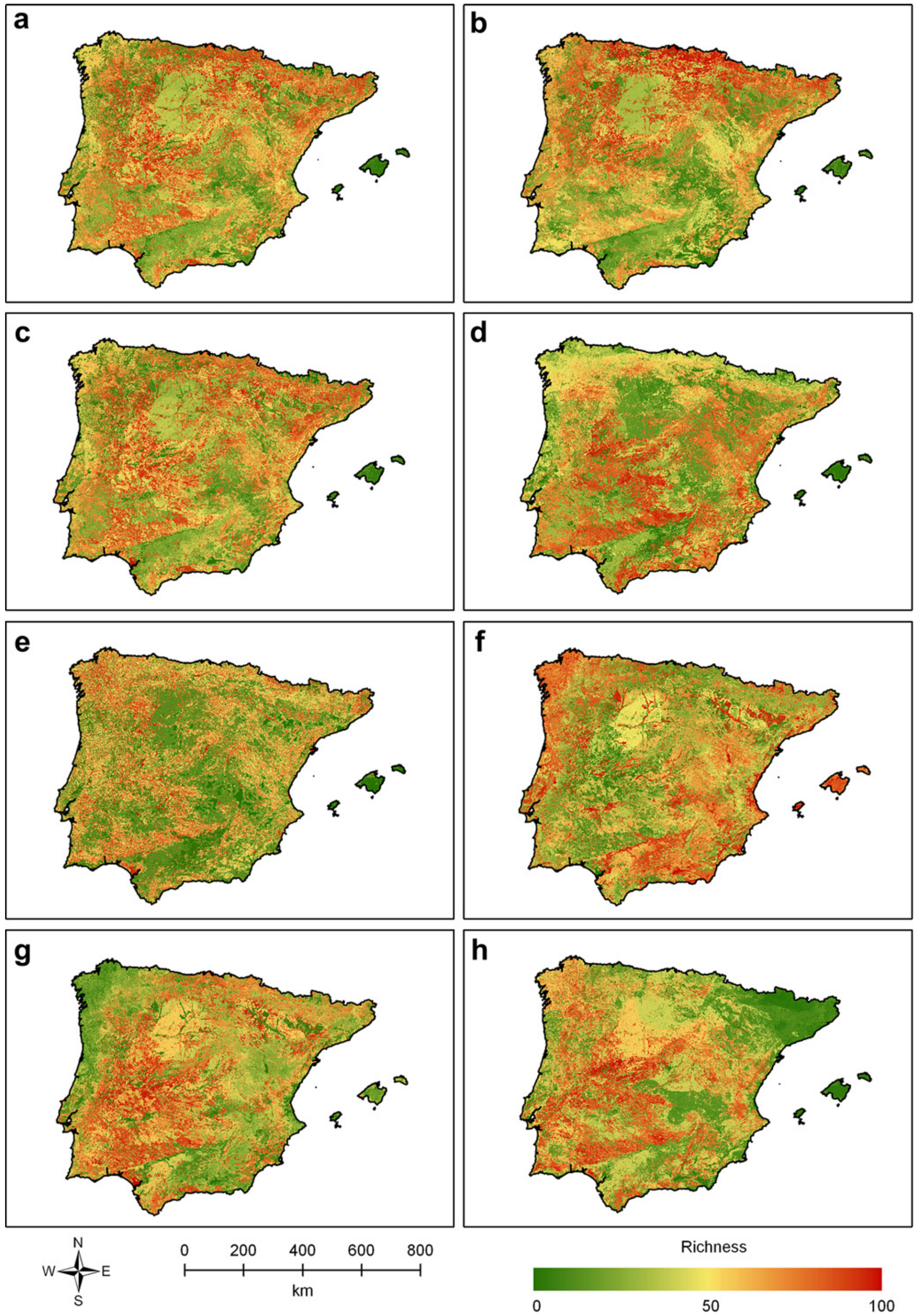

Fig. 4. Species richness maps. (a) all species; (b) mammals; (c) breeding birds; (d) reptiles; (e) amphibians; (f) all-IUCN species (critically endangered, endangered, vulnerable, near threatened, data deficient); (g) threatened-IUCN species (critically endangered, endangered and vulnerable species); (h) endemic species.

Considering all species (Fig. 4a), large areas of the Iberian Peninsula are characterized by high numbers of species (median species richness value = 111 species per pixel) but the hotspots of species richness cover only 3.7% of the study area, mainly located in the western and northern portion of the Mediterranean biogeographical region (Fig. 5a; Table 3), including the border between Portugal and Spain, and the southern parts of the Cantabric and Pyrenean mountain ranges. Also important are some areas along the Mediterranean coast in southern Spain.

Considering mammals richness (Figs. 4b and 5b), the areas with higher number of species are located in the Atlantic region and in the Northern Castilian plateau, with the main hotspots (7.7% of the Iberian Peninsula, 45,390 km^2; Table 3) located in northern Spain (Basque country, Northern Navarra, Cantabria and Asturias). Species richness for breeding birds (Fig. 4c) shows a spatial pattern that is clearly similar to that measured for total richness, as it was expected considering that breeding birds account for 62% of all species in the Iberian Peninsula. The hotspots of species richness for

