

High endemism areas in the Iberian Peninsula

J. MARTÍN, E. GARCÍA-BARROS, P. GURREA, M.J. LUCIAÑEZ,
M.L. MUNGUIRA, M.J. SANZ¹ & J.C. SIMÓN

Departamento de Biología, Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain (e-mail : jose.martin.cano@uam.es).

¹ Present address: Universidad Internacional SEK, Campus de Santa Cruz la Real, c/ Cardenal Zúñiga s/n, E-40003-Segovia, Spain.

Abstract

A comparison between different groups of organisms in the Iberian Peninsula was made to establish and analyse the high endemism areas and patterns of endemism within this territory. The analysis was based on distribution maps of endemic species of the following groups: monocotyledons (Monocotyledoneae), amphibians (Amphibia) & reptiles (Reptilia), springtails (Hexapoda, Collembola), weevils (Coleoptera, Curculionidae) and butterflies & moths (Lepidoptera, Papilionoidea and Noctuidae). Distribution data were taken from published records and from the database 'Endemica' that was built for this project. Geographic distributions for each group were represented using UTM maps with a 100 km grid. The areas with a highest concentration of endemic species generally fit to mountain areas. However, each group has its own density pattern of endemic species, and that of amphibians and reptiles is the most distinct when compared with the rest. Relevant areas with a high concentration of endemic species include the Western Pyrenees, Cantabrian Mountains, Macizo Galaico, Sistema Central and Cordillera Penibética, among which Sierra Nevada is of special interest.

Keywords : biodiversity, biogeography, conservation, animals, plants.

Introduction

The species of restricted distribution or endemic species play an important role as components of biodiversity. Together with the study of speciation, evolution and coevolution, there is a growing concern towards the study of such species (CROUAEU-ROY, 1989; WILSON, 1988, 1990).

The importance of the areas of high endemicity goes beyond the mere interest for conservation purposes, since they are also valuable for the study of

general biogeographic patterns. Islands or isolated territories show little differences among distribution ranges, species richness and endemism areas, whereas in continental areas the differences among these type of areas can be important (CASE & CODY, 1987; AXELIUS, 1991; HARTE & KINZIG, 1997).

Patterns of species richness together with geographic patterns of endemism are necessary for the design of conservation policies in nature (PIMM *et al.*, 1995; GUEGEN *et al.*, 1998; REID, 1998; OBERDORFF *et al.*, in press). The loss of endemic species is closely related with global ecosystem alteration and with the biodiversity crisis (OBERDORFF *et al.*, 1999). A net loss of endemic species can be predicted as a result of the global biodiversity crisis, and this results in a renewed interest in detecting areas with particular endemism richness or high endemic areas (geographic zones with a high number of endemic species), usually termed hot spots (CRISCI *et al.* 1991, PLATNICK, 1991; HAROLD & MOOI, 1994; MORRONE 1994; MORRONE & CRISCI, 1995). The conservation of areas with high concentration of rare endemic species should be considered a priority for nature conservation policies (SAMWAYS, 1995).

Contrary to the general belief, endemic species and highly endemic areas are poorly known in Western Europe (DEHARVENG, 1996). The reason is that the great majority of observations are related to birds and mammals (BIBBY *et al.*, 1992). Two of the European books on nature conservation (UICN, 1983; COLLINS & WELLS, 1987) highlight the importance of endemic species. BIBBY *et al.* (1992) stress the development of distribution patterns of endemic species in taxa different from birds, as a priority for the conservation of the European natural environment.

