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Species richness and endemicity in the Spanish vascular flora

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Data from an updated and revised checklist of the Spanish flora is analyzed. The Spanish vascular plant flora is composed of 204 families, 1433 genera and 7071 species. Floristic data are analysed by considering three regions: mainland Spain with 5984 species, the Balearic Islands with 1521 species and Canary Islands with 2066 species. Extinct species are included in the analysis, with an extinction rate of 0.35% of the flora. A total of 1488 endemic species are recognized, which account for 21% of the Spanish flora. The rate of endemism in the Canary Islands is 25.9%, considerably higher than for the Balearic Islands (6.9%) and for mainland Spain (13.8%). A list of the 35 strict endemic genera is compiled, of which 65.7% are Canarian, and another list of 27 subendemic genera of which 48.1% are also Canarian. An estimated 12% of the Spanish flora is non-native, with large variation between the 20.7% of the Canary flora, 10.5% of mainland Spain and 9.7% of the Balearic Islands. Finally, the composition of the Spanish flora for large groups and families is analysed. The data show that species richness and endemicity rates have been overestimated by previous authors, and are similar to other Mediterranean countries. It is concluded that a complete revision of the Macaronesian flora is strongly needed to obtain an accurate comparison with the flora of other areas.

It is widely accepted in the botanical literature that the Mediterranean basin has a great floristic richness with ca 25 000 plant species (Greuter 1994, Médail and Quézel 1997). Despite the efforts made in recent years (Greuter et al. 1984–2008), the Mediterranean flora is far from being as well explored as the floras of central and northern Europe. The still unfinished 'Flora Iberica' (Castroviejo 1986–2012) is contributing to fill this gap in our knowledge. The growing need for numerical data on the flora, necessary to identify the most diverse areas and to contribute to the improvement of the quality of the management has led us to undertake this work.

Historic review

As a starting point for the systematization of floristic knowledge in Spain, one is obliged to mention the 'Flora Española' by Quer (1762–1764), whose last two volumes were published by Gómez Ortega (1784). However, this work was structured in such a way that it is hardly comparable to modern floras, e.g. the alphabetical arrangement by genera and the explicit waiver of Linnaean nomenclature. Still, this work is the first attempt to systematize the knowledge of Spanish plants. Quer recognized the floristic richness of the Iberian Peninsula flora and stated in the introduction that "… there were so many plants, which without a doubt I think we have more, and more abundantly, than any other region of Europe". However, according Colmeiro (1885, CXX) this flora treats 2050 species only.

After the failed attempt of Lagasca, who apparently lost the material he had been preparing for a Spanish Flora around 1823 (González and Rodríguez 1996, p. 623), one can mention the compilations by Colmeiro (1885–1889) or Amo (1871–1873) who stockpiled herbarium and bibliographic information, but did not critically analyse it.

Willkomm and Lange (1861–1880) published the *Prodromus* over a period of twenty years. In this work they listed and described the vascular plants of mainland Spain. The Balearic Islands as well as Portugal were excluded from their work, although both territories were mentioned occasionally in distribution notes. According to the numbers provided at the end of each group, there were 1030 genera and 5092 species described in *Prodromus*, as well as a considerable number of infraspecific taxa. These infraspecific taxa, varieties in general, have in many cases been accepted by later authors as species or subspecies. Willkomm (1893) published the 'Supplementum', which raised the number of taxa to 1048 genera and 5570 species. This meticulous and careful work, based largely on a critical study of the material collected by the authors for years, can be considered as the starting point of the modern knowledge of the mainland Spanish flora.

Spanish botanists do not seem to respond with works of the same importance and continue with more or less complete compilations, like 'Compendio de la flora Española', by Lázaro (1920–1921), which in its third edition mentions 5531 species of vascular plants (Lázaro 1921, p. 479), or 'Flora analítica de España', by Caballero (1940).

Galiano (1975) mentioned that the flora of mainland Spain and the Balearic Islands would consist of 7500 species, an estimate of uncertain origin that has been used uncritically by subsequent authors (i.e. Castroviejo 2002). On the centenary of the completion of Willkomm and Lange's *Prodromus*, Smythies (1984) published an updated checklist using the taxonomic concepts of 'Flora Europaea'. This author also lists the species proposed by C. Pau, Sennen and other botanists that were omitted by 'Flora Europaea'. As a result, Smythies (1984) recognized 5323 species of which 910 could be endemic to mainland Spain and the Balearics Islands.

In response to the obvious need for an updated Spanish flora, different plans were drawn up which resulted in the project 'Flora Iberica' whose starting point can be placed in the early 80s of the last century (Castroviejo 1986–2012). This work describes the species of the Iberian Peninsula and the Balearic Islands including mainland Portugal and Andorra, but not the Macaronesian Islands of Spain and Portugal. This work, widely accepted by European colleagues (cf. Greuter 1991), is now in its final phase. Until now, 17 of the 21 planned volumes of 'Flora Iberica' have been published, covering 164 of the 189 families represented in this territory, but it should not be forgotten that the two largest families, Compositae and Gramineae, remain unpublished.

The flora of the Balearic Islands has generally been studied together with the Iberian flora. In contrast, the flora of the Canary Islands has been considered independently of the rest of the Spanish flora, probably due to its considerable originality. As pointed out by Bramwell and Bramwell (2001, pp. 5–8) the first Canarian checklist was published by Webb and Berthelot (1836–1850). Sixty years later, Pitard and Proust (1909) published a new checklist based on their own collections and a critical study of the work of their predecessors. They concluded that the Canarian flora consisted of 1352 species of which 468 are endemic (Pitard and Proust 1909, p. 69). Although at present a descriptive treatment of the Canarian flora is lacking, Hohenester and Welβ (1993) have published a taxonomic key following the German tradition of the 'Exkursionsflora'. In the recent compilation of Arechavaleta et al. (2010), 2091 vascular plant species (539 endemic) are recognized for the Canary Islands.