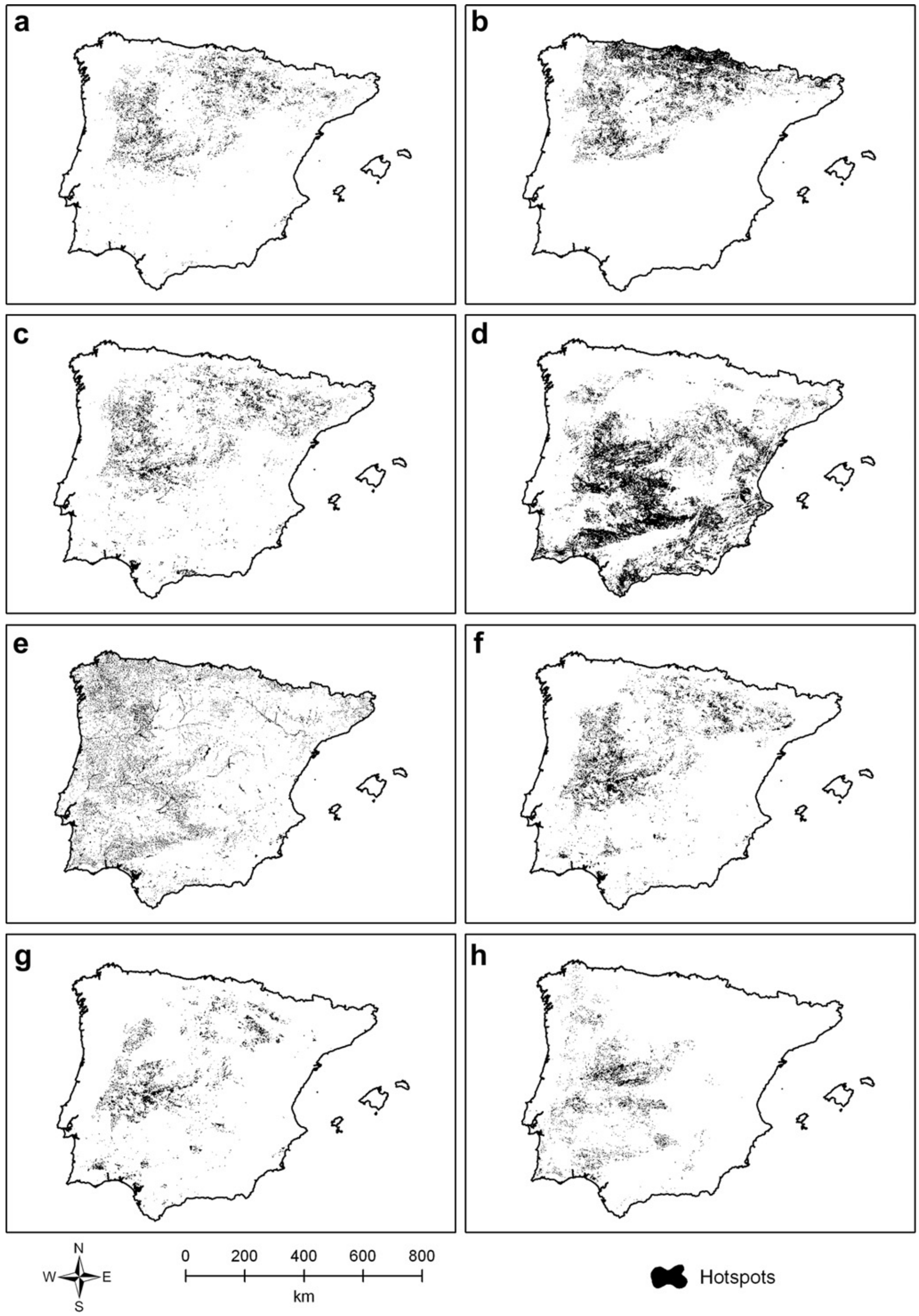

Fig. 5. Hotspots in the Iberian Peninsula. (a) all species; (b) mammals; (c) breeding birds; (d) reptiles; (e) amphibians; (f) all-IUCN species (critically endangered, endangered, vulnerable, near threatened, data deficient); (g) threatened-IUCN species (critically endangered, endangered and vulnerable species); (h) endemic species.

this taxon (4.8% of the study area; Table 3) are in The Doñana National Park, southwestern Spain (Extremadura, northern Andalusia), inland Portugal and in all the Iberian mountain ranges (Fig. 5c) along the medium elevation areas. The areas of high species richness for reptiles (Figs. 4d and 5d) are located in the most arid portions of southern and southeastern Spain (Andalusia and Murcia), as well as in the central and western Spain (i.e., Central Mountain range and regions of Extremadura and Castilla-La Mancha), with hotspots occupying more than 16% of the study area (Table 3). Considering amphibians, the areas of high species richness are widely distributed in the entire Iberian Peninsula (Fig. 4e), with the main hotspots of species richness (6.9% of the study area; Table 3) located in inland wetlands and small ponds, especially in the medium and high courses of the main rivers (Fig. 5e). Coastal wetlands (e.g., Doñana National Park and the Delta of the Ebro River) are also important areas for amphibians (Fig. 4e).

Table 3
Area occupied by the different types of hotspots in the Iberian Peninsula, in the PAs, in the Natura 2000, and in the sum of PAs and Natura 2000 (the percentage over the overall area of the Iberian Peninsula is shown in brackets). All measures are given in km^2.

	Hotspots							
	All species	Mammals	Birds	Reptiles	Amphibians	All IUCN[a]	Threatened IUCN[b]	Endemic
Iberian Peninsula	21,610 (3.7)	45,391 (7.7)	28,279 (4.8)	96,654 (16.4)	40,734 (6.9)	31,787 (5.4)	19,011 (3.2)	15,415 (2.6)
PAs	1122 (0.2)	5030 (0.9)	1652 (0.3)	15,659 (2.7)	6144 (1.0)	2529 (0.4)	1585 (0.3)	2129 (0.4)
Natura 2000	4822 (0.8)	12,346 (2.1)	6110 (1.0)	41,485 (7.1)	13,611 (2.3)	8373 (1.4)	4722 (0.8)	6948 (1.2)
PAs + Natura 2000	4893 (0.8)	13,293 (2.3)	6202 (1.1)	42,167 (7.2)	14,237 (2.4)	8480 (1.4)	4828 (0.8)	7031 (1.2)

[a] Species listed according to IUCN criteria (critically endangered, endangered, vulnerable, near threatened, data deficient).
[b] Critically endangered, endangered and vulnerable species.

