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DIVERSITY AND ECOLOGICAL CHARACTERISTICS OF THE VASCULAR FLORA IN THE WESTERN MEDITERRANEAN (EASTERN ANDALUSIA, SPAIN)

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ABSTRACT . *Diversity and ecological characteristics of the vascular flora in the western mediterranean (Eastern Andalusia, Spain)*. This work highlights the importance of the vascular flora of eastern Andalusia within the hotspot of the Mediterranean Basin, analysing 3726 taxa, which represent 42.0% of the Iberian Peninsula and 29.9% of European floras. Notably, 10.3% of the flora is endemic (350 taxa), constituting 34.3% of the endemism of the Iberian Peninsula and Balearic Islands, and 2.6% of those of the Mediterranean Basin, which include 6 of the 17 endemic genera of the Iberian Peninsula and Balearic Islands, 3 of these being exclusive of the territory analysed. Chamaephytes and hemicryptophytes make up 45.5% of the flora, with decreasing values for the therophytes as altitudes rise (41.1-8.1%) and increasing values for hemicryptophytes (22.4%-63.2%). Mediterranean taxa comprise 39.2%, followed by Ibero-North African taxa (15.3%), Iberian (13.9%), European (11.3%) and local endemism (9.4%). Of these taxa, 12.5% are threatened, according to the criteria of the UICN. *Tanacetum funkii*, exclusive of this area, is considered extinct. Only 6 families account for 43.5% of the threatened taxa. The Mesomediterranean thermotype (600-1400 m a.s.l.) harbours 82.8% of the species, with a maximum of between 700-800 m a.s.l. and with two zones of minimums: from -100 to 0 m a.s.l. and from 3300 to 3400 m a.s.l.

Key words. Floristic richness, endemic species, altitudinal distribution, life forms; conservation.

RESUMEN. *Diversidad y características ecológicas de la flora vascular en el Mediterráneo Occidental (Andalucía Oriental, España)*. Se resalta la importancia de la Flora vascular de Andalucía Oriental en el hotspot Cuenca Mediterránea; para ello se analizan los 3.726 táxones (especies y subespecies) detectados

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en dicha flora, que suponen más del 42 % de la flora de la Península Ibérica y el 29,9 % de la flora europea. Un 10,3 % de la flora es endémica (350 táxones), que representan el 34,3 % de los endemismos peninsulares y baleares y el 2,6 % de los de la Cuenca Mediterránea, entre los que se incluyen 6 de los 17 géneros endémicos de la Península Ibérica e Islas Baleares, 3 de ellos exclusivos del territorio analizado. Caméfitos y hemicriptófitos suponen el 45 % de la flora, con valores decrecientes para los terófitos al ascender en altitud (del 41,1 al 8,1 %) y creciente para los hemicriptófitos (del 22,4 al 63,2 %). Un 39,2 % de los táxones son mediterráneos, seguidos por los iberonorteafricanos (15,3 %), los ibéricos (13,9 %) y en quinto lugar los endemismos locales (9,4 %). El 12,5 % de los táxones están amenazados según los criterios de la UICN y de un 5,1 no se tienen datos suficientes. *Tanacetum funkii*, exclusivo de este área, se considera extinto. Solo 6 familias concentran el 43,5 % de los táxones amenazados. En el termotipo mesomediterráneo (600-1.400 m) se desarrollan el 82,8 % de las especies presentes, con un máximo entre los 700-800 m, y mínimos en el ámbito marino (-100-0 m) y, por el contrario, en las cotas más elevadas (3.300-3.400 m).

Palabras clave. Riqueza florística, endemismos, distribución altitudinal, formas de vida, conservación.

INTRODUCTION

The declaration of legally protected areas is the starting point for the conservation of biodiversity. In this sense, it is desirable to identify the areas having the greatest biodiversity (Stanley 1987). In 2011, the IUCN had 130,709 protected areas registered at the national level and 27,188 at the international (http://www.wdpa.org/Statistics.aspx), with a surface area of 24,236,478.69 km^2 (some 10.9 % of the land surface of the earth and 2.2% of the water surface). Due to the needs of natural resources and cultivation by humans, it is probable that these figures will never reach values high enough to cover a significant percentage of biological diversity, and it will be necessary furthermore to evaluate whether the areas that are listed are effective at protecting the biodiversity on the world scale.

With the aim of establishing conservation priorities, different organizations (World Conservation Monitoring Centre [WCMC], Birdlife International, Conservation International, etc.) have pointed out different areas that have high levels of biodiversity and endemic species and that moreover are submitted to a high degree of threat, these areas being called hotspots (Myers 1988, 1990; Primack and Ros 2002).

After the work of Médail and Quézel (1997), Myers *et al.* (2000) listed the Mediterranean Basin as one of the 25 biodiversity hotspots at the world level, stressing the importance of areas of the Mediterranean type in five of such areas. In a later work, Médail and Quézel (1999) underscored the importance of Andalusia in the Mediterranean Basin, together with Morocco, as part of one of the main biodiversity centres existing in the basin.