Under the project 'Flora Iberica' the program ANTHOS (< www.anthos.es >) was set up in 1999. It was developed as a partnership between the Fundación Biodiversidad (Dept of Agriculture, Food and Environment) and the Real Jardín Botánico (CSIC) to facilitate public access on the internet to plant biodiversity information in Spain. ANTHOS, whose main taxonomic information system is generated by 'Flora Iberica', has incorporated the Canarian taxonomic structure from Arechavaleta et al. (2010), making it compatible with the 'Flora Iberica' structure. This makes ANTHOS a unique tool in which all Spanish flora information is available to the public and periodically updated. It would be interesting if similar initiatives were developed in other European and Mediterranean countries to facilitate the access of floristic information on a larger scale.

In April 2002, the Sixth Conference of the Parties to the Convention on Biological Diversity adopted the Global Strategy for Plant Conservation (GSPC). Target 1 of the GSPC is to develop "… a widely accessible working list of all plant species known, as a step towards a complete world flora". In order to contribute to this objective and as requested by the Spanish Ministry of Agriculture, Food and Environment, the ANTHOS project working group at CSIC has developed an updated checklist of the Spanish flora. This checklist cannot be displayed in this article due to its length, but is available from the corresponding author upon request. The checklist will continue to be updated with new taxonomic and floristic data although the information presented here is a reflection of the present knowledge. The aim of this work is to investigate patterns of overall species richness and endemicity as reflected in this checklist.

Material and methods

Geographical areas

Data provided in this article refers to three well-defined geographical areas. The first and most important in extension is the Spanish part of the Iberian Peninsula, hereafter referred to as mainland Spain. Included are the enclave of Llivia (in France) and the Spanish territories of the north slope of the Pyrenees, which are not strictly part of the Iberian Peninsula, as the Valley of Arán and the headwaters of some valleys of the Navarre province. Likewise, some small islands along the Spanish coast are included as part of the mainland, e.g. the island Columbretes, near to Castellón, the Cíes and the Ons islands close to Pontevedra and the island of Alborán, equidistant to Africa and Almería, but belonging to the latter. The second area considered is the Balearic Islands that include Mallorca, Menorca, Ibiza, Formentera and some smaller islands. The third area corresponds to the Canary Islands, including Tenerife, La Gomera, La Palma, El Hierro, Gran Canaria, Fuerteventura, Lanzarote, Graciosa and some smaller islands (Fig. 1). The small Spanish territories of North Africa, i.e. the autonomous cities of Ceuta and Melilla, as well as the Chafarinas Islands and some other islands, have been excluded due to lack of available data to provide a checklist of the species in these areas. In addition, these territories comprise a very small area (just over 30 km^2), are mainly urban, and their flora is very similar to that of northern Morocco.

Classification

The 'Flora Iberica' (Castroviejo 1986–2012) is the main data source used for the two first geographic areas, i.e. mainland Spain and the Balearic Islands. This data has been extracted from published volumes (I–VIII, X–XV, XVII, XVIII, XXI) and those in advanced stages of editing (IX, XX). A detailed study of the two largest families still remain to be completed: Compositae (Vol. XVI) and Gramineae (Vol. XIX). For these families the main source used was Med-Checklist (Greuter et al. 2008) for the former and 'Flora Europaea' (Tutin et al. 1980) for the latter.

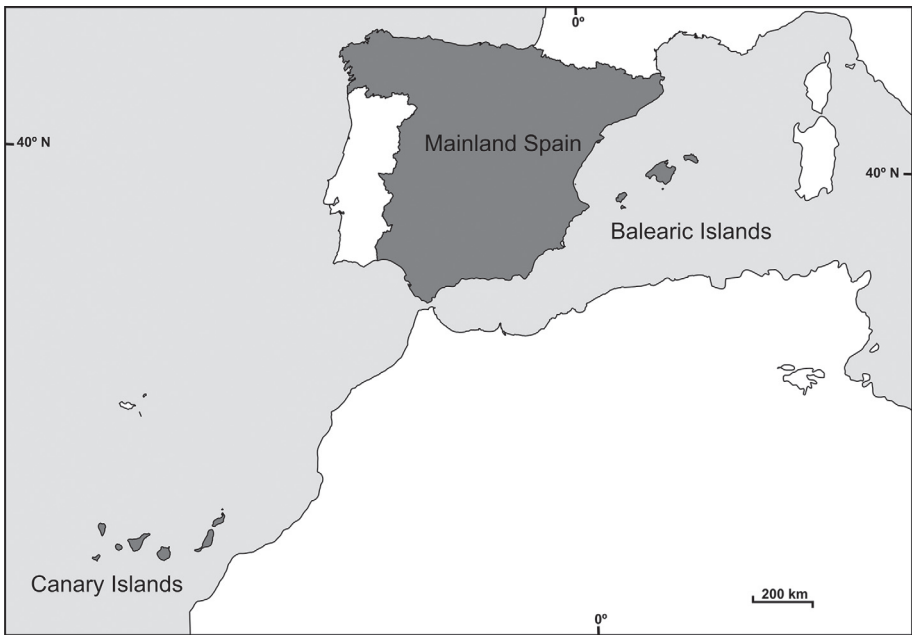

Figure 1. Map showing the three territories used in the current study to analyse the Spanish flora.