3.2. *Vulnerability hotspots*

Hotspots for all-IUCN species cover the 5.4% of the study area (31,787 km^2; Table 3), whereas hotspots for threatened-IUCN species cover only 3.2% (19,011 km^2; Table 3), with western and southwestern Iberian Peninsula, the Ebro River valley, the Mediterranean wetlands and the boundaries among the Mediterranean, Alpine and Atlantic regions (in northern Spain) representing the stronghold of maximum diversity for both (Fig. 5f). Considering threatened IUCN-species (Figs. 4g and 5g) also the Balearic Islands (particularly Mallorca, Menorca and Cabrera archipelago) and some valleys of the Pyrenees (like the Aran Valley) are important, while a particular case is represented by The Doñana National Park (southwestern Spain), the main hotspot, where five out of twelve critically endangered species are present.

3.3. *Endemic species hotspots*

Most of the endemic species (mainly reptiles and amphibians) are present in the Mediterranean biogeographical region, especially along the medium elevations of mountain ranges (Fig. 4h), such as the Central System, going from Madrid to inner Portugal (Fig. 5h). The Doñana National Park is also a hotspot for endemic species along with southwestern Iberian Peninsula, inner and northern Portugal, the medium courses of the main Atlantic rivers, and Northwestern Spain (Galicia).

3.4. *Species richness in protected areas and Natura 2000*

Existing PAs occupy more than 51,500 km^2, corresponding to 8.8% of the Iberian Peninsula (Fig. 1). The Natura 2000 network, if approved as proposed now, will occupy more than 144,000 km^2 (24.6% of the study area; Fig. 1), and, added to the existing PAs, it will raise the total area protected to more than 150,000 km^2, 25.6% of the Iberian Peninsula.

Existing PAs are not particularly concentrated on areas of high species richness (median number of species per pixel = 118 in the PAs), with only 5.2% of the hotspots of total richness being currently protected (Table 3). The same pattern is true also considering particular taxonomic groups (with a minimum coverage of 5.8% for the hotspots for breeding birds and a maximum of 16.2% for reptiles; Table 3), endangered species (only 7.9% of the hotspots for listed species are included in existing PAs; Table 3), and endemic species (13.8% of the hotspots of endemic species are covered by PAs; Table 3).

The proposed Natura 2000 network will provide a marked improvement with respect to existing PAs, even though on the average the protection offered to areas of high species richness will not be highly different from the average condition in the Iberian Peninsula (median number of species per pixel = 119 in the Natura, 2000 network). Considering all species, 22.3% of the hotspots of total richness are covered by areas designated under Natura 2000 (Table 3), with a maximum coverage of 42.9% for the hotspots of reptiles' species richness and a minimum of 21.6% for mammals. Particularly high is the coverage offered by the Natura 2000 network to endemic species, whose hotspots are covered for 45.1% (Table 3).

4. Discussion

Our results provide a fine-scale analysis of congruency among species richness and protected areas for terrestrial vertebrates available at the level of the entire Iberian Peninsula. Previous works were mainly focused at a national scale (considering either Spain or Portugal) and on different taxa (Castro-Parga et al., 1996; Araújo, 1999; Martín-Piera, 2001; Lobo and Araújo, 2003; Rey-Benayas and de la Montaña, 2003; Nogués-Bravo and Martínez-Rica, 2004; Abellán et al., 2005; Rey-Benayas et al., 2006; Martínez et al., 2006; Traba et al., 2007; Zamora et al., 2007). In fact, Rey-Benayas and de la Montaña, (2003) and Araújo et al. (2007) were the only ones to provide an Iberian-wide evaluation of the existing PAs. However, both papers presented their analyses using a coarse spatial resolution (2500 km^2), usually considered for continent-wide atlases (Gasc et al., 2004; Hagemeijer and Blair, 1997; Mitchell-Jones et al., 1999), and much coarser than what is usually required for a nation-wide or even continent-wide gap analyses (e.g., 1 km^2 for the entire South-East Asia as in Catullo et al., 2008; 90 m^2 for the US Gap Analysis Program which covers the entire US; http://gapanalysis.nbii.gov/). Such resolution might be of limited help for practical conservation planning to be implemented in the Iberian Peninsula because of the highly fragmentation and strong diversity of landscapes that characterize the Mediterranean region (Médail and Quézel, 1999; Atauri and de Lucio, 2001). Moreover, it is widely recognized that reserve selection outcomes vary in relation to the quality and reliability of the input dataset (Freitag and Van Jaarsveld, 1998; Hopkinson et al., 2000; Rodrigues and Gaston, 2001; Araújo, 2004; Seo et al., 2009) and both Rey-Benayas and de la Montaña (2003) and Araújo et al. (2007) recognized this problem, urging for better biodiversity data to be compiled with higher resolution. Furthermore, a number of works have clearly indicated the negative influence that commission errors can have in conservation planning (Rodrigues et al., 2004; Harris and Pimm, 2007; Hurlbert and Jetz, 2007).

In developing our approach, we aimed at reducing errors of commission associated with EOOs (Jetz et al., 2008). We collected the most updated information available on species ecology and distribution for almost all vertebrate species that are present in the Iberian Peninsula. We used this information to refine the available EOOs considering the finest possible spatial detail. Using independently collected data coming from national atlases, we tested the predictive value for 96% of our models, and for 87.5% of them the results were positive, providing a rough measure of the reliability of our effort.

4.1. Hotspots, protected areas, and conservation options

We found no clear surrogacy among the different types of hotspots in the Iberian Peninsula (Figs. 4 and 5), result that partially confirm what has been found by others (e.g., Orme et al., 2005). The pattern of species richness differ from those based on vulnerability and endemism alone, but vulnerability and endemism are closely related, probably because of the high number of endemic species that are also classified in one of the IUCN red list classes.