With this work, the objective is to analyse and highlight the importance of vascular flora of eastern Andalusia, as it is an exceptional focal point within the hotspot of the Mediterranean Basin, in good part due to its strategic position of bridging the Iberian Peninsula and North Africa at the end of the Miocene. As well as serving as a refuge for the flora of continental Europe during the period of the glaciations (Blanca 1993) and bearing diverse substrates with nutritional imbalances for plants (volcanic, peridotitic, dolomitic, gypsiferous, saline, etc.), giving rise to in a multitude, at the world level, of territories rich in endemic taxa (Johnston 1941; Rivas Goday and Esteve Chueca 1972; Rivas Goday 1973, 1974; Esteve and Varo 1975; Rivas Goday and López González 1979; Kruckerberg 1986, 1992; Cabezudo *et al.* 1989; Mota *et al.* 1993, 2008; Cowling *et al.* 1995; Stevanovič *et al.* 2003; Reeves and Adigüzel 2004; Safford *et al.* 2005; Figueroa 2006; Selvi 2007; Fuente *et al.* 2007; Heads 2008; Lendínez *et al.* 2011; Mota *et al.* 2011; García-Barriuso *et al.* 2012; Pérez-Latorre *et al.* 2013), as well as being due to the climatic and pedological aridity (Mota *et al.* 2003; Ozenda 2008), climatic and orographic variety, in addition to geographical isolation and abrupt ecological gradients (Blanca 1997).

MATERIAL AND METHODS

Eastern Andalusia is situated in the south-east of the Iberian Peninsula, composed of the administrative provinces Almería, Granada, Jaén, and Málaga (fig. 1).

This territory covers an area of 42,079 km^2, of which 9301 (22.1 %) are currently protected, a figure that rose to 15,160.6 km^2 (36 %) after new spaces were proposed as Sites of Community Importance (SCI). Also, 10 spaces are included on the list of RAMSAR (Salinas del Cabo de Gata; Albufera de Adra; Punta Entinas-Sabinar; Humedales y turberas de Padul; Laguna Honda; Laguna del Chinche; Laguna Grande; Laguna de Fuente de Piedra; Lagunas de Campillos; Lagunas de Archidona) and 5 Biosphere Reserves (Intercontinental del Mediterráneo Andalucía (España)-Marruecos; Cabo de Gata-Níjar; Sierras de Cazorla, Segura y Las Villas; Sierra Nevada; and Sierra de las Nieves y su entorno). This is an abrupt terrain, with an average slope of 22% and an altitudinal range from 0 m on the coast to 3480 m of Mulhacén Peak in Sierra Nevada (the highest peak of the Iberian Peninsula), these extremes lying only 33.7 km from each other in a straight line.

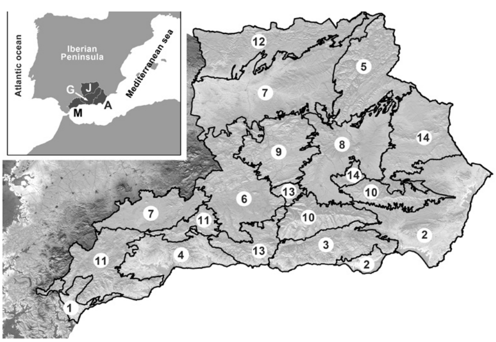

Figure 1. Geographic position of eastern Andalusia and environmental units defined in that zone (according to Blanca *et al.* 2009). Administrative provinces: A (Almería); J (Jaén); G (Granada) and M (Málaga). Environmental units: 1 (Aljibe); 2 (Almería); 3 (Alpujarras); 4 (Axarquía); 5 (Cazorla); 6 (Granada); 7 (Guadalquivir); 8 (Guadiana Menor); 9 (Mágina); 10 (Nevada-Filabres); 11 (Ronda); 12 (Sierra Morena); 13 (Trevenque-Almijara) and 14 (Vélez-Baza).

In such an extensive territory, and given the high environmental heterogeneity (altitude, lithology, soil, climate), Blanca *et al.* (2009) identified 14 environmental units: Aljibe, Almería, Alpujarras, Axarquía, Cazorla, Granada, Guadalquivir, Guadiana Menor, Mágina, Nevada-Filabres, Ronda, Sierra Morena, Trevenque-Almijara, and Vélez-Baza (fig. 1). The physical and climatic characteristics of these units are summarized in tables 1 and 2, respectively.

The data base used was compiled during the preparation of the *Flora Vascular de Andalucía Oriental* (Blanca *et al.* 2009, 2011), resulting from the review of the herbaria located in the territory (ALME, GDA, HUAL, JAEN, and MGC), as well as in others in Spain (mainly BC, BCF, MA, MAF, and SEV) and afterwards others in different countries (COI, G, MPU, among others). Also, collections were made in areas without prior records, which are deposited in the aforementioned herbaria (initials according to the Index Herbariorum). The systematic treatment and nomenclature followed is the same as in Blanca *et al.* (2009, 2011).

The chorological elements used were those proposed by Takhtajan (1986), with modifications used by Blanca *et al.* (2009) to enable comparisons and groupings of the floristic catalogue. The life forms correspond to those of Raunkiaer (1934): phanerophytes, chamaephytes, hemicryptophytes, geophytes, therophytes, helophytes, and hydrophytes.