This general criterion has been largely avoided when published reviews or genus drafts of 'Flora Iberica' were available. With regards to the Compositae we used the following sources: *Aster* L. (C. Aedo unpubl.), *Bellis* L. (C. Aedo unpubl.), *Helichrysum* Mill. (Galbany et al. 2006), *Hieracium* L. and *Pilosella* Hill (G. Mateo at <www.floraiberica.org>), *Senecio* L. (J. Calvo and C. Aedo unpubl.), *Taraxacum* F. H. Wigg. (A. Galán at <www.floraiberica.org>). With regards to the Gramineae, the following sources were used: *Avena* L. (Romero Zarco 1990, 1994), *Avenula* (Dumort.) Dumort. (Romero Zarco 1985a), *Festuca* L. (Ferrero 1999), *Helictotrichon* Besser (Romero Zarco 1985b), *Koeleria* Pers. (A. Quintanar unpubl.), *Stipa* L. (R. Gonzalo unpubl.). In the case of the Gramineae partial treatments published in regional floras (Bolòs and Vigo 1984–2001, Valdés et al. 1987, Aizpuru et al. 1999, Blanca et al. 2009, Sánchez and Guerra 2011) have been very helpful.

New taxa described after the appearance of the corresponding genus in 'Flora Iberica' have been compiled on the project website (<www.floraiberica.org>). These taxa have been accepted when the author is the same as for the treatment of the genus in 'Flora Iberica'. Otherwise the name has been placed as a synonym of the closest species, whilst a new generic revision is not published, with the exception of the *Campanula lusitanica* complex that was accepted from the treatment of Cano-Maqueda and Talavera (2011).

For the flora of the Canary Islands we have essentially followed the compilation of Arechavaleta et al. (2010). Inconsistencies between 'Flora Iberica' and the Canarian checklist have been resolved giving preference to the former because it is based on the study of herbarium material reviewed by taxonomists with extensive experience. For further accuracy we have also cross checked the Canarian list with the 'Index synonymique de la Flore d'Afrique du Nord' (Dobignard and Chatelain 2010–2011), especially for the Compositae and Gramineae. In cases of conflicts between this index and the Canarian checklist, we gave preference to the former.

The circumscription of families is that used by 'Flora Iberica' following Stebbins (1974) for flowering plants and Pichi Sermolli (1977) for ferns and fern allies. Although these systems may seem obsolete nowadays, they were 'modern' in 1986 when the first volume of this work was published. Thus, the numbers that refer to families would be different if other systems, such as the APG III classifications, were used.

We have mainly used the species category in our numerical data analysis. When data refer to number of taxa, this includes the species and subspecies, but not varieties or categories below. Thus, if a species is represented in a territory by a single subspecies we have taken just one species and one taxon into account. If, by contrast, one species in a specific territory has three subspecies, we have taken one species and three taxa. Hybrids have been omitted.

Results

The Spanish flora is comprised of 204 families, 1433 genera and 7071 species. The distribution of the flora in different regions is shown in Table 1. Mainland Spain has the largest number of species (5984), representing 84.6% of the total, which is consistent with the largest area and the great diversity of habitats and biogeographic territories. However, the ratio between the number of species and the surface area is very low compared with that of the island territories. The Canary Islands are home to 2066 species of vascular plants and the Balearic Islands to 1521, representing a percentage somewhat higher than 20% of all Spanish species in both cases. The species per 1000 km^2 ratio is far superior to that of the mainland in the two archipelagos,

Table 1. Number of accepted species and taxa (i.e. species and subspecies) for the different Spanish regions.

	Surface area (km^2)	No. of species	% of total species	species/1000 km^2	No. of taxa	% of total taxa
Balearic Islands	4991	1521	21.5	300	1585	19.9
Canary Islands	7490	2066	29.2	270	2084	26.2
Mainland Spain	492 127	5984	84.6	12.1	6704	84.3
Mainland Spain + Balearic Islands	497 118	6152	87.0	12.3	6909	86.9
Total Spain	504 608	7071			7948	

with 276 and 305, respectively. The total number of taxa follow a similar pattern, with 6704 in the Peninsula, 2084 in the Canary Islands and 1585 in the Balearic Islands.

The total number of species shared among two or more of the three regions is 1809 (Table 2), representing 25.6% of the total. Of these, only 691 species are present in all the three examined regions. Mainland Spain and the Balearic Islands share a greater number of species (662) than do mainland Spain and the Canary Islands (499). The connection between the Canary and the Balearic islands is minimal, with only seven shared species, not present in mainland Spain.

Although mainland Portugal has not been considered in this study derived data is available from the 'Flora Iberica' and ANTHOS projects. In Portugal, 2829 species have been recorded of which 2700 (95.4%) are found in mainland Spain and the Balearic Islands. The remaining 129 are 67 endemic species, 15 not endemic and 47 non-natives, not present in mainland Spain.

Extinct species have been included in the data. Information about their status was taken from Castroviejo (1986–2012) and Bañares et al. (2007, 2010) and modifications were made. Their number is very low, with a total of 25 extinct species (Table 3). Among them, five were found in the Canary Islands and one in the Balearic Islands, and yet another species was found both in the Balearic Islands and mainland Spain. The remaining 18 were found in mainland Spain. Among them, seven were endemic, three from the Canary Islands, one from the Balearic Islands and three from mainland Spain.

The number of endemic species is shown in Table 4. For the the whole of the Spanish flora we detected a total of 1488 endemic species, representing 21%. Although more than half of the endemic species are found in mainland Spain, the relatively high number that appears in the Canary Islands is significant. No shared endemism between the mainland and the Canary Islands have been detected, but there are 19 endemic species present both in mainland Spain and the Balearic Islands. If we analyse the degree of endemicity in each of the three regions, the flora of the Canary Islands is considerably more original than that of the other two areas, with a rate of endemicity of 25.9%. The total number of taxa follow a similar pattern in terms of regional distribution.