As a general pattern, the richest areas as well as those including most vulnerable and endemic species, are located in the western and southwestern portions of the Iberian Peninsula (Castilian Plateau, Extremadura and northern Andalusia) all in the Mediterranean biogeographical region. A possible explanation of this general pattern is probably linked to biogeographical and refugia effects occurred during the last glaciations (Rey-Benayas and de la Montaña, 2003). From (roughly) 80,000 to (roughly) 15,000 years ago many species could have been limited to the southern parts of Europe, and this could have lead to the specific biota we currently found in the southern and southwestern Iberian Peninsula (López-López et al., 2008). The Spanish Imperial Eagle (*Aquila adalberti*) and the Iberian Lynx (*Lynx pardinus*), both endemic of the Iberian Peninsula, have been suggested as good examples of this type of speciation (Ferrer and Negro, 2004). Moreover, the high-richness level of the Mediterranean part of the study area can also be explained considering climatic factors like precipitation and temperature that make the Mediterranean climate particularly favorable for amphibians and reptiles (Rey-Benayas and de la Montaña, 2003).

There is only a partial match between our results and those found in previous papers, even considering those papers focused on vertebrate diversity (Rey-Benayas and de la Montaña, 2003; Araújo et al., 2007). For example, our results for species richness match quite closely with previous results found by Rey-Benayas and de la Montaña (2003), particularly for mammals, and breeding birds, and partially for amphibians, but not for reptiles. These small differences can be explained as a result of the different spatial resolution of the input dataset (Rey-Benayas and de la Montaña (2003) and Araújo et al. (2007) used 2500 km^2 grid cells, whereas we used 10,000 m^2 grid cells to represent the distribution of single species and 16 km^2 grid cells to represent species richness), and of the different algorithms used for identifying hotspots.

We have provided an accurate and detailed dataset on species distribution for terrestrial vertebrates in the Iberian Peninsula, and we used a pre-defined mathematical criterion to define hotspots (Bartolino et al., 2011). In fact, using cumulative distribution functions we defined as hotspots those areas with high species richness where the accumulation in the number of species increases faster than the area considered, delimiting as hotspots only those areas with the highest species concentration. However, it is still important to underline that a different method may have identified different hotspots (Bartolino et al., 2011).

As already pointed out by Araújo et al. (2007), the Natura 2000 network can potentially constitute an important baseline for protecting vertebrate diversity in the Iberian Peninsula. In fact, the coverage offered by Natura 2000 and existing PAs is much higher if compared to PAs alone, but particular attention is necessary in interpreting our results. The Natura 2000 network covers nearly a quarter of the entire Iberian Peninsula and we cannot exclude that the higher coverage provided to vertebrates is the result of a random effect. In fact, a much more efficient (e.g., same area and higher coverage, or same coverage in smaller area) network of areas could probably have been devised using the principles and algorithms of systematic conservation planning (Margules and Pressey, 2000), as proposed by Araújo et al. (2007).

Maiorano et al. (2007) found similar results for the Italian Peninsula and concluded that the Natura 2000 network cannot constitute a viable conservation strategy if taken alone. In fact, protected areas, if considered as islands in a human dominated landscape, cannot ensure long term conservation (e.g., Maiorano et al., 2008). Moreover, the biodiversity that we found nowadays in the Mediterranean region is the result of millennia of human occupation of the territory. This entails a consequent alteration and transformation of the landscape, as well as a series of species' extinctions that historically occurred. We suggest taking a step forward in conservation planning in the Mediterranean basin, a step forward that explicitly consider the history of the region as well as its present environmental context (Foster et al., 2003), and that would allow moving from traditional reserve design to new insights in conservation planning. Traditional farming practices, extensive agriculture and sustainable use of natural resources should be taken into account for the development of conservation strategies in the Mediterranean region. It would be also desirable to take into account the traditional farming systems outside the PAs, since in most cases, these areas present higher biodiversity levels than PAs (e.g., cereal steppes, mosaics of non-irrigated crops, etc.) (Traba et al., 2007; Cox and Underwood, 2011).

The case of Extremadura and western Andalucía in Spain provides a clear example of the coincidence between a biodiversity hotspots (based on vulnerability, endemism or richness criteria) and traditional practices of land management. In these areas, designing protected areas and limiting (or even prohibiting) traditional management and farming practices, and implementing a "laissez faire" policy can potentially result in an effective loss of biodiversity, and the initially well-intentioned conservation policies may become inefficient with time.

We suggest that the development of a coherent conservation policy to be applied in the entire Mediterranean Europe and the Iberian Peninsula could lead the way in this framework. Biodiversity hotspots in Spain and Portugal are clearly not associated with isolated, non-human-dominated areas. To preserve biodiversity in Mediterranean landscapes it is therefore necessary to incorporate the human dimension in conservation policies (in economical, social and cultural terms), as well as explicitly considering the "processes" that contributed to the generation of the high biodiversity values that we observe today, rather than a static view focused merely on the observed biodiversity "patterns".

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Appendix I

List of species considered in the analysis. Abbreviations: EOO, extent of occurrence; DM, distribution model; A, amphibian; B, bird; M, mammal; R, reptile; GAA, Global Amphibian Assessment (IUCN, 2006b); EMA = European Mammal Assessment (IUCN 2007); AES, Spanish Atlas of Mammals (Palomo and Gisbert, 2002); GRA, Global Reptile Assessment; EBBA = European Breeding Bird Atlas (Hagemeijer and Blair, 1997); AVE, Spanish Breeding Bird Atlas (Martí and Del Moral, 2003); AAER, Atlas of Amphibians and Reptiles in Europe (Gasc et al., 2004); SAAR, Spanish Atlas of Amphibians and Reptiles(Pleguezuelos et al., 2004)