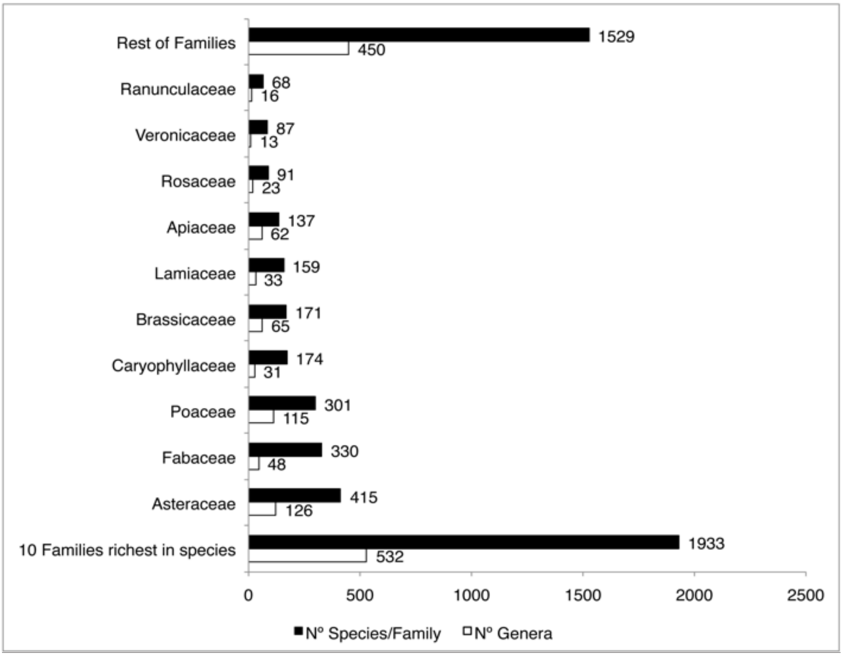

Figure 2. Number of genus and species in the 10 families with the greatest representation of the vascular flora of eastern Andalusia.

Unit	Surface area (km^2)	Altitude (m)		Average slope (%)	Predominant Substrates
		Range	Average		
Aljibe	641.5	0-1120	346.1	26.4	Siliceous
Almería	4533.3	0-1380	377.9	16.3	Basic
Alpujarras	2060.8	0-2240	793.2	34.3	Basic and Siliceous
Axarquía	2046.3	0-1217	313.8	26.1	Siliceous
Cazorla	3040.3	367-2380	1225.6	33.2	Basic
Granada	3375.5	360-1660	813.8	18	Basic
Guadalquivir	7074.1	13-1920	495.8	11.5	Basic
Guadiana Menor	3469.5	410-1731	913.7	13.9	Basic
Mágina	2313.9	451-2160	1085.3	23.7	Basic
Nevada-Filabres	2683.1	220-3480	1613.1	34.4	Siliceous
Ronda	3195.3	0-1900	714.1	30.1	Basic
Sierra Morena	3129.9	160-1280	599.3	21	Siliceous
Trevenque-Almijara	1521.9	0-2220	1015.5	36.4	Basic
Vélez-Baza	3111.7	479-2260	1126.6	18.4	Basic

Table 1. Physical characteristics of the environmental units in eastern Andalusia.

Unit	Temperature (º C)		Rainfall (mm)	
	Range	Average	Range	Average
Aljibe	13.1-18.2	16.6	595.1-1760.3	959.1
Almería	12.7-20.3	17.6	152.8-413.1	266.7
Alpujarras	9.3-19.2	15.5	176.1-680.2	407.2
Axarquía	12.8-19.4	16.8	410.1-1009	548.4
Cazorla	7.8-18.1	12.8	289.4-1145.8	725.6
Granada	10.6-17.6	14.6	326.4-802.9	502.5
Guadalquivir	9.5-19.2	16.7	393.5-859.2	511.1
Guadiana Menor	10.8-17.6	14.3	270.9-718.5	361
Mágina	9-18.1	13.8	335-802.9	543.9
Nevada-Filabres	4.6-18.8	11.7	211.6-746.1	439.5
Ronda	8.1-19.1	14.9	347.3-1360.5	710.4
Sierra Morena	12.6-19	16	443.9-832.2	558.8
Trevenque-Almijara	9.2-18.4	14	375.5-1003	590.3
Vélez-Baza	7.6-17	13.7	212.1-510.8	351.9

Table 2. Climatic characteristics of the environmental units in eastern Andalusia (prepared from the data of Rediam, 2013)

	Nº	Families		Genera		Taxa	
		Nº	%	Nº	%	Nº	%
Pteridophytes		20	12.1	28	2.8	63	1.7
Gymnosperms		5	3	14	1.4	36	1
	Liliidae	31	18.8	208	21.2	677	18.2
	Ranunculiidae	104	63	727	74	2941	78.9
Angiosperms	Magnoliidae	4	2.4	4	0.4	8	0.2
	Ceratophylliidae	1	0.6	1	0.1	1	0.02
	Total Angiosperms	140	84.8	940	95.7	3627	97.3
Total Vascular Flora		165		982		3726	

Table 3. Representation of the large groups of vascular plants in the vascular flora of eastern Andalusia.