The current knowledge of the fauna in the Iberian Peninsula, and particularly of the endemic species, is far from being adequate. A compilation of Iberian fauna (project 'Fauna Ibérica') started just ten years ago, with a delay of almost a century when compared with other European countries (RAMOS, 1990). At present the thoroughly studied groups are just a few, and with the exception of amphibians and reptiles, there is little detailed information on the species distribution. Also, the birds (*Aves*) are a group with a well known distribution, but their contribution to the overall number of endemic animals is irrelevant. The necessity for updating our knowledge of the Iberian fauna is shown by the fact that in the last 17 years (1980-1995) a total of 2000 new animal species have been described in Iberia and the Balearic Islands (ESTEBAN & SANCHIZ, 1997). Besides, these species were described throughout the Iberian and Balearic land, stating that the lack of knowledge is a widespread phenomenon that is not limited to a handful of unexplored areas (MARTÍN & GURREA, 1999). The number of recently described species represents the 3 % of the total Iberian fauna known to date. New descriptions are still being published, and in fact there is a tendency towards a growth of the number of species described each year (ESTEBAN & SANCHIS 1997). As a principle, all these new species should be considered endemic as a result of the poor knowledge of the Iberian fauna compared with other European countries. Therefore, it is difficult to think of a wider distribution of these new species outside the Iberian Peninsula.

Given the importance of the Iberian Peninsula as a stepping stone for the spread of Northern African and Subsaharian species into Europe and *vice versa*, and its importance for the overall biodiversity in Europe, we consider the study of Iberian endemic species a priority. It is also relevant to pinpoint the areas where major concentrations of such endemic species occur.

The objective of this paper is to compare the density patterns of endemic species from several groups in which the distribution of endemic species is reasonably well known. As a result of the study, the high endemic areas and endemism patterns in the Iberian Peninsula are described, serving as a base for future biogeography studies and conservation policies.

Material and Methods

The study was carried out with five groups of organisms from which distribution maps of endemic species (i.e. those restricted to the Iberian Peninsula) were available or were produced by our team. The studied groups and data sources are the following:

* Springtails (Collembola), weevils (Curculionoidea) and butterflies (Papilionoidea) were taken from the database 'Endemica' that was produced for the High Endemism Areas (HEA) European project. This database includes information regarding endemic species from South Western Europe coming from several sources (published material, collections). For each of the groups and geographic areas considered in this study the database comprises:

- 813 springtail records taken from bibliography (378 references, i.e. the total of the known references regarding Iberian Collembola) and from the samplings carried out for this project.
- The data on weevils consist of 4569 records taken from published papers, museum collections and new field data collected specifically for this study.
- In the case of endemic butterflies the number of records was 1398, coming from 272 published references, museum collections and new samplings.

* Monocotyledon plant data come from the Distribution Atlas published by MORENO SAIZ & SAINZ OLLERO (1992).

* Amphibians and reptiles were taken from PLEGUEZUELOS (1997). The number of species in this work is larger than that in SALVADOR (1998), because in the latter a subspecific status is given to some of the taxa considered at the species level in the former.

* Noctuid moths (Noctuidae) data come from the maps published in CALLE (1986). We also took into account the taxonomic corrections that appeared in BUSTILLO, ARROYO & YELA (1986). Species described posteriorly to these two works were not included in our study.

In the analysis data from Amphibia, Reptilia, Collembola, Curculionoidea, Noctuidae and Papilionoidea were added to obtain a model of all the studied groups and compare them with data from the monocotyledon plants. The addition of the studied groups is termed 'animals' (Animalia) in this paper.

All the geographic distributions were represented using the UTM (Universal Transverse Mercator) projection with 100×100 km squares. UTM is regarded as the most convenient coordinate system for the study of distribution areas (e.g. PERRING & WALTER, 1962). We have considered as 'endemic species' all the taxa at the species level that are exclusively present in the Iberian Peninsula (including the Pyrenees) and/or Balearic Islands. A map was produced with the number of endemic species present in each square for each group considered.

The Iberian Peninsula is on the Westernmost limit of the Palaearctic area and in the South-West corner of continental Europe. It is separated from Africa by a gap of 15 km in its narrowest point. Its surface area is $0,58 \times 10^6$ km². The relief is acute with several mountain areas surpassing 2500 or 3000 m of altitude. Most of the Peninsula has a typical mediterranean climate, but the Western part of the Northern half has an atlantic type climate. From the geological point of view it lies in the Euroasiatic plate, in the contact zone with the African plate. This has caused important geological activity, with emerging lands, foldings, etc. A summary of all these events can be found in JONG (1997) and the literature cited therein. During the ice age, glaciations have affected the Peninsula in an important way. The main mountain ranges are parallel to the equator, the opposite situation to what happens in other European Mediterranean peninsulas. This fact has undoubtedly played an important role in the spread of animal or plant populations during glacial periods. A summary of these ideas can be found in ZAGWIJN (1992). The different glaciations and interglacial periods have produced repeated cycles of isolation and sympatry resulting in the formation of a large number of endemic species. The geographic situation of the Iberian Peninsula and Balearic Islands in the corridor between two continents, together with a complex geology and history have resulted in a high species richness and high percentage of endemic taxa.