Table 2. Number of shared species between the different Spanish regions.

	Number of shared species
Mainland Spain – Balearic Islands – Canary Islands	691
Mainland Spain – Balearic Islands	662
Mainland Spain – Canary Islands	449
Balearic Islands – Canary Islands	7
Total Spain	1809

The number of endemic genera is a variable that is strongly influenced by analytical or synthetic taxonomy trends, and should be taken with some caution. Of the total 35 strictly endemic genera of the Spanish flora, 23 are in the Canary Islands, nine in mainland Spain and one in the Balearic Islands (Table 5, Fig. 2). In Table 5, the 27 subendemic genera (i.e. with some species present in adjacent territories) are reported. Of these, five are shared between mainland Spain and the south of France and seven with mainland Portugal, one is shared between the Balearic Islands and Corsica and another between mainland Spain and Morocco. On the other hand, 13 subendemic genera are found in the Canarian and Madeiran territories, sometimes with isolated species in Morocco.

The number of non-native plant species is growing at present and usually provides controversial data. Some authors prefer to include all alien species in the floras and checklists. Others, however, prefer to stick to those that are fully naturalized, excluding those that are merely occasional. Therefore, available data are not homogeneous even in the same flora (due to different criteria applied by different contributing authors). In Spain we have classified 846 non-native species, representing 12% of the total flora. The percentage of these species is very similar in the Peninsula and the Balearics, in both cases about ca 10%. However, the rate in the Canary Islands is more than twice as high (Table 6).

When the composition of the Spanish flora is examined with respect to large taxonomic groups, a predominance of dicots (80.9% of species), followed by monocots (16.7%) is seen. Gymnosperms and pteridophytes have a marginal representation with 1.9% and 0.6% of the species, respectively (Table 7). If examined by region, the amount of species in each group is virtually identical in mainland Spain and the Balearic Islands. The most notable difference is the relatively greater amount of pteridophytes in the Canaries.

A more detailed examination of the Spanish flora can be made by choosing a representation of the main families. The 10 best represented families in the whole territory are listed in Table 8. These 10 families account for 56.8% of Spanish vascular plants with a total of 4016 species. The Compositae is the best represented family with 1003 species, followed by the Leguminosae with 594 species, the Gramineae with 500 species, and the Labiatae with 329. When studying the three territories separately, there are slight differences in the composition and relative importance of the ten families most rich in species. However, the total contribution of each territory is similar to the 51.8%

Table 3. Taxa that are extinct in the Spanish flora. * = extinct in wildness (EW) sensu IUCN (2001).

Taxa	Range in Spain	Total range
Astragalus algerianus E. Sheld.	mainland Spain	south Spain, north Africa
Astragalus baionensis Loisel.	mainland Spain	southwest France, north Spain
Aurinia sinuata (L.) Griseb.	mainland Spain	Balkans, Italy and central Spain
Carthamus matritensis (Pau) Greuter	mainland Spain	endemic
Cicuta virosa L.	mainland Spain	Europe, Asia
Clethra arborea Aiton	Canary Islands	Canary I and Madeira
Draba incana L.	mainland Spain	Europe and North America
Galium tunetanum Lam.	mainland Spain	south Spain, Sicily, northwest Africa
Kunkeliella psilotoclada (Svent.) Stearn	Canary Islands	endemic
Linaria polygalifolia subsp. *lamarckii* (Rouy) D. A. Sutton*	mainland Spain	south Portugal, south Spain
Lindernia procumbens (Krock.) Philcox	Spain peninsular	Eurasia
Lysimachia minoricensis J. J. Rodr.*	Balearic Islands	endemic
Marsilea quadrifolia L.*	mainland Spain	Europe
Nolletia chrysocomoides (Desf.) Less.	mainland Spain	south Spain, north Africa
Nonea calycina (Roem. & Schult.) Selvi et al.	mainland Spain	south Spain, north Africa
Normania nava (Webb & Berthel.) Franc.-Ortega & Lester	Canary Islands	endemic
Oenanthe aquatica (L.) Poir.	mainland Spain	Europe, Asia
Pharbitis preauxii Webb & Berthel.	Canary Islands	endemic
Polygonum robertii Loisel.	mainland Spain	northeast Spain, France, Italy
Potentilla grandiflora L.	mainland Spain	north Spain and Alps
Pulicaria undulata (L.) C. A. Mey.	Canary Islands	north Africa
Sagittaria sagittifolia L.	mainland Spain	north Spain to Eurasia
Silene uniflora subsp. *thorei* (L. Dufour) Jalas	mainland Spain	southwest France, north Spain
Tanacetum funkii Willk.	mainland Spain	endemic
Trapa natans L.	mainland Spain and Balearic Islands	Europe, Asia and Africa
Verbascum faurei subsp. commixtum (Murb.) Benedí	mainland Spain	south Spain, north Africa

in found in the Balearic Islands, 56.3% in the Canary Islands and 57.8% in mainland Spain. In the Balearic Islands, the Leguminosae is best represented. It is possible that the ranking of the Compositae as the second largest family is due to the low representation of *Hieracium* L. s.l. and *Taraxacum* Weber in these islands, and not compensated by other groups. Similarily, the Rosaceae falls out of the group of the richest families due to the lack of representatives of the genus *Alchemilla* L. in this territory. *Alchemilla* received an analytical treatment in 'Flora Iberica' and provides many species to the entire Spanish flora. In the Canary Islands and in the mainland, the best represented families are the same as those for the whole of Spain, and in similar proportions. In the Canary Islands, Scrophulariaceae, Rosaceae and Plumbaginaceae are outnumbered from the top positions for Crassulaceae, Liliaceae and Euphorbiaceae. The presence of certain very diverse genera in the Canaries, like *Aeonium* Webb & Berthel., *Aichryson* Webb & Berthel. and *Euphorbia* L., determines the position of these families in the most species rich group.