In the analysis of the state of conservation of plants, the reference works used were Blanca *et al.* (1999, 2000), Cabezudo *et al.* (2005), Bañares *et al.* (2004, 2007, 2009, 2011), and Moreno (2008), using the threat categories of the IUCN (2001). The belts of vegetation used in the altitudinal distribution correspond to the thermotypes of Rivas Martínez (2007): Thermomediterranean, Mesomediterranean, Supramediterranean, Oromediterranean, and Cryoromediterranean.

RESULTS AND DISCUSSION

Taxonomical composition

The vascular flora of eastern Andalusia is composed of 165 families, including 982 genera and 3462 species, or 3726 taxa (species + subspecies). In relation to other figures provided for the entire Iberian Peninsula by Aedo *et al.* (2013), the flora studied here represents more than 42% of the peninsular flora on a surface area of less than 10% of the overall peninsula, and 29.9% of European flora. Table 3 lists each of the large plant groups studied. The distribution of species in large taxonomical groups is similar to that of overall Spanish flora: pteridophytes, 1.7% vs. 1.9% for Spain; gymnosperms 1% vs. 0.6% for Spain; angiosperms 97.8% vs. 97.6% for Spain.

The majority group, angiosperms, represents 97.3% of the flora. Notable are the Ranunculiidae, with 78.9%. In eastern Andalusia, the families with the greatest representation are Asteraceae (126 genera, 415 species), Fabaceae (48 genera, 330 species), and Poaceae (115 genera, 301 species); also significant are the families Caryophyllaceae (31 genera, 174 species), Brassicaceae (65 genera, 171 species), Lamiaceae (33 genera, 159 species), and Apiaceae (62 genera, 137 species). The 10 families richest in species of eastern Andalusian flora constitute 54.2% of the genera and 55.8% of the species present in the area (fig. 2). The genera with the greatest representation are *Centaurea* (48 species/18 locally endemic), *Silene* (45/3), *Teucrium* (40/14), *Trifolium* (39/0), *Carex* (33/2), *Ononis* (33/0), *Vicia* (32/1), *Galium* (32/8), *Ranunculus* (31/3), and *Astragalus* (30/3).

The endemic flora of eastern Andalusia is made up of 350 taxa, i.e. 10.3% of the total, representing 34.3% of the total endemic taxa of the Iberian Peninsula and Balearic Islands and 2.6% of the Mediterranean Basin. Of the 12 richest areas in endemic taxa of the Iberian Peninsula and Balearic Islands identified by Moreno *et al.* (2013), 4 are found in eastern Andalusia (Subbetic System; Málaga and Granada; Sierras of Grazalema and Ronda; and Sierra Nevada). The families with the highest number of endemic taxa (fig. 3) are Asteraceae (60 taxa, 17.1%), Brassicaceae (34 taxa, 9.7%), and Lamiaceae (32 taxa, 9.1%). Of the 17 endemic genera of the Iberian Peninsula and Balearic Islands (Aedo *et al.* 2013), 6 are present in eastern Andalusia, with 3 being exclusive of this area (*Castrilanthemum*, Cazorla unit; *Euzomodendron*, Almería unit, and *Rothmaleria*, Trevenque-Almijara unit).

Life forms

The analysis of the distribution of taxa according to life forms (fig. 4) reflect a predominance of therophytes (1283; 33%), followed by hemicryptophytes (1163; 30%), chamaephytes (594; 15%), phanerophytes (396; 10%), geophytes (347; 9%), hydrophytes (55; 2%), and helophytes (33; 1%).

In table 4 appears the proportion of taxa according to the life forms by thermoclimatic belts.

The results of the distribution of life forms according to altitude coincide with the trends expressed by other authors (e.g. Voliotis 1982; Cueto *et al.* 1991). The proportion of therophytes reaches its maximum in the Thermomediterranean (41.1%), close to the value of 56% indicated by Braun-Blanquet

(1979) for the El Golea desert in the Sahara and far higher than the 15% cited by Cowling *et al.* (1996) for local flora of all the regions with a Mediterranean climate, progressively diminishing with altitude (with a lowering of temperature and dryness). Meanwhile, the hemicryptophytes increase with altitude until reaching their maximum in the Cryoromediterranean (63.2%), a value similar to the 68% indicated by Braun-Blanquet (l.c.) for the zone between 2000-3000 m of the Alps.

Chorological spectrum

The predominant floristic element in peninsular Spain is Mediterranean in the broad sense, followed by the Euro-Siberian and, third, endemic elements (Moreno 2012). In eastern Andalusia (fig. 5) the Mediterranean taxa also predominate (1461; 39.2%), followed by Iberian-North African (569; 15.3%), Iberian (453; 139%), European (423; 11.3%), and in fifth place of endemic taxa of the study area, eastern Andalusia (350; 9.4%).

One of the main causes of the uniqueness of the flora of this territory is due above all to the percentage of Iberian-North African species, the floristic element that, on the contrary, represents a minority group for the overall Iberian Peninsula. The Iberian-North African elements penetrate the south and east and differentiate beginning from a xerophytic and heterogeneous stock of ancestral plants, resulting in numerous endemic taxa having affinities with Saharan-Arab taxa (Thompson 2005).