Results

The levels of endemicity are very variable among different groups (Table 1). They vary between 507 endemic species from a total of 1500 in the Curculionoidea (35.0% of endemicity), to just 39 species from a total of 937 in Papilionoidea and Noctuidae (4.2%). Collembola with 32.3% and Amphibia & Reptilia with 28.2% have also high values, whereas monocotyledons have an intermediate value (18.1%).

There are also differences in the width of the distribution ranges in the different groups (Table 1). Springtails and weevils show a strong percentage of microendemisms and therefore the average of occupation of squares per endemic species is very low. Butterflies and moths have intermediate values of occupa-

tion and are very close to monocotyledons. Finally, amphibians and reptiles with an average occupation of 20 squares have endemic species with generally widespread distribution ranges.

Table 1. Total number of species, number of Iberian endemic species, percentage of endemism, and average size range in the study area, for each of the taxonomic groups considered. Range sizes were measured as the percentage of 100×100 km squares occupied per species, averaged for each taxon.

Taxon	Number of Iberian species	Number of Iberian endemic species	Percentage of endemism	Average range size
Monocotyledons	1072	194	18.1	8.55
Animals	3223	797	24.7	2.77
Springtails	715	231	32.3	1.62
Weevils	1500	507	35.0	2.19
Lepidopterans	937	39	4.2	8.97
Amphibians & Reptiles	71	20	28.2	18.75

Table 2. Relationships among the patterns of endemism of the animal and plant groups considered. The data used for calculations are the number of endemic species per 100×100 km square, for each taxon (r = Pearson correlation coefficient).

	Monocotyledons	Animals	Amphibians & reptiles	Springtails	Weevils
Animals	$r=0.880$ ($p < 0.001$)				
Amphibians & reptiles	$r=0.642$ ($p < 0.001$)	$r=0.498$ ($p < 0.001$)			
Springtails	$r=0.453$ ($p < 0.001$)	$r=0.701$ ($p < 0.001$)	$r=0.215$ ($p = 0.014$)		
Weevils	$R=0.622$ ($p < 0.001$)	$R=0.857$ ($p < 0.001$)	$r=0.275$ ($p = 0.002$)	$r=0.466$ ($p < 0.001$)	
Lepidopterans	$r=0.475$ ($p < 0.001$)	$r=0.628$ ($p < 0.001$)	$r=0.080$ ($p = 0.209$)	$r=0.417$ ($p < 0.001$)	$r=0.538$ ($p < 0.001$)

The density of endemic species is shown in Figure 1. The areas with highest density of endemic monocotyledons are the Northern cornice (Galicia, the Cantabrian Mountains and the Western Pyrenees), the Sistema Central (including the Serra da Estrela, Ayllón and contacting with the Western Pyrenees through the northern part of the Sistema Ibérico) and the Sierras Penibéticas (Sierra Nevada and the oriental sierras with a drier climate).