Table 4. Number of endemic species and taxa (i.e. species and subspecies) in the Spanish flora.

	Endemic species	% of total taxa	Endemic taxa	% of total taxa
Balearic Islands	105	6.9	135	8.5
Canary Islands	536	25.9	637	30.6
Mainland Spain	828	13.8	1175	17.5
Mainland Spain + Balearic Islands	952	15.5	1335	19.3
Total Spain	1488	21.0	1972	24.8

Discussion

Floristic affinities

According to Tutin et al. (1980), the European flora consist of 11 557 species. Allthough this number is not up to date with more modern treatments, it can be useful to for comparisons on the wide basis outlined henceforth. The Spanish flora (excluding Canarian plants) contains 53.2% of the European plant species. Other Mediterranean floras are equally rich. The Italian flora with 5599 species (Pignatti 1982), would contain a 48.4% of all European species. The flora of Turkey with 9084 species (Güner et al. 2000) exceeds the above, but cannot be compared in the same way with the European flora as only a small part of its territory was included in Tutin et al. (1980). In central Europe the number of species decreases considerably. In Switzerland, ca 3000 species can be found (Lauber and Wagner 2007) and 3084 in Germany (Haeupler and Muer 2001), which represents 25.9% and 26.6%, respectively, of the European species. The African countries of the Mediterranean (possibly due to a lower level of exploration and also due to larger extensions of desert) have somewhat less rich floras. According to Médail and Quézel (1997) there are 4200 species in Morocco and 3150 species inhabit Algeria. According to Boulos (2005) 2075 species of vascular plants can be found in Egypt. Médail and Quézel (1997) estimated 10.8 species per 1000 km^2 for the Mediterranean basin. The values we have found for mainland Spain (12.2 species per 1000 km^2) and for the same area plus the Balearic Islands (12.4 species per 1000 km^2) are somewhat higher but of the same magnitude. However,

Table 5. Endemic and subendemic genera in the Spanish flora.

Genera	Range in Spain	Shared with (for subendemic)
Aichryson Webb et Berthel.	Canary Islands	Madeira
Allagopappus Cass.	Canary Islands	–
Astydamia DC.	Canary Islands	Madeira, Morocco?
Atalanthus D. Don	Canary Islands	–
Babcockia Boulos	Canary Islands	–
Boleum Desv.	mainland Spain	–
Borderea Miég.	mainland Spain	south France
Castrilanthemum Vogt & Oberpr.	mainland Spain	–
Ceballosia G. Kunkel	Canary Islands	–
Cedronella Moench	Canary Islands	Madeira
Chrysoprenanthes (Sch. Bip.) Bramwell	Canary Islands	–
Dendriopoterium Svent.	Canary Islands	–
Dethawia Endl.	mainland Spain	south France
Dicheranthus Webb	Canary Islands	–
Distichoselinum García Martín & Silvestre	mainland Spain	Portugal
Endressia J. Gay	mainland Spain	south France
Euzomodendron Coss.	mainland Spain	–
Femeniasia Susanna	Balearic Islands	–
Gesnouinia Gaudich.	Canary Islands	–
Gonospermum Less.	Canary Islands	–
Greenovia Webb et Berthel.	Canary Islands	–
Guillonea Coss.	mainland Spain	–
Guiraoa Coss.	mainland Spain	–
Gyrocaryum B. Valdés	mainland Spain	–
Hispidella Lam.	mainland Spain	Portugal
Isoplexis (Lind.) Loudon	Canary Islands	Madeira
Ixanthus Griseb.	Canary Islands	–
Kunkeliella Stearn	Canary Islands	–
Lactucosonchus (Sch. Bip.) Svent.	Canary Islands	–
Lepidophorum Neck.	mainland Spain	Portugal
Lycocarpus O. E. Schulz	mainland Spain	–
Marcetella Svent.	Canary Islands	Madeira
Micropyropsis Romero Zarco & Cabezudo	mainland Spain	Morocco
Monanthes Haw.	Canary Islands	Madeira, Morocco
Naufraga Constance & Cannon	Balearic Islands	Corsica (apparently extinct)
Navaea Webb et Berthel.	Canary Islands	–
Neochamaelea (Engl.) Erdtm.	Canary Islands	–
Normania Lowe	Canary Islands	Madeira
Ortegia L.	mainland Spain	Portugal
Parolinia Webb	Canary Islands	–
Pericallis D. Don	Canary Islands	Madeira
Petrocoptis Endl.	mainland Spain	south France
Phalacrocarpum (DC.) Willk.	mainland Spain	Portugal
Phyllis L.	Canary Islands	Madeira
Picconia DC.	Canary Islands	Azores, Madeira
Pleiomeris A. DC.	Canary Islands	–
Plocama Aiton	Canary Islands	–
Pseudomisopates Güemes	mainland Spain	–
Pterocephalidium G. López	mainland Spain	Portugal
Rothmaleria Font Quer	mainland Spain	–
Rutheopsis A. Hansen & G. Kunkel	Canary Islands	–
Schizogyne Cass.	Canary Islands	Madeira
Semele Kunth	Canary Islands	Madeira, Morocco
Spartocytisus Webb et Berthel.	Canary Islands	–
Sventenia Font Quer	Canary Islands	–
Teesdaliopsis (Willk.) Gand.	mainland Spain	Portugal
Tinguarra Parl.	Canary Islands	–
Todaroa Parl.	Canary Islands	–
Vieraea Sch. Bip.	Canary Islands	–
Visnea L. f.	Canary Islands	Madeira
Xatardia Meisn. & Zeyh.	mainland Spain	Andorra, south France