Some of the genera of the most genuinely Mediterranean flora, and which have a diversification centre in the Iberian Peninsula, are: *Genista, Narcissus, Linaria, Helianthemum, Thymus, Teucrium*, etc. (Thompson l.c.). In eastern Andalusia, all these genera are represented by more than 10 species, with the genus *Teucrium* reaching 40 species. These are autochthonous taxa that developed and differentiated during the Tertiary due to isolation processes of the microplates and climatic change during this period (Zohary 1973).

The number of taxa present in the environmental units (fig. 6) ranges from a maximum of 1894 taxa (50.8%) in the Ronda unit to a minimum of 1129 taxa (30.3%) in the Guadiana Menor. It was noted that the units with the greatest number of taxa are those having substrates that are predominantly basic (Ronda, Trevenque-Almijara, Cazorla, Vélez-Baza, etc.), with the exception of Nevada-Filabres, in fourth place, on siliceous substrates, followed by the Alpujarras unit, where basic and siliceous substrates coexist.

The singularity of each environmental unit can be evaluated by the presence of elements that differ from the others. The data compiled support the territorial division established on the basis of environmental characteristics and expert knowledge. Notable are the units Nevada-Filabres, Almería, and Cazorla, with 181 differential elements (72 local endemic taxa), 128 (28), and 126 (27), respectively (tab. 5).

The Sierra Nevada, from the geological standpoint, including the central siliceous core (within the Nevada-Filabres unit) and the north-western calcareous part (within the Trevenque-Almijara unit) is the most important centre of plant diversity in the western Mediterranean region (Molero-Mesa and Pérez Raya 1987; Blanca 1996; Heywood 1996; Blanca *et al.* 1998; Fernández 2012). The data reveal its floristic importance, since, of the 350 endemic taxa of eastern Andalusia, 174 belong to Sierra Nevada, 90 being exclusive of this massif. On the other hand, 215 taxa of eastern Andalusian flora are exclusive to Sierra Nevada, some being: Alpine, such as *Artemisia umbelliformis* Lam. and *Gentiana alpina* Vill.; Arctic-Alpine, such as *Ranunculus glacialis* L. and *Saxifraga oppositifolia* L. subsp. *oppositifolia*; Circumboreal, such as *Silene rupestris* L. and

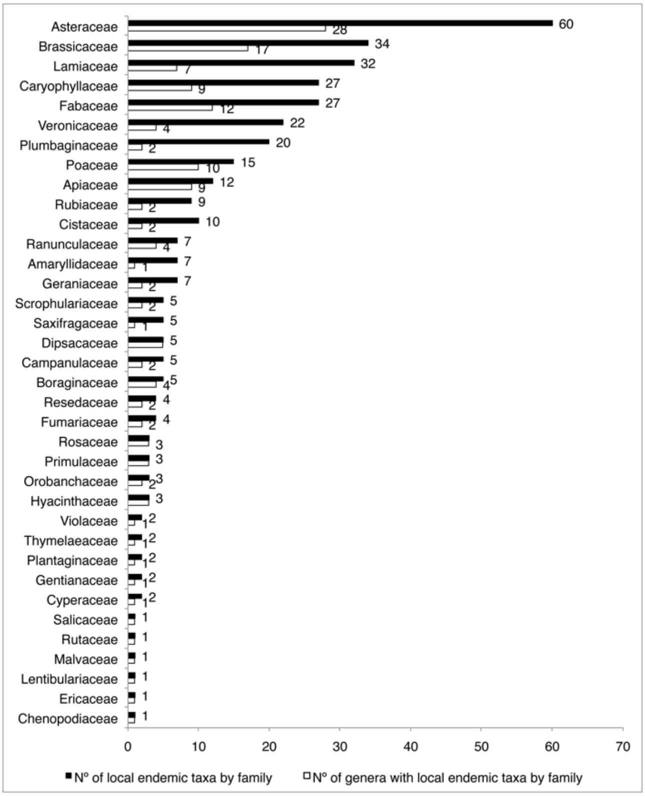

Figure 3. Number of local endemic taxa and number of genera with local endemic taxa by family of the vascular flora of eastern Andalusia.

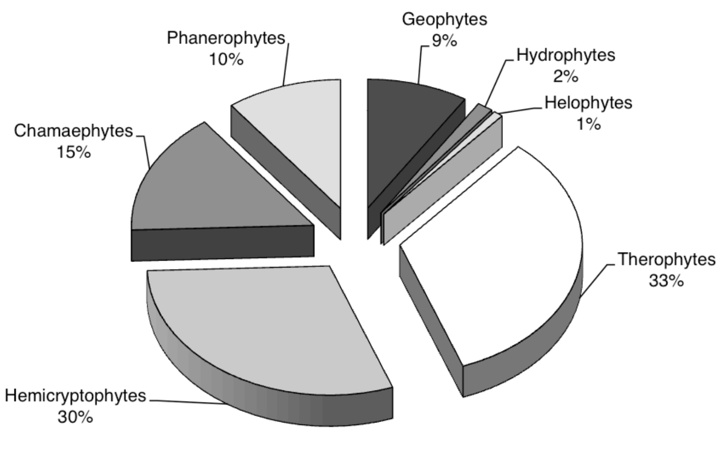

Figure 4. Distribution of the vascular flora of eastern Andalusia according to the life forms of Raunkiaer (1934).