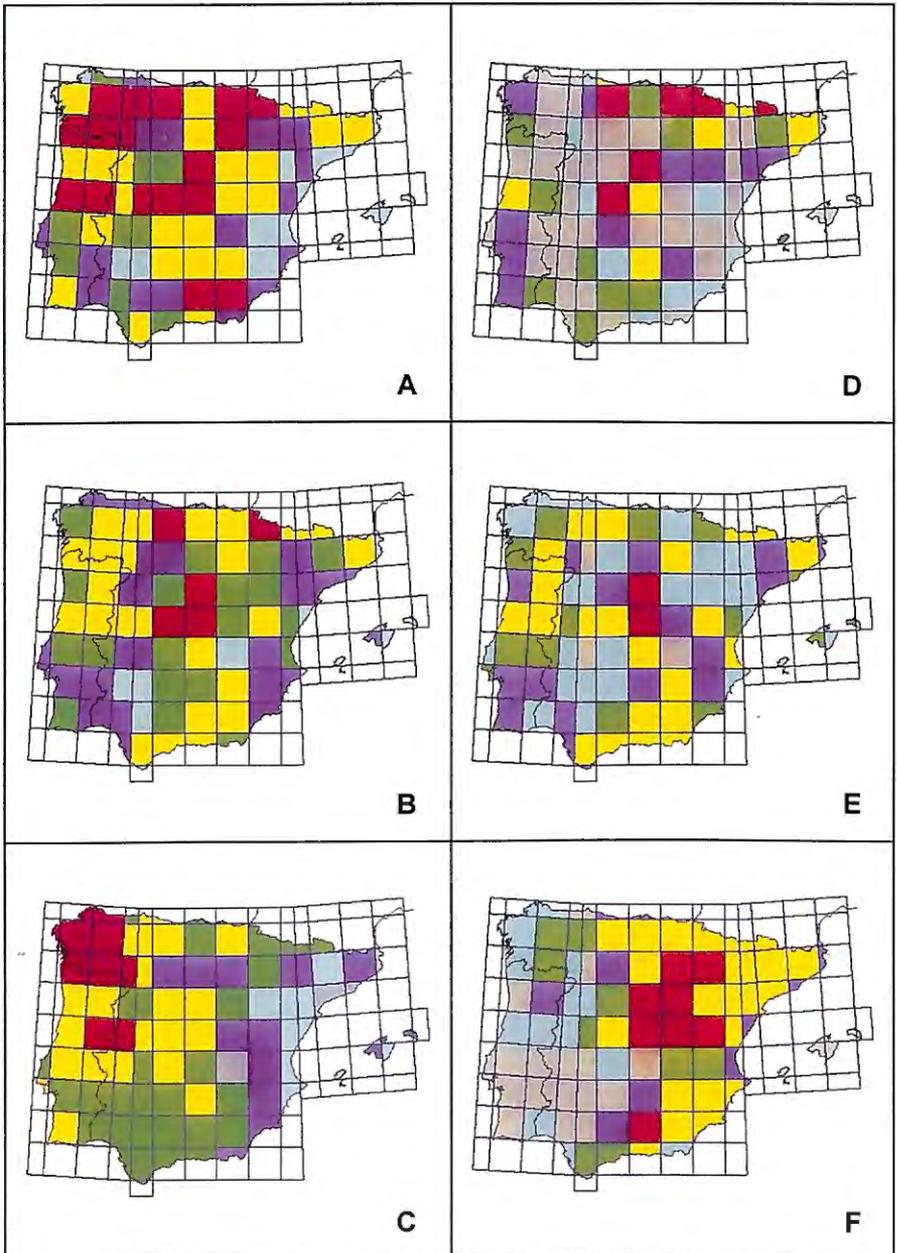


Fig. 1. Densities of endemic species in the Iberian Peninsula. Quadrats are 100×100 km UTM square. We assigned different colours to express density variation. The scale, from minimum to maximum, is: dark blue, light blue, green, yellow, red. Squares without endemic species are represented in grey. A - Monocotyledon plants. B.- Animals (C+D+E+F). C.- Amphibians and reptiles. D.- Springtails. E.- Weevils. F.- Butterflies and moths. *

Regarding the 'animals' overall, Northern Iberia shows an important concentration of endemisms. The central sector of this area emerges as the most relevant, with several squares in the Oriental Pyrenees with the highest densities. The second area regarding the number of endemic species is the Central Iberia. The Southern area loses importance for this group. More in detail, the areas of highest concentration of endemic species for amphibians and reptiles occur in the Western half of the Peninsula, particularly in the North West. Endemic springtails concentrate in the centre of the Iberian Peninsula, the Cantabrian Mountains and the Western Pyrenees. The centre of the Iberian Peninsula is highlighted as the most important area for endemic weevils, followed by the North West area, in a pattern that roughly follows the peninsular Hercinian Arc, and the South East including the Sierra Nevada. For the studied Lepidoptera the areas with higher endemic density are in the Sistema Ibérico and Eastern Sistema Central, and in the central core of Sierra Nevada.