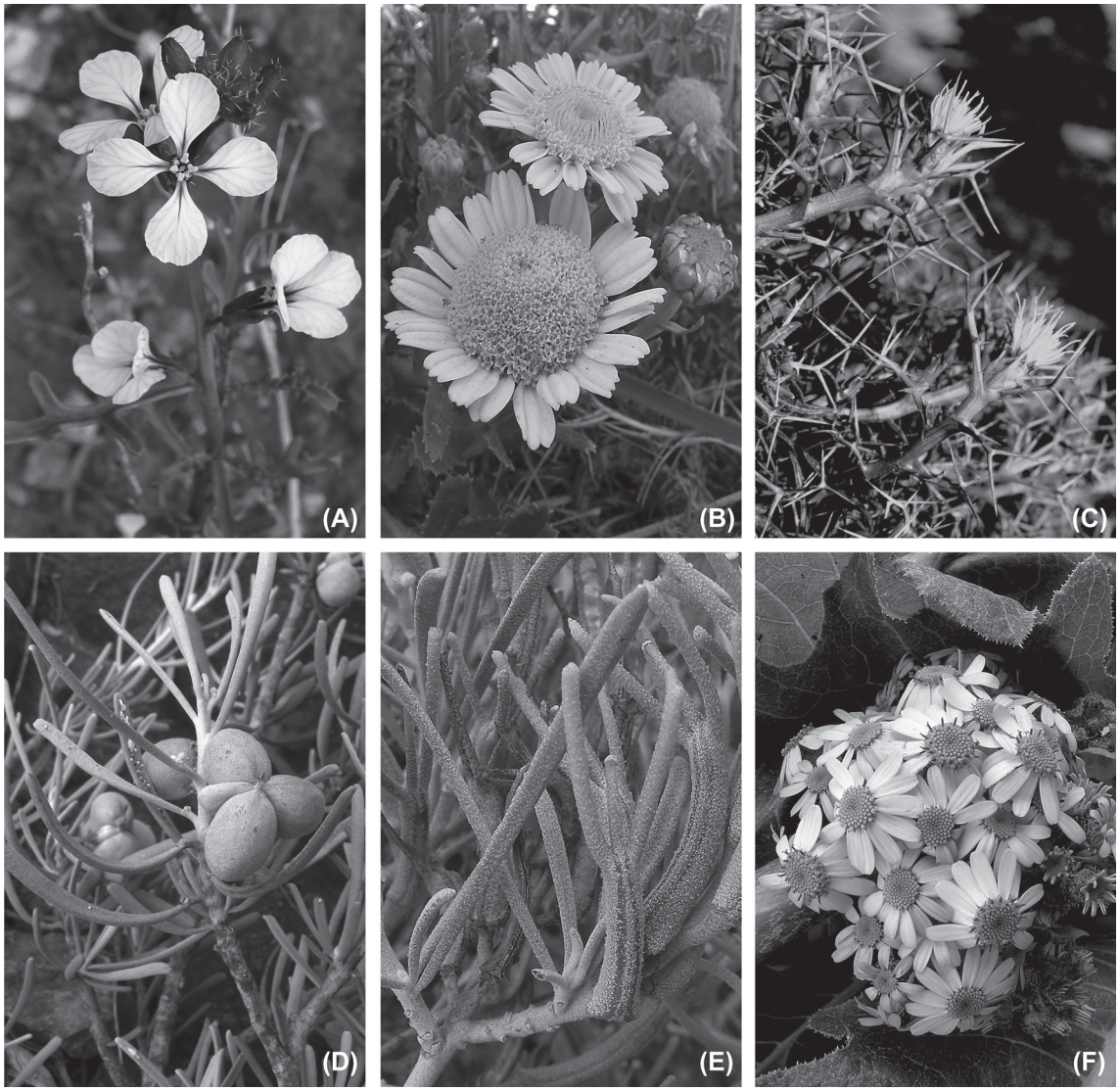

Figure 2. Representative species of endemic or subendemic genera of the Spanish flora. (A) *Euzomodentron bourgaeanum* Coss. (based on Aedo 18118, MA), (B) *Lepidophorum repandum* (L.) DC. (based on Quintanar 3922, MA), (C) *Femeniasia balearica* (Rodr. Fem.) Susanna (without voucher), (D) *Neochamaelea pulverulenta* (Vent.) Erdtman, fruit (based on Aedo 17270, MA), (E) *Parolinia filifolia* Kunkel, fruit (based on Aedo 17278, MA), (F) *Pericallis webbii* Sch. Bip. & Bolle (based on Aedo 17191, MA).

if this ratio is calculated for the Mediterranean archipelagos, higher ratios are obtained. In the Balearic Islands 304 species per 1000 km^2 can be found, similar to Corsica (274 species per 1000 km^2) (Jeanmonod and Gamisans 2007).

The Canarian flora should more properly be compared with the Macaronesian flora than with the European flora. According to Press and Short (1994) 1226 species can be found in Madeira compared with 2066 species for the Canaries. However, it should be noted that the archipelago of Madeira has much fewer islands and only 1/10 the area of the Canaries. In relative terms Madeira would be floristically richer, with 154 species per 100 km^2 compared to 27 species per 100 km^2 in the Canaries. This data should be taken with caution as they are based on different taxonomic treatments, made at different times, and cannot be considered homogeneous. However, the comparison indicates certain trends that cannot be ignored.