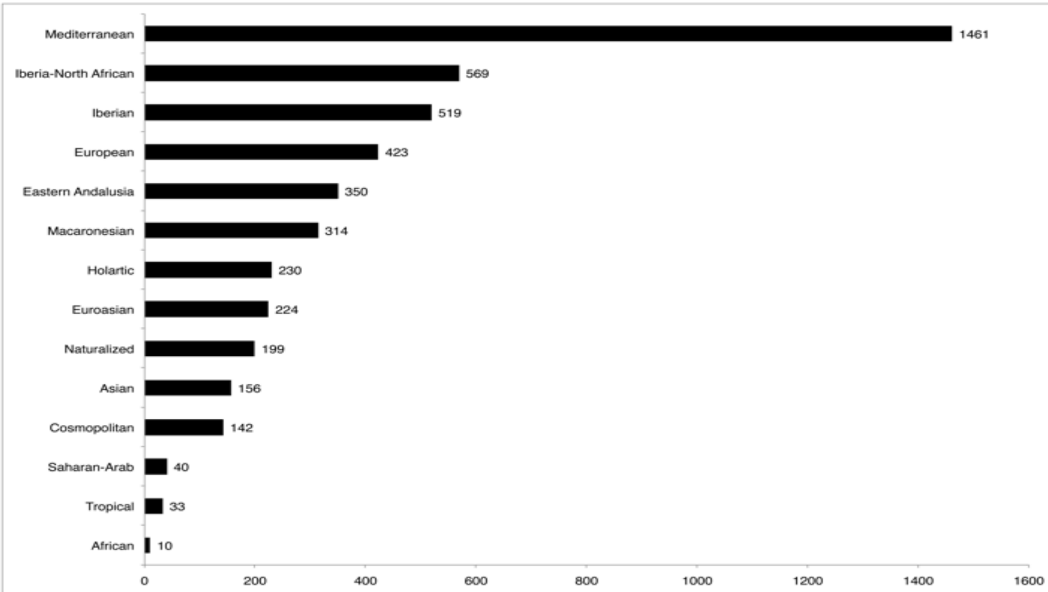

Figure 5. Chorological spectrum of the vascular flora of eastern Andalusia.

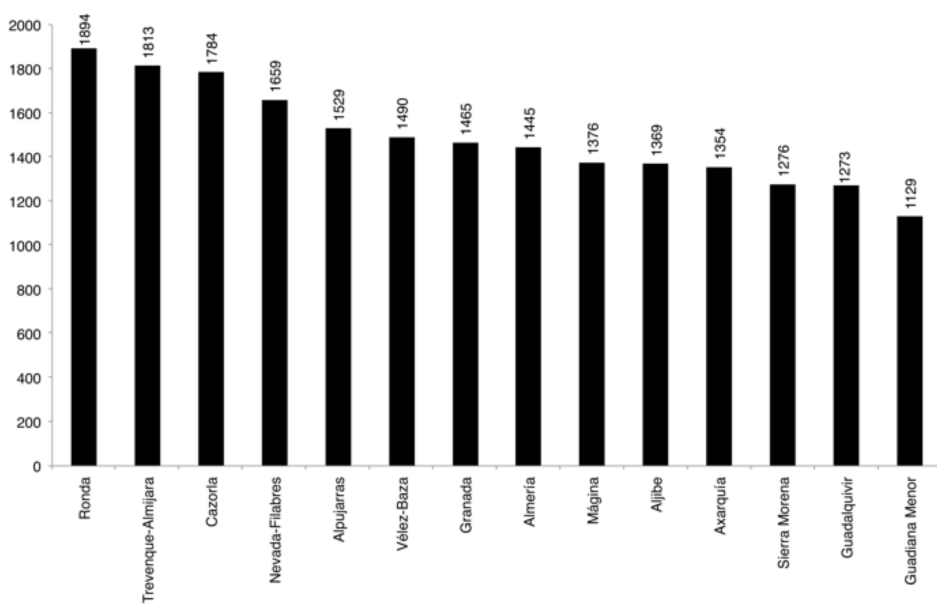

Figure 6. Number of taxa of the vascular flora of eastern Andalusia in each environmental unit of the territory studied.

Sibbaldia procumbens L.; Holarctic, such as *Asplenium septentrionale* (L.) Hoffm. subsp. *septentrionale* and *Gymnocarpium robertianum* (Hoffm.) Newman; or Iberian-North African, such as *Murbeckiella boryi* (Boiss.) Rothm., *Epilobium atlanticum* Litard. & Maire, and *Saxifraga trabutiana* Engl. & Irmsch.

State of conservation

Figure 7 summarizes the state of conservation of the flora analysed. Of the taxa evaluated (2600), 69.8% are included in the category LC (less concern), 10.4% (389) in NT (nearly threatened), 7.7% (286) in VU (vulnerable), 2.7% (102) in EN (endangered), 2% (76) in CR (critically endangered), 0.2% (8) EX (extinct), and 5.2% (192) in DD (deficient data). From the figures, it can be deduced that 1.25% of the taxa (464) are threatened (VU, EN, and CR), while 5.2% do not have sufficient data, which at least in part could increase the number of threatened taxa.