Table 2 shows the correlations between the absolute numbers of endemic species in each of the 106 UTM squares (100 × 100). The correlations are significant for most groups and only the lepidoptera and amphibians & reptiles are not significantly correlated. The highest correlations were obtained between 'animals' and monocotyledons, and between 'animals' and weevils, probably because the weight of the latter group is important for the overall pattern. The reason is the very high number of weevil endemic species: almost two thirds of the total number of endemic 'animals' of the study are weevils (see Table 1). The lowest correlations were obtained between amphibians & reptiles and the insect groups, showing that the distribution pattern of endemic herpetofauna differs from that of insects at least as far as the studied groups are concerned.

Discussion

The criterion of endemism adapted in this study (Iberian endemic species) allows for the inclusion of some species with a relatively wide distribution, which in some cases are even split into isolated subspecies. Example of this are the butterfly *Aricia morronensis* RIBBE, 1910 (Lepidoptera, Lycaenidae), together with several amphibian or reptile species while this definition of endemism may result in a coarse resolution it has the advantage of providing an objective selection of endemic taxa that is consistent with the fact that the Iberian Peninsula is a biogeographic unit, as suggested by e.g. MORENO SAIZ & SAINZ OLLERO (1992) and PLEGUEZUELOS (1997).

We can make several remarks concerning the reliability of the data used. Data coming from previously published monographs and atlases are thorough in the case of monocotyledons and amphibians and reptiles. In the case of Noctuidae the coverage is far from being complete, and there are areas in the Iberian Peninsula with little or no information. In the cases where the distribution was obtained with the aid of the 'Endemica' database, we can say that the compilation of published records is exhaustive, but the level of knowledge is

different in the three groups. While the level of knowledge on butterfly distribution may be judged as relatively complete (see GARCÍA-BARROS, GARCIA-PEREIRA & MUNGUIRA, 2000), this seems not to be the case for the weevils, and even less for springtails.

Amphibians and reptiles were considered together for the analyses due to the low number of endemic species of these two groups. The density of endemic species per square was roughly similar for the two taxa ($r=0.620$, $p<0.001$, $n=106$), and thus no information is added by treating them separately. The same is true for butterflies and noctuids (correlation: $r=0.525$; $p<0.001$; $n=106$).

The scale used to draw the maps and analyse data (100×100 km squares) makes it easy to draw general conclusions on patterns of endemism. However, it has also some drawbacks due to the large size of the grid. First of all it groups those species that are not sympatric, particularly in areas where several species live in adjacent but distinct areas like the Pyrenees, the Cantabrian Mountains or the Sistema Central. As a consequence small areas that are relevant for their endemic fauna, loose importance with the comparison. An example of the latter is the Sierra Nevada that has a high altitude, many endemic species, but a small size (compared with the 100×100 km grid), having sympatric species without addition to the adjacent squares. The problem of the scale has been addressed to by GARCÍA-BARROS, GARCIA-PEREIRA & MUNGUIRA (2000), with the conclusion that only a relatively large grid size may be suitable to draw general conclusions in biogeography research in the Iberian Peninsula.

The areas with major concentration of endemic species are generally coincident with mountain areas, but each taxonomic group has different areas with maximum and minimum densities. The reason has probably something to do with different dispersal abilities, and also with different aspects of biogeographic history for each group.

Regarding the Lepidoptera, the areas of maximum endemism do not exactly match with the areas of maximum species richness that were pointed out in the maps from MARTÍN & GURREA (1990). Butterfly richness reaches a maximum value in the Pyrenees and gradually decreases towards the South West following mountain ranges and to reach a minimum value in the lowlands far away from the Pyrenees. On the other hand rich areas for endemic Lepidoptera can also be found in Eastern Iberia, and in the mountains, but in this case the most important areas are Sierra Nevada followed by the Sistema Ibérico and the Pyrenees. The relative importance of these biodiversity important three mountain chains changes therefore in our analysis.