Species Name	Group	EOO	DM	Evaluated	Red List Category	Endemism
Alytes cisternasii	A	GAA	x	x	NT	x
Alytes dickhilleni	A	GAA	x	x	VU	x
Alytes muletensis	A	GAA			CR	x
Alytes obstetricans	A	GAA	x	x	NT	
Bufo bufo	A	GAA	x	x	LC	
Bufo calamita	A	GAA	x	x	LC	
Bufo viridis	A	GAA	x	x	VU	
Chioglossa lusitanica	A	GAA	x	x	VU	x
Discoglossus galgai	A	GAA	x	x	LC	x
Discoglossus jeanneae	A	GAA	x	x	NT	x
Euproctus asper	A	GAA	x	x	NT	x
Hyla arborea	A	GAA	x	x	NT	
Hyla meridionalis	A	GAA	x	x	NT	
Pelobates cultripes	A	GAA	x	x	NT	
Pelodytes ibericus	A	GAA	x	x	DD	x
Pelodytes punctatus	A	GAA	x	x	LC	
Pleurodeles waltl	A	GAA	x	x	NT	
Rana dalmatina	A	GAA	x	x	EN	
Rana iberica	A	GAA	x	x	VU	x
Rana perezi	A	GAA	x	x	LC	
Rana pyrenaica	A	GAA	x	x	VU	x
Rana temporaria	A	GAA	x	x	LC	
Salamandra salamandra	A	GAA	x	x	VU	
Triturus alpestris	A	GAA	x	x	VU	
Triturus boscai	A	GAA	x	x	LC	x
Triturus helveticus	A	GAA	x	x	LC	
Triturus marmoratus	A	GAA	x	x	LC	
Triturus pygmaeus	A	GAA	x	x	VU	x
Tachybaptus ruficollis	B	EBBA	x	x	LC	
Podiceps cristatus	B	EBBA	x	x	LC	
Podiceps nigricollis	B	EBBA	x	x	NT	
Calonectris diomedea	B	AVE			EN	
Puffinus mauretanicus	B	AVE			CR	x
Hydrobates pelagicus	B	AVE			VU	
Phalacrocorax carbo	B	AVE			LC	
Botaurus stellaris	B	EBBA	x	x	CR	
Ixobrychus minutus	B	EBBA	x	x	LC	
Nycticorax nycticorax	B	EBBA	x	x	LC	
Ardeola ralloides	B	EBBA	x	x	NT	
Bubulcus ibis	B	EBBA	x	x	LC	
Egretta garzetta	B	EBBA	x	x	LC	
Ardea cinerea	B	EBBA	x	x	LC	
Ardea purpurea	B	EBBA	x	x	LC	
Ciconia nigra	B	EBBA	x	x	VU	
Ciconia ciconia	B	EBBA	x	x	LC	
Plegadis falcinellus	B	AVE			VU	
Platalea leucorodia	B	EBBA	x	x	VU	
Phoenicopterus roseus	B	AVE			NT	
Tadorna tadorna	B	EBBA	x	x	NT	
Anas strepera	B	EBBA	x	x	LC	
Anas crecca	B	AVE			VU	
Anas platyrhynchos	B	EBBA	x	x	LC	
Anas acuta	B	AVE			VU	
Anas querquedula	B	EBBA	x	x	VU	
Anas clypeata	B	EBBA	x	x	NT	
Marmaronetta angustirostris	B	EBBA	x	x	CR	
Netta rufina	B	EBBA	x	x	VU	
Aythya ferina	B	EBBA	x	x	LC	
Aythya nyroca	B	AVE			CR	
Oxyura leucocephala	B	EBBA	x	x	EN	
Pernis apivorus	B	EBBA	x	x	LC	
Elanus caeruleus	B	EBBA	x	x	NT	
Milvus migrans	B	EBBA	x	x	NT	
Milvus milvus	B	EBBA	x	x	EN	

Appendix I (*continued*)

Species Name	Group	EOO	DM	Evaluated	Red List Category	Endemism
Gypaetus barbatus	B	EBBA	x	x	EN	
Neophron percpterus	B	EBBA	x	x	EN	
Gyps fulvus	B	EBBA	x	x	LC	
Aegypius monachus	B	EBBA	x	x	VU	
Circaetus gallicus	B	EBBA	x	x	LC	
Circus aerugisus	B	EBBA	x	x	LC	
Circus cyaneus	B	EBBA	x	x	LC	
Circus pygargus	B	EBBA	x	x	VU	
Accipiter gentilis	B	EBBA	x	x	LC	
Accipiter nisus	B	EBBA	x	x	LC	
Buteo buteo	B	EBBA	x	x	LC	
Aquila adalberti	B	EBBA	x	x	EN	x
Aquila chrysaetos	B	EBBA	x	x	NT	
Hieraaetus pennatus	B	EBBA	x	x	LC	
Hieraaetus fasciatus	B	EBBA	x		EN	
Falco naumanni	B	EBBA	x	x	VU	
Falco tinnunculus	B	EBBA	x	x	LC	
Falco subbuteo	B	EBBA	x	x	NT	
Falco eleorae	B	AVE			NT	
Falco peregrinus	B	EBBA	x	x	LC	
Lagopus mutus	B	EBBA	x	x	VU	
Tetrao urogallus	B	EBBA	x	x	EN	
Alectoris rufa	B	EBBA	x	x	DD	
Perdix perdix	B	EBBA	x	x	VU	
Coturnix coturnix	B	EBBA	x	x	DD	
Rallus aquaticus	B	EBBA	x	x	LC	
Porzana pusilla	B	EBBA	x	x	DD	
Gallinula chloropus	B	EBBA	x	x	LC	
Porphyrio porphyrio	B	EBBA	x	x	LC	
Fulica atra	B	EBBA	x	x	LC	
Fulica cristata	B	EBBA	x	x	CR	
Tetrax tetrax	B	EBBA	x	x	VU	
Otis tarda	B	EBBA	x	x	VU	
Haematopus ostralegus	B	EBBA	x	x	NT	
Himantopus himantopus	B	EBBA	x	x	LC	
Recurvirostra avosetta	B	EBBA	x	x	LC	
Burhinus oedicnemus	B	EBBA	x	x	EN	
Glareola pratincola	B	EBBA	x	x	VU	
Charadrius dubius	B	EBBA	x	x	LC	
Charadrius alexandrinus	B	EBBA	x	x	VU	
Vanellus vanellus	B	EBBA	x	x	LC	
Gallinago gallinago	B	EBBA	x	x	EN	
Scolopax rusticola	B	EBBA	x	x	LC	
Tringa totanus	B	EBBA	x	x	VU	
Actitis hypoleucos	B	EBBA	x	x	LC	
Larus ridibundus	B	EBBA	x	x	LC	
Larus genei	B	EBBA	x	x	VU	
Larus audouinii	B	AVE			VU	
Larus fuscus	B	AVE			LC	
Larus cachinnans	B	EBBA	x	x	LC	
Rissa tridactyla	B	AVE			VU	
Gelochelidon nilotica	B	EBBA	x	x	VU	
Thalasseus sandvicensis	B	EBBA	x	x	NT	
Sterna hirundo	B	EBBA	x	x	NT	
Sterna albifrons	B	EBBA	x	x	NT	
Chlidonias hybrida	B	EBBA	x	x	VU	
Chlidonias niger	B	EBBA	x	x	EN	
Uria aalge	B	AVE			CR	
Pterocles orientalis	B	EBBA	x	x	VU	
Pterocles alchata	B	EBBA	x	x	VU	
Columba livia/domestica	B	EBBA	x	x	LC	
Columba oenas	B	EBBA	x	x	DD	
Columba palumbus	B	EBBA	x	x	LC	
Streptopelia decaocto	B	EBBA	x	x	LC	
Streptopelia turtur	B	EBBA	x	x	VU	
Clamator glandarius	B	EBBA	x	x	LC	
Cuculus carus	B	EBBA	x	x	LC	
Tyto alba	B	EBBA	x	x	LC	
Otus scops	B	EBBA	x	x	LC	
Bubo bubo	B	EBBA	x	x	LC	
Athene ctua	B	EBBA	x	x	LC	
Strix aluco	B	EBBA	x	x	LC	
Asio otus	B	EBBA	x	x	LC	