In Spain, 25 taxa are considered extinct (Aedo *et al.* 2012); of these16 survive in the wild of other countries; 4 more are conserved *ex situ*; and 5 are known only from herbarium specimens: *Carduncellus matritensis, Kunkeliella psilotoclada, Normania nava, Pharbitis preauxii*, and *Tanacetum funkii* (Moreno 2008). Of this latter, only the original sheet collected on Sierra Nevada (Granada) is known, and thus can be considered the only Andalusian species extinct in the strict sense, although some authors have pointed out that doubts remain on whether it is an independent species or simply a deviant form of another species (Aedo *et al.* l.c.).

According to the Spanish Red List (Moreno 2008), Andalusia is the second territory with the greatest number of threatened taxa (227) after the Canary Islands, with 247 taxa. In particular, the Betic Sierras (especially the province of Granada) appear as a critical area for the conservation of flora (Moreno 2008). The five families with the greatest presence on the Spanish Red List are: Asteraceae (279 taxa), Plumbaginaceae (111), Lamiaceae (109), Fabaceae (108), and Brassicaceae (96). In terms of genera, these are *Limonium* (84 species and subspecies), *Sideritis* (36), *Centaurea* (31), *Argyranthemum* (27), and *Armeria* (27). In eastern Andalusia, the families with the most threatened taxa being (tab. 6): Asteraceae (72), Brassicaceae (37), and Fabaceae (35).

Distribution by altitude

By altitudinal distribution, the taxa follow a normal distribution (fig. 8): a maximum in the band at 700 to 800 m, harbouring 2.252 taxa; and minimums from 0 to -100 m with 4 taxa, restricted to the marine ambit, and from 3.300 to 3.400 m on land, 32 taxa.

The Mesomediterranean and Thermomediterranean thermotypes occupy 93.2% of the territory, followed by the Supramediterranean (5.7%), Oromediterranean (1%) and Cryoromediterranean (0,1%) (Table 7). However, although the proportion of taxa present in the thermotypes with the greatest surface area (Meso- and Thermomediterranean) is 87.1%, in the upper 3 thermotypes (with a surface area of only 6.8%), the proportion is 49.4%, indicating that the thermotypes with the smallest surface area nevertheless have a substantial number of taxa.

In comparison with the latitudinal gradient, the altitudinal one implies a sharp variation in environmental conditions over short distances (Odland 2009), characterized generally by a fall in temperatures and evapotranspiration, a rise in moisture and solar radiation, and a decline in competition (e.g. Barry 1992; Körner 1999; Löffler 2002).

The variation in species richness over an altitudinal gradient has two main models: a regular decline in richness with an ascent in altitude, and a normal distribution with the highest value of species richness near the middle of the gradient. The two options have been related to different environmental

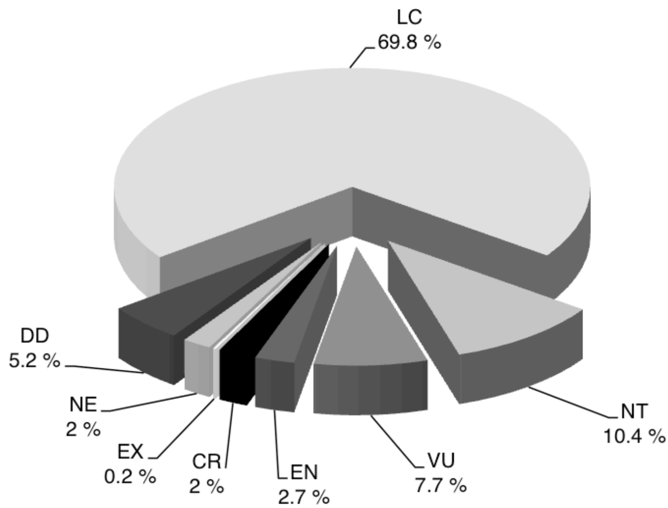

Figure 7. Percentages of taxa of the vascular flora of eastern Andalusia according to the categories of the IUCN (2001). NE: not evaluated; DD: deficient data; LC: least concern; NT: nearly threatened; VU: vulnerable; EN: endangered; CR: critically threatened; EX: extinct.

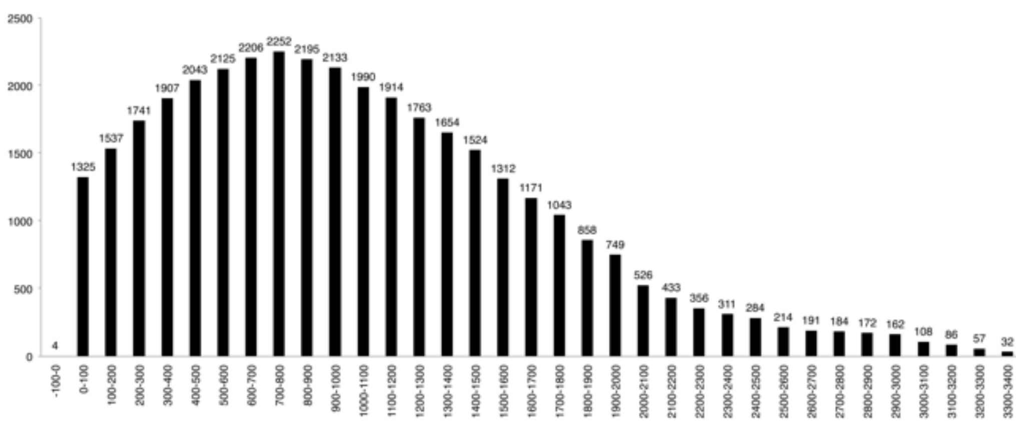

Figure 8. Number of taxa within the vascular flora of eastern Andalusia according to altitude (in bands of 100 m).