Table 6. Number of non-native species in the different Spanish regions.

	Non-native	% of total species
Balearic Islands	147	9.7
Canary Islands	428	20.7
Mainland Spain	631	10.5
Total Spain	846	12.0

The number of shared species between mainland Spain and the Balearic Islands is somewhat higher than that shared between mainland Spain and the Canaries (662 vs 449). This difference is somewhat lower than would be expected if we take into account that mainland Spain and the Balearic Islands are geographically very close and both form part of the Mediterranean floristic region. The Canaries is not only further away but belongs to the Macaronesian region. Although there is no precise data available, a brief analysis of the common species indicates that mainly

Table 7. Number of species by major taxonomic groups in the Spanish flora.

	Pteridophytes	% pteridophytes of total species	Gymnosperms	% gymnosperms of total species	Dicots	% dicots of total species	Monocots	% monocots of total species
Balearic Islands	30	2.0	9	0.6	1212	79.7	270	17.8
Canary Islands	61	3.0	10	0.5	1633	79.0	362	17.5
Mainland Spain	113	1.9	35	0.6	4789	80.0	1047	17.5
Total	131	1.9	39	0.6	5719	80.9	1182	16.7

plants inhabiting disturbed habitats are widely distributed. Thus, the original Canarian biogeography is attenuated by these species. The connection between the Balearics and the Canaries is very low, with seven shared species that cannot be found in mainland Spain. They are species that are present in northern Africa. Unfortunately, we do not have comparative data with other Mediterranean or Macaronesian areas to allow a deeper analysis.

The flora of mainland Portugal is very similar to that of mainland Spain as there are no biogeographical barriers of importance between the two territories, and they share 95.4% of the species. Setting aside endemic and non-native species we have identified 15 species present in mainland Portugal which are not present in the rest of the Iberian Peninsula. These species are also found in northwest Africa (i.e. *Coleostephus paludosus* (Durieu) Alavi) or are widely distributed aquatic species (i.e. *Damasonium alisma* Mill. s.s.). Andorra has no endemic species. We have identified only four species present in Andorra which have not been recorded in mainland Spain. Probably a more detailed exploration of the southern slopes of the Pyrenees could offer some more localities of these species.

Extinction

Greuter (1994) analysed the extinction of species in the Mediterranean basin and mentioned that the rate of documented extinctions was very low in relation to other Mediterranean areas worldwide, with 0.13% extinct species compared to 0.40% in California or 0.66% in Western Australia. The advance of floristic studies causes some of this data to quickly become obsolete, as the author stated. Among Spanish plants Greuter (1994) considered *Allium rouyi* Gaut. (Cabezudo et al. 1992) and *Silene tomentosa* Otth (cf. Linares et al. 1996) to be extinct, but both have subsequently been relocated, and *Diplotaxis siettiana* Maire successfully reintroduced (Bañares et al. 2007). Similarly, the 'Spanish Red Book' (Bañares et al. 2007, 2010) lists *Ranunculus lingua* L. as extinct, but it has been found in Navarra (Aizpuru et al. 2003), and *Linaria coutinhoi* Valdés, which is now treated as a synonym of *L. intricata* Coincy in 'Flora Iberica'. The data gathered at present indicate that 0.35% of the Spanish flora has become extinct. There is a significant difference between the rate of extinction of mainland Spain and the Balearic Islands (0.35%), and the Canaries (0.14%). This difference may be influenced by the intense effort of documentation of the 'Flora Iberica' project that has no equivalent in the Canaries. We agree with Greuter (1994), that the low rates of recorded extinctions in the Mediterranean basin are probably distorted by pre-botanical extinctions and by the poor floristic monitoring of these areas.

Endemicity

Médail and Quézel (1997) suggested that endemic species richness is superior in Mediterranean floras of the Southern Hemisphere compared to California or the Mediterranean basin. These authors indicate that in the Cape Floristic region, the rate of endemic species is 68%, and 75% in southwest Australia. According to Baldwin et al. (2012) the flora of California have 22% endemic species. A slightly lower rate of 48% is proposed by Médail and Quézel (1997) for this region. These authors point out an endemicity rate

Table 8. Number of species per region of the ten most species rich families of the Spanish flora.

	Total Spain	% over total species of Spain	Balearic Islands	% of total species of Balearic Islands	Canary Islands	% of total species of Canary Islands	Mainland Spain	% of total species of mainland Spain
Compositae	1003	14.2	155	10.2	295	14.3	824	13.8
Leguminosae	594	8.4	171	11.2	202	9.8	504	8.4
Gramineae	500	7.1	99	6.5	198	9.6	442	7.4
Labiatae	329	4.7	57	3.7	89	4.3	256	4.3
Cruciferae	326	4.6	65	4.3	83	4.0	284	4.7
Caryophyllaceae	320	4.5	57	3.7	83	4.0	290	4.8
Scrophulariaceae	279	3.9	46	3.0			256	4.3
Rosaceae	253	3.6					242	4.0
Umbelliferae	237	3.4	54	3.6	49	2.4	208	3.5
Plumbaginaceae	175	2.5	46	3.0				
Orchidaceae			38	2.5				
Crassulaceae					68	3.3		
Lilaceae					50	2.4		
Euphorbiaceae					46	2.2		
Cyperaceae							151	2.5