(*continued on next page*)

Appendix I (*continued*)

Species Name	Group	EOO	DM	Evaluated	Red List Category	Endemism
Asio flammeus	B	EBBA	x	x	NT	
Aegolius funereus	B	EBBA	x	x	NT	
Caprimulgus europaeus	B	EBBA	x	x	LC	
Caprimulgus ruficollis	B	EBBA	x	x	LC	
Apus apus	B	EBBA	x	x	LC	
Apus pallidus	B	EBBA	x	x	LC	
Tachymarptis melba	B	EBBA	x	x	LC	
Apus caffer	B	EBBA	x	x	VU	
Alcedo atthis	B	EBBA	x	x	NT	
Merops apiaster	B	EBBA	x	x	LC	
Coracias garrulus	B	EBBA	x	x	VU	
Upupa epops	B	EBBA	x	x	LC	
Jynx torquilla	B	EBBA	x	x	DD	
Picus viridis	B	EBBA	x	x	LC	
Dryocopus martius	B	EBBA	x	x	LC	
Dendrocopos major	B	EBBA	x	x	LC	
Dendrocopos medius	B	EBBA	x	x	NT	
Dendrocopos leucotos	B	EBBA	x	x	LC	
Dendrocopos mir	B	EBBA	x	x	LC	
Chersophilus duponti	B	EBBA	x	x	EN	
Melacorypha calandra	B	EBBA	x	x	LC	
Calandrella brachydactyla	B	EBBA	x	x	VU	
Calandrella rufescens	B	EBBA	x	x	NT	
Galerida cristata	B	EBBA	x	x	LC	
Galerida theklae	B	EBBA	x	x	LC	
Lullula arborea	B	EBBA	x	x	LC	
Alauda arvensis	B	EBBA	x	x	LC	
Riparia riparia	B	EBBA	x	x	LC	
Ptyoprogne rupestris	B	EBBA	x	x	LC	
Hirundo rustica	B	EBBA	x	x	LC	
Hirundo daurica	B	EBBA	x	x	LC	
Delichon urbica	B	EBBA	x	x	LC	
Anthus campestris	B	EBBA	x	x	LC	
Anthus trivialis	B	EBBA	x	x	LC	
Anthus spiletta	B	EBBA	x		LC	
Motacilla flava	B	EBBA	x	x	LC	
Motacilla cinerea	B	EBBA	x	x	LC	
Motacilla alba	B	EBBA	x	x	LC	
Cinclus cinclus	B	EBBA	x	x	LC	
Troglodytes troglodytes	B	EBBA	x	x	LC	
Prunella modularis	B	EBBA	x	x	LC	
Prunella collaris	B	EBBA	x	x	LC	
Cercotrichas galactotes	B	EBBA	x	x	EN	
Erithacus rubecula	B	EBBA	x	x	LC	
Luscinia megarhynchos	B	EBBA	x	x	LC	
Luscinia svecica	B	EBBA	x	x	LC	
Phoenicurus ochruros	B	EBBA	x	x	LC	
Phoenicurus phoenicurus	B	EBBA	x	x	VU	
Saxicola rubetra	B	EBBA	x	x	LC	
Saxicola torquata	B	EBBA	x	x	LC	
Oenanthe oenanthe	B	EBBA	x	x	LC	
Oenanthe hispanica	B	EBBA	x	x	NT	
Oenanthe leucura	B	EBBA	x	x	LC	
Monticola saxatilis	B	EBBA	x	x	LC	
Monticola solitarius	B	EBBA	x	x	LC	
Turdus torquatus	B	EBBA	x	x	LC	
Turdus merula	B	EBBA	x	x	LC	
Turdus philomelos	B	EBBA	x	x	LC	
Turdus viscivorus	B	EBBA	x	x	LC	
Cettia cetti	B	EBBA	x	x	LC	
Cisticola juncidis	B	EBBA	x	x	LC	
Locustella naevia	B	EBBA	x	x	LC	
Locustella luscinioides	B	EBBA	x	x	NT	
Acrocephalus melapogon	B	EBBA	x	x	VU	
Acrocephalus scirpaceus	B	EBBA	x	x	LC	
Acrocephalus arundinaceus	B	EBBA	x	x	LC	
Hippolais pallida	B	EBBA	x	x	NT	
Hippolais polyglotta	B	EBBA	x	x	LC	
Sylvia sarda	B	EBBA	x	x	LC	
Sylvia undata	B	EBBA	x	x	LC	
Sylvia conspicillata	B	EBBA	x	x	LC	
Sylvia cantillans	B	EBBA	x	x	LC	
Sylvia melacephala	B	EBBA	x	x	LC	
Sylvia hortensis	B	EBBA	x	x	LC	
Sylvia communis	B	EBBA	x	x	LC	