Our results seem to indicate that the areas of high endemism in the Iberian Peninsula are concentrated in mountain areas in agreement with the European pattern (BALLETO, 1995), but that each taxonomic group follows a different pattern related to its different ecology or dispersal ability, characteristics that are different in the studied groups. This is in agreement with the idea that the

role of history is relevant to explain biogeography patterns (MARTÍN & GURREA, 1990; DENNIS *et al.*, 1998).

The policy of creating Nature Reserves on mountain areas is consistent with our results of a maximum density of endemic species in such areas. Nevertheless, it is important to stress that the Iberian Peninsula has many mountain areas with a large number of endemic species, particularly microendemisms, and some of them are not included in the actual network of protected areas. It is therefore necessary to create new reserves to provide protection for as many endemic species as possible. Creating new reserves to protect endemic species has proved to be a necessary approach when dealing with insect conservation in the European Mediterranean countries (MUNGUIRA, 1995).

For the Iberian Peninsula, it is still necessary to provide new information concerning the distribution and taxonomy of those groups of organisms in which there are still gaps in our detailed knowledge (eg. noctuid moths, weevils or springtails). This will indeed favour a more efficient implementation of the present European Union policy towards the conservation of biodiversity.

Acknowledgements

The research was part of the Project HEA (High Endemism Areas, Endemic Biota and the Conservation of Biodiversity in Western Europe), and was financially supported by the EU project PL93-1917 and the Spanish DGICYT project UE95-0038.

References

- AXELIUS B., 1991. - Areas of distribution and areas of endemism. *Cladistics*, 7: 197-199.
- BALLETO E. 1995. - Endemism, areas of endemism, biodiversity and butterfly. Conservation in the Euro-Mediterranean area. *Bollettino del Museo Regionale di Scienze Naturali-Torino*, 13: 445-491.
- BIBBY C.J., COLLAR N.J., CROSBY N.J., HEATH M.F., IMBODEN CH., JOHNSON T.H., LONG A.J., STATTERSFIELD A.J. & THIRGOOD S.J., 1992. - *Putting biodiversity on the map: priority areas for global conservation*. ICBP, Cambridge, 90 pp.
- CALLE J.A., 1982. - Noctuidos españoles. *Boletín del Servicio contra Plagas e Inspección Fitopatológica*, Fuera de serie nº1: 1-430.
- CASE T.J. & CODY M.L., 1987. - Testing theories of island biogeography. *American Scientist*, 75: 159-170.
- COLLINS N.M. & WELLS S.M., 1987. - *Invertebrates in need of special protection in Europe*. Nature and Environment, series nº 35. Council of Europe, Strasbourg, 162 pp.
- CRISCI J.V., GIGLIANO J.J., MORRONE J.J. & ROIG JUNENNT S., 1991. - Historical biogeography of southern South America. *Systematic Zoology*, 40: 152-171.
- CROUAU-ROY B., 1989. - Population studies of an endemic troglitic beetle: geographical patterns of genetic variation, gene flow and genetic structure compared with morphometric data. *Genetics*, 121: 571-582.
- DEHARVENG L., 1996. - Soil Collembola diversity, endemism, and reforestation: a