Thermotypes	G	T	Hyd	Hel	Hemi	C	Ph
Thermomediterranean	8.7	41.1	1.6	0.9	22.4	14.2	11.1
Mesomediterranean	9.9	34.9	1.2	0.9	28.6	14.2	10.3
Supramediterranean	9.1	28	0.8	0.5	36.6	17	8
Oromediterranean	8	16	0.5	0.7	48.8	20.3	5.6
Cryoromediterranean	7	8.1	1.6	0.6	63.2	18.4	1.1

Table 4. Distribution, by thermotypes, of the plant taxa (in %) according to life forms. G: geophytes; T: therophytes; Hyd: hydrophytes; Hel: helophytes; Hemi: hemicryptophytes; C: chamaephytes; Ph: phanerophytes

Unit	Nº Families	Nº Genera	Nº Taxa	End. unit	End. Eastern Andalusia
Aljibe	22	48	51	1	9
Almería	41	92	128	28	44
Alpujarras	19	26	27	8	59
Axarquía	11	16	16	1	20
Cazorla	36	96	126	27	88
Granada	9	12	13	1	17
Guadalquivir	13	20	24	0	3
Guadiana Menor	16	26	29	5	21
Mágina	9	12	13	4	49
Nevada-Filabres	45	111	181	72	110
Ronda	25	47	65	32	77
Sierra Morena	29	53	70	4	4
Trevenque-Almijara	23	35	47	30	100
Vélez-Baza	15	23	24	6	61

Table 5. Differential elements (exclusively present in a unit) in the environmental units established for the flora of eastern Andalusia. Nº of Families: number of families to which the differential elements belong; Nº Genera: number of genera to which the differential elements belong; Nº of Taxa: number of differential taxa (species and subspecies) of each unit; End. Unit: number of exclusive endemic taxa in each unit; End. Eastern Andalusia: number of endemic taxa of the vascular flora of eastern Andalusia present in each unit.

	VU	EN	CR	Threatened
Asteraceae	43	16	13	72
Brassicaceae	26	6	5	37
Fabaceae	18	7	10	35
Poaceae	14	5	1	20
Caryophyllaceae	13	4	2	19
Veronicaceae	13	2	4	19
Apiaceae	9	3	4	16
Lamiaceae	11	3	2	16
Plumbaginaceae	4	9	3	16
Ranunculaceae	8	3	2	13
Orobanchaceae	6	3	3	12
Rubiaceae	7	4	1	12
Geraniaceae	6	0	2	8
Cistaceae	5	1	1	7
Rosaceae	3	2	2	7
Saxifragaceae	5	1	1	7
Amaryllidaceae	4	2	0	6
Campanulaceae	4	2	0	6
Fumariaceae	4	2	0	6
Gentianaceae	4	1	1	6
Zannichelliaceae	6	0	0	6
Boraginaceae	3	1	1	5
Chenopodiaceae	2	0	3	5
Lentibulariaceae	5	0	0	5

Table 6. Families with more than 5 taxa in the threatened category. VU: Vulnerable; EN: Endangered; CR: Critically threatened; Threatened: sum of VU, EN, and CR.

Thermotypes	Altitude (m)	Area	Taxa	
		Surface (km^2) and (%)	Number and (%)	Taxa/km^2
Thermomediterranean	<600	19586.5 (46.4)	2411 (69.6)	0.12
Mesomediterranean	600–1400	19729.1 (46.8)	2866 (82.8)	0.14
Supramediterranean	1400–2000	2400.4 (5.7)	1735 (50.1)	0.72
Oromediterranean	2000–2800	438.5 (1)	583 (16.8)	1.32
Cryoromediterranean	>2800	42.5 (0.1)	180 (5.2)	4.23
Thermo and Mesomediterranean	0-1400	39315.6 (93.2)	3245 (87.1)	0.08
Supra, Oro and Cryoromediterranean	>1400	2881.4 (6.8)	1841 (49.4)	0.64

Table 7. Altitudinal range, surface area, and percentage of the total of eastern Andalusia, number of plant species, and percentage of the total of eastern Andalusia, and number of species per area for each thermotype.

variables (e.g. Rahbek 1995, 2005; Grytnes 2003). This can be explained taking into account that many species can adapt to living better under intermediate environmental conditions than under extreme ones (Grace 1999; Van der Meulen *et al.* 2001).

Eastern Andalusia has a very pronounced terrestrial altitudinal gradient (from 0 m a.s.l. on the coast to 3480 m a.s.l. on Sierra Nevada). The richness of species follows the normal distribution model, given that the maximum richness appears towards the middle of the gradient (700-800 m, fig. 8).

The floristic uniqueness, however, follows an inverse altitudinal pattern —that is, it increases with altitude. The endemic flora follows this same pattern, as reported by Giménez *et al.* (2004).

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