Appendix I (*continued*)

Species Name	Group	EOO	DM	Evaluated	Red List Category	Endemism
Sylvia borin	B	EBBA	x	x	LC	
Sylvia atricapilla	B	EBBA	x	x	LC	
Phylloscopus bonelli	B	EBBA	x	x	LC	
Phylloscopus collybita	B	EBBA	x		LC	
Regulus regulus	B	EBBA	x	x	LC	
Regulus ignicapilla	B	EBBA	x	x	LC	
Muscicapa striata	B	EBBA	x	x	LC	
Ficedula hypoleuca	B	EBBA	x	x	LC	
Panurus biarmicus	B	EBBA	x	x	NT	
Aegithalos caudatus	B	EBBA	x	x	LC	
Parus palustris	B	EBBA	x	x	LC	
Parus cristatus	B	EBBA	x	x	LC	
Parus ater	B	EBBA	x	x	LC	
Parus caeruleus	B	EBBA	x	x	LC	
Parus major	B	EBBA	x	x	LC	
Sitta europaea	B	EBBA	x	x	LC	
Tichodroma muraria	B	EBBA	x	x	LC	
Certhia familiaris	B	EBBA	x	x	LC	
Certhia brachydactyla	B	EBBA	x	x	LC	
Remiz pendulinus	B	EBBA	x	x	LC	
Oriolus oriolus	B	EBBA	x	x	LC	
Lanius collurio	B	EBBA	x	x	LC	
Lanius mir	B	AVE			CR	
Lanius meridionalis	B	EBBA	x	x	NT	
Lanius senator	B	EBBA	x	x	NT	
Garrulus glandarius	B	EBBA	x	x	LC	
Cyapica cyana	B	EBBA	x	x	LC	
Pica pica	B	EBBA	x	x	LC	
Pyrrhocorax graculus	B	EBBA	x	x	LC	
Pyrrhocorax pyrrhocorax	B	EBBA	x	x	NT	
Corvus monedula	B	EBBA	x	x	LC	
Corvus frugilegus	B	AVE			VU	
Corvus corone	B	EBBA	x	x	LC	
Corvus corax	B	EBBA	x	x	LC	
Sturnus vulgaris	B	EBBA	x	x	LC	
Sturnus unicolor	B	EBBA	x	x	LC	
Passer domesticus	B	EBBA	x	x	LC	
Passer hispaniolensis	B	EBBA	x	x	LC	
Passer montanus	B	EBBA	x	x	LC	
Petronia petronia	B	EBBA	x	x	LC	
Montifringilla nivalis	B	EBBA	x	x	LC	
Fringilla coelebs	B	EBBA	x	x	LC	
Serinus serinus	B	EBBA	x	x	LC	
Serinus citrinella	B	EBBA	x	x	LC	
Carduelis chloris	B	EBBA	x	x	LC	
Carduelis carduelis	B	EBBA	x	x	LC	
Carduelis spinus	B	EBBA	x	x	LC	
Carduelis cannabina	B	EBBA	x	x	LC	
Loxia curvirostra	B	EBBA	x	x	LC	
Bucanetes githagineus	B	EBBA	x	x	NT	
Pyrrhula pyrrhula	B	EBBA	x	x	LC	
Coccothraustes coccothraustes	B	EBBA	x	x	LC	
Emberiza citrinella	B	EBBA	x	x	LC	
Emberiza cirlus	B	EBBA	x	x	LC	
Emberiza cia	B	EBBA	x	x	LC	
Emberiza hortulana	B	EBBA	x	x	LC	
Emberiza schoeniclus	B	EBBA	x	x	EN	
Miliaria calandra	B	EBBA	x	x	LC	
Erinaceus europaeus	M	EMA	x	x	LC	
Talpa europaea	M	EMA	x	x	LC	
Talpa occidentalis	M	AES	x		LC	x
Galemys pyrenaicus	M	EMA	x	x	EN	x
Sorex minutus	M	EMA	x	x	LC	
Sorex araneus	M	EMA	x	x	LC	
Sorex coronatus	M	AES	x		LC	
Sorex granarius	M	EMA	x	x	NT	x
Neomys fodiens	M	EMA	x	x	LC	
Neomys amalus	M	EMA	x	x	LC	
Suncus etruscus	M	EMA	x	x	LC	
Rhilophus ferrumequinum	M	EMA	x	x	NT	
Rhilophus hipposideros	M	EMA	x	x	NT	
Rhilophus euryale	M	EMA	x	x	VU	
Rhilophus mehelyi	M	AES	x		EN	
Myotis bechsteinii	M	EMA	x	x	VU	

Appendix I (*continued*)