- case study in the Pyrenees (France). *Conservation biology*, 10 (1): 74-84.
- DENNIS R.L.H., WILLIAMS W.R. & SHREEVE T.G. 1998. - Faunal structures among European butterflies: evolutionary implications of bias for geography, endemism and taxonomic affiliation. *Ecography*, 21: 181-203.
- ESTEBAN M. & SANCHIZ B., 1997. - Descripción de nuevas especies animales de la Península Ibérica e Islas Baleares (1978-1994): tendencias taxonómicas y listado sistemático. *Graellsia*, 53: 111-175.
- GARCÍA-BARROS E., GARCIA-PEREIRA P. & MUNGUIRA M.L., 2000. - The geographic distribution and state of butterfly faunistic studies in Iberia (Lepidoptera: Papilionoidea, Hesperioidea). *Belgian Journal of Entomology*, 2 : 111-124.
- GÓMEZ BUSTILLO M.R., ARROYO M. & YELA J.L., 1986. - *Mariposas de la Península Ibérica, 5: Heteróceros III (Noctuidae, I)*. ICONA, Madrid, 263 pp.
- GUEGAN J.F., LEK S. & OBERDORFF T., 1998. - Energy availability and habitat heterogeneity predict global riverine fish diversity. *Nature*, 362: 444-446.
- HAROLD A.S. & MOOI R.D., 1994. - Areas of endemism: definition and recognition criteria. *Systematic Biology*, 43: 261-266.
- HARTE J. & KINZIG A.P., 1997. - On the implications of species-area relationships for endemism, spatial turnover, and food web patterns. *Oikos*, 80: 417-427.
- JONG H. DE, 1998. - In search of historical biogeographic patterns in the western Mediterranean terrestrial fauna. *Biological Journal of the Linnean Society*, 65: 99-164.
- MARTÍN J. & GURREA P., 1990. - The peninsular effect in Iberian butterflies (Lepidoptera: Papilionoidea and Hesperioidea). *Journal of Biogeography*, 17: 85-96.
- MARTÍN J. & GURREA P., 1999. - Áreas de especiación en España y Portugal. *Boletín de la Asociación española de Entomología*, 23(1-2): 83-103.
- MORENO SAIZ J.C. & SAINZ OLLERO H., 1992. - *Atlas corológico de las Monocotiledóneas endémicas de la Península Ibérica e Islas Baleares*. ICONA, Colección Técnica, Madrid, 354 pp.
- MORRONE J.J., 1994. - On the Identification of Areas of Endemism. *Systematic Biology*, 43: 438-441.
- MORRONE J.J. & CRISCI J.V., 1995. - Historical Biogeography: Introduction to Methods. *Annual Review of Ecology and Systematics*, 26: 373-401.
- MUNGUIRA M.L., 1995. - *Conservation of butterfly habitats and diversity in European Mediterranean countries*. In: *Ecology and Conservation of Butterflies*. PULLIN A.S. (ed.). Chapman & Hall, London: 277-289.
- OBERDORFF T., LEK S. & GUEGAN J.-F., 1999. - Patterns of endemism in riverine fish of the Northern Hemisphere. *Ecology Letters*, 2(2): 75-81.
- PERRING F.H. & WALTERS S.N. (eds.), 1962. - *Alas of the British Flora*. Nelson, London, 472 pp.
- PIMM S.L., RUSSEL G.J., GITTLEMAN J.L. & BROOKS T.M., 1995. - The future of biodiversity. *Science*, 269: 347-350.
- PLATNICK N.I., 1991. - On the areas of endemism. *Australian Systematic Botany*, 4: 11-12.
- PLEGUEZUELOS J.M. (ed.), 1997. - *Distribución y biogeografía de los anfibios y reptiles en España y Portugal*. Universidad de Granada, Granada, 245 pp.
- RAMOS M.A., 1990. - *Fauna Ibérica: necesidad de un proyecto*. In: *Fauna Ibérica*, Vol. 0. RAMOS M.A. ET AL. (eds.). Museo Nacional de Ciencias Naturales. CSIC.

Madrid: 13-16.

- REID W.V., 1998. - Biodiversity hotspots. *Trends in Ecology and Evolution*, 13: 275-280.
- SALVADOR A., 1997. - *Reptiles*. In: *Fauna Ibérica*, Vol. 10. RAMOS M.A. et al. (eds.). Museo Nacional de Ciencias Naturales. CSIC. Madrid, 705 pp.
- SAMWAYS M.J., 1995. - *Insect Conservation Biology*. Chapman & Hall, London, 358 pp.
- UICN (Threatened Plants Unit), 1983. - *List of rare, threatened and endemic plants in Europe*. Nature and Environment, series n° 27. Council of Europe, Strasbourg, 357 pp.
- WILSON E.O., 1988. - *Biodiversity*. National Academy press, Washington, 521 pp.
- WILSON E.O., 1990. - *Foreword - Presentación*. In: *Fauna Ibérica*, Vol. 0. RAMOS M.A. et al. (eds.). Museo Nacional de Ciencias Naturales. CSIC. Madrid: 9-11.
- ZAGWIN W.H., 1992. - Migration of vegetation during the Quaternary in Europe. *Courier Forschungsinstitut Senckenberg*, 153: 9-20.