of 50% in the Mediterranean basin as a whole (Table 1 in Médail and Quézel 1997). However, when analysing the endemicity rate by countries the result is significantly lower. Médail and Quézel (1997) attributed an endemicity rate of 30.8% to Turkey (32.9% according Güner et al. 2000), 21.4% to Morocco and 19.1% to mainland Spain. Gómez Campo and Malato Beliz (1985) offered a further analysis of the endemicity areas in the Iberian Peninsula. These authors attributed 6.5% endemicity rate to the Balearic Islands and similar figures for other large Mediterranean islands with up to 10% for the island of Crete. The Macaronesian Islands appear to have a far more original flora with 31.8% endemicity for the Canary Islands and 16.9% for Madeira (10% according to Press and Short 1994). Our data indicate an endemicity rate of 21% for the whole of Spain, but a much lower rate for mainland Spain and the Balearic Islands (13.8% and 6.9%, respectively) than for the Canaries (25.8%). Médail and Quézel (1997) seem to overestimate the degree of endemicity of mainland Spain and the Canary Islands, as did Domínguez and Schwartz (2005) overestimate the Iberian endemicity (25–30%). Although the flora of mainland Spain has a high degree of originality, it appears to maintain endemicity rates similar to other Mediterranean countries (13% for mainland Greece and 11.7% for mainland Italy; Médail and Quézel 1997) but higher than central and northern European countries. As an example, Haeupler and Muer (2001) attributed an endemicity of 0.7% for the German flora.

Non-native species

The results for the non-native flora are more difficult to compare than total species number or endemicity, as the uncertainty derived from differences of taxonomic criteria derived from the different degrees of naturalization of non-native species. Some authors refer (in floras and checklists) exclusively to the species clearly naturalized whilst others add those that are ephemeral to some degree. Our own data which are principally based on the 'Flora Iberica' are heterogeneous, as previously mentioned. Our estimation of 12% non-native species in the flora of Spain is similar to the one proposed by Sanz Elorza et al. (2004) who indicated a proportion of 10.0–13.4%. These proportions are very close to the ones calculated by Jeanmonod and Gamisans (2007) for Corsica (16.4%), and Heywood (1989) for Italy (12%) and France (11%). Güner et al. (2000) recognized only 2.5% non-native species in Turkey, which is probably an underestimation as the flora of Turkey has not been studied in depth in this sense. Pyšek et al. (2002) showed a much higher rate for the Czech Republic (33.4% non-native species). Baldwin et al. (2012) recorded 19.9% for California and Weeb et al. (1988) 50% for New Zealand. This could indicate that the countries in the Mediterranean basin, with a long history of migrations and commerce, have better resisted the recent invasion of non-native floras than have oceanic islands or other territories.

Taxonomic groups

The available information on the relative weight of major taxonomic groups in different floras is scarce. In floras with some resemblance to the Spanish one, like the one of Turkey (Güner et al. 2000) or California (Baldwin et al. 2012), the relative importance of pteridophytes and gymnosperms is also very low. In California, pteridophytes represent 1.7% and in Turkey 0.9%, and gymnosperms 1% and 0.2%, respectively. In the Spanish flora we find 1.9% pteridophytes and 0.6% gymnosperms. Similarly, Californian dicots account for 79.5% and monocots for 17.8%, whereas in Turkey they account for 82.5% and for 16.4%, respectively. In the Spanish flora these groups account for 80.9% and 16.7%, respectively. In tropical floras it is well known that the relative weight of pteridophytes is much higher. For example, in the Gulf of Guinea islands the proportions range between 17.3 and 22.8% (Exell 1944). In Ecuador, Jørgensen and León (1999) indicated that pteridophytes account for 8.5%, gymnosperms for 0.1%, dicots for 57.6% and monocots for 33.8% of the flora. The relative weight of the main families of angiosperms is also significantly different in the tropics. Orchidaceae accounts for 19.6% of the flora in Ecuador, whereas Compositae (the second most species rich family) only accounts for 5.6%. Melastomataceae with 3.6% and Rubiaceae with 3.2% are the other most important families in this area. Stannard (1995) offers a different pattern for the flora of the Pico das Almas in Brazil. In this area, according to the subterritories, the dominant families are Leguminosae (10.5%) or Compositae (10.0–12.6%), followed by Melastomataceae and Gramineae (between 6–8%). In the Mediterranean basin floras the Compositae is usually dominant, followed by Gramineae and Leguminosae.

As Dominguez and Wheeler (1997) indicated, taxonomic stability is undesirable. Changes in classification, as well as new floristic data are good indicators of that scientific activity has taken place. Following publication of the volumes of 'Flora Iberica' at least 69 new species have been described for the Iberian–Balearic region and around 20 native species (< www.floraiberica.org >), not previously known in the area, have been recorded. These new findings have become known thanks to new gatherings in poorly prospected areas. It would therefore be desirable that bureaucratic obstacles to collection were transformed into facilities and support so that researchers can carry out their task. It is important to point out that according to the presently available data for Spain, no species have become extinct due to irresponsible collection. The most important threat to species in the area is the change of land use. During the preparation of this article, it has become evident that the limited information available for various areas of the Mediterranean basin make comparisons more difficult. Fortunately, there are several floristic projects under way (Strid and Tan 1997–2002, Fennane and Tattou 2005–2008) that will contribute to fill these gaps. With respect to our area of work, the weakest point is the lack of a Macaronesian Flora. This flora, which we believe should cover the Macaronesian territories of Spain and Portugal (i.e. the archipelagos of Canary, Azores and Madeira), would be the appropriate complement and the natural continuation of the 'Flora Iberica' project. This 'Flora Macaronesica' would be a magnificent opportunity for a critical evaluation

of the endemics of each island, that at times have been described without appropriate comparison with nearby islands, and for a review of many species that are present both on these islands and in the Iberian Peninsula.

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