Species Name	Group	EOO	DM	Evaluated	Red List Category	Endemism
Myotis myotis	M	EMA	x	x	VU	
Myotis blythii	M	EMA	x	x	VU	
Myotis nattereri	M	EMA	x	x	NT	
Myotis emarginata	M	EMA	x	x	VU	
Myotis mystacinus	M	AES	x		NT	
Myotis daubentonii	M	EMA	x	x	LC	
Myotis capaccinii	M	EMA	x	x	EN	
Pipistrellus pipistrellus	M	EMA	x	x	LC	
Pipistrellus nathusii	M	AES	x		NT	
Pipistrellus kuhlii	M	EMA	x	x	LC	
Hypsugo savii	M	EMA	x	x	NT	
Nyctalus leisleri	M	EMA	x	x	NT	
Nyctalus ctula	M	AES	x		VU	
Nyctalus lasiopterus	M	EMA	x	x	VU	
Eptesicus serotinus	M	EMA	x	x	LC	
Barbastella barbastellus	M	EMA	x	x	NT	
Plecotus auritus	M	EMA	x	x	NT	
Plecotus austriacus	M	EMA	x	x	NT	
Miniopterus schreibersii	M	EMA	x	x	VU	
Tadarida teniotis	M	EMA	x	x	NT	
Canis lupus	M	AES	x		NT	
Vulpes vulpes	M	EMA	x	x	LC	
Mustela erminea	M	EMA	x	x	VU	
Mustela nivalis	M	EMA	x	x	LC	
Mustela lutreola	M	EMA	x	x	EN	
Martes martes	M	EMA	x	x	LC	
Martes foina	M	EMA	x	x	LC	
Meles meles	M	EMA	x	x	LC	
Lutra lutra	M	EMA	x	x	NT	
Ursus arctos	M	AES	x		CR	
Genetta genetta	M	EMA	x	x	LC	
Felis silvestris	M	EMA	x	x	VU	
Lynx pardinus	M	EMA	x	x	CR	x
Sus scrofa	M	EMA	x	x	LC	
Cervus elaphus	M	EMA	x	x	VU	
Dama dama	M	EMA	x	x	LC	
Capreolus capreolus	M	EMA	x	x	LC	
Rupicapra pyrenaica	M	EMA	x	x	NT	
Capra pyrenaica	M	EMA	x	x	VU	x
Marmota marmota	M	EMA	x	x	LC	
Sciurus vulgaris	M	EMA	x	x	LC	
Arvicola terrestris/amphibius	M	EMA	x	x	LC	
Arvicola sapidus	M	AES	x		VU	
Chiomys nivalis	M	EMA	x	x	NT	
Microtus gerbei	M	EMA	x	x	LC	x
Microtus lusitanicus	M	EMA	x	x	LC	x
Microtus arvalis	M	EMA	x	x	LC	
Microtus cabrerae	M	EMA	x	x	VU	x
Micromys minutus	M	EMA	x	x	LC	
Apodemus flavicollis	M	AES	x		LC	
Apodemus sylvaticus	M	EMA	x	x	LC	
Mus spretus	M	AES	x		LC	
Glis glis	M	AES	x		NT	
Eliomys quercinus	M	EMA	x	x	LC	
Lepus europaeus	M	EMA	x	x	NT	
Lepus granatensis	M	EMA	x	x	LC	x
Lepus castroviejoi	M	EMA	x	x	VU	x
Oryctolagus cuniculus	M	EMA	x	x	VU	x
Myodes glareolus	M	EMA	x	x	LC	
Crocidura russula	M	EMA	x	x	LC	
Crocidura suaveolens	M	EMA	x	x	LC	
Microtus agrestis	M	EMA	x	x	LC	
Microtus duodecimcostatus	M	EMA	x	x	LC	x
Mus domesticus/musculus	M	EMA	x	x	LC	
Mustela putorius	M	EMA	x	x	NT	
Rattus rvegicus	M	EMA	x	x	LC	
Rattus rattus	M	EMA	x	x	LC	
Herpestes ichneumon	M	EMA	x	x	DD	
Acanthodactylus erythrurus	R	GRA	x	x	LC	
Algyroides marchi	R	GRA	x	x	VU	x
Blanus cinereus	R	GRA	x	x	LC	x
Chalcides bedriagai	R	GRA	x	x	NT	x
Chalcides striatus	R	GRA	x	x	LC	
Hemorrhois hippocrepis	R	GRA	x	x	LC	
Hierophis viridiflavus	R	GRA	x	x	LC	
Coronella girondica	R	GRA	x	x	LC	
Elaphe longissima	R	AARE	x	x	DD	
Rinechis scalaris	R	GRA	x	x	LC	x
Emys orbicularis	R	AARE	x	x	VU	
Hemidactylus turcicus	R	AARE	x	x	LC	
Lacerta aranica	R	GRA			CR	x
Lacerta aurelioi	R	GRA			EN	x
Lacerta bilineata	R	GRA	x	x	LC	
Lacerta bonnali	R	AARE	x	x	VU	x
Timon lepidus	R	GRA	x	x	LC	
Lacerta monticola	R	GRA	x	x	NT	x
Lacerta schreiberi	R	GRA	x	x	NT	x
Lacerta vivipara	R	AARE	x	x	NT	
Macroprotodon cucullatus	R	GRA	x	x	NT	
Malpolon monspessulanus	R	AARE	x	x	LC	
Mauremys leprosa	R	AARE	x	x	VU	
Natrix maura	R	GRA	x	x	LC	
Natrix natrix	R	AARE	x	x	LC	
Podarcis atrata	R	SAAR			VU	x
Podarcis bocagei	R	GRA	x	x	LC	x
Podarcis carbonelli	R	GRA	x	x	LC	x
Podarcis hispanica	R	GRA	x	x	LC	
Podarcis lilfordi	R	GRA			EN	x
Podarcis muralis	R	AARE	x	x	LC	
Podarcis pityusensis	R	GRA	x	x	NT	x
Podarcis sicula	R	AARE	x	x	LC	
Psammodromus algirus	R	GRA	x	x	LC	
Psammodromus hispanicus	R	GRA	x	x	LC	x
Tarentola mauritanica	R	GRA	x	x	LC	
Testudo graeca	R	AARE	x	x	EN	
Testudo hermanni	R	AARE	x	x	EN	
Vipera aspis	R	GRA	x	x	LC	
Vipera latastei	R	GRA	x	x	NT	
Vipera seoanei	R	GRA	x	x	LC	x
Macroprotodon brevis	R	GRA	x	x	NT	
Iberolacerta cyreni	R	GRA	x	x	EN	x
Podarcis vaucheri	R	GRA	x	x	LC	

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