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Estimation of threatened orophytic flora and priority of its conservation in the Baetic range (S. Spain)

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Abstract

The Baetic range (SE Spain) constitutes an important centre of diversity and speciation in the Mediterranean Basin. However, numerous species are threatened by different human activities and by global climatic change. In this work, we provide data on the conservational state of orophilous plants of the Baetic range and propose priorities for their protection. For this, we analysed 82 threatened taxa and 17 mountain areas using correspondence analysis (CA) and complementarity analysis. Of the 2,197.5 km^2 of high-mountain areas analysed, only 1,654.5 km^2 are currently protected (75.3%). Of the 82 threatened species, 16 have no type of protection, eight are critically endangered and six are endangered (according to the categories of the UICN): Overgrazing and natural causes are the main factors threatening most of the species. The Sierra Nevada mountain (Granada and Almería provinces) and Cazorla-Segura mountain (Jaén province) provide protection for 67.5% of the total number of threatened orophilous species, and 71.7% of the species evaluated as critically endangered. We propose Gádor and Sagra mountains as new priority areas for the conservation of threatened orophilous flora.

Key words: *Complementarity analysis, conservation, correspondence analysis, hotspot, orophilous species, Spain, threatened flora*

Introduction

Numerous works indicate the importance of the Mediterranean region as a centre of plant biodiversity on a world scale (Mooney, 1990; Heywood, 1995; Médail & Quézel, 1997, 1999; Myers et al., 2000). Nevertheless, within the Mediterranean, the diversity is not uniformly distributed but rather has different hotspots. In this sense, the Baetic range constitutes an important reservoir of diversity and speciation (Gómez-Campo, 1987; Rivas-Martínez et al., 1991; Molero-Mesa, 1994; Domínguez et al., 1996). Recently, the endemic plants of the Baetic range and their phytogeographical relationships have been analysed (Rivas-Martínez et al., 1997; Mota et al., 2002). However, no work has focussed on threatened flora. A major part of this threatened flora is comprised of endemic species with a local distribution, but other components of great weight exist in the mountainous Baetic areas, such as boreo-alpine, submediterranean or the Baetic-North African species.

Recent works, both regional (Andalusia, S Spain; Blanca et al., 1999, 2000) as well as the national (VVAA, 2000; Bañares et al., 2003), point out the great importance of Mediterranean mountain zones for the conservation of flora.

On the other hand, many changes are occurring in mountainous regions worldwide and particularly in Mediterranean high-mountain areas. These mountains are especially sensitive to slight climatic changes (Hódar & Zamora, 2004) as well as to different types of impact on the vegetation, such as overgrazing, changes in mountain agriculture, or the increase in tourist pressure, these factors often acting synergetically.

In the present work, we provide data on threatened plants of the Baetic high-mountain areas, selecting priority zones for protection and conservation to answer the following questions. (i) What is the

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situation of threatened high-mountain flora of the Baetic area? (ii) What is the status of the plants in the network of Protected Natural Spaces of Spain and official protection lists? (iii) What weight do the different zones have in terms of their contribution to plant conservation?

Materials and methods

Study area

The Baetic range, located in the south-eastern Iberian Peninsula, covering some 45,000 Km^2, has particularly complex orography, with the highest peak on the peninsula (Mulhacén peak, 3,482 m a.s.l.). The predominant geology is calcareous, although there are islands of siliceous lithology. The climate is Mediterranean, with a wide range of precipitation, from 300 to 1,200 mm per year (Rivas-Martínez et al., 1997).

For this study, we selected the areas above 1,600 m a.s.l. (upper supramediterranean, oromediterranean, and cryomediterranean thermotypes; Rivas-Martínez et al., 2002; Valle et al., 2003). To calculate the total surface area of the protected zones, we used ArcGis 8.3, over a vectorial layer of protected natural spaces of Andalusia (REDIAM; Red de Información Ambiental de Andalucía).

Threatened flora

First, we selected the threatened orophilous species and compiled information about them (Blanca et al., 1999, 2000, Bañares et al., 2003). We selected a total of 82 threatened taxa for which the populations appeared at between 1,600 m a.s.l. (lowest altitude studied) and 3,482 m (the highest, Mulhacén peak), these being mainly narrow endemic species, but also a set of rare species with a broad distribution are included. The data for each species were completed or annotated with works on species and/or concrete areas (Lorite et al., 2003) together with field observations made in the period 1999–2004. For each species, we included data on the family, general distribution in the Baetic range considered in this work, habitat, altitudinal range, number of populations (subpopulations *sensu IUCN*, 2001), total number of reproductive individuals, category according to regional legislation (Anonymous, 2003), categories of threat assigned following the proposal of the IUCN (2001), with modifications for regional assessment (IUCN, 2003) and threat factors according to the WRI (1992), with modifications proposed by Blanca et al. (1998) (Appendix 1).

We also formulated a matrix with the presence/absence data of species per selected area (81 rows and 17 columns; data available from author J.L.). Multivariate data analyses were performed to explore the underlying structures in species and sample data, using Canoco for Windows v4® (ter Braak & Smilauer, 1998). Correspondence analysis was used as a basic ordination method (indirect gradient-analysis methods, focus scaling on inter-sample distance, biplot scaling, non-transformed data). These analyses gave an ordination diagram in which a species score was a weighted average of the sample scores. Therefore, the species' point in the correspondence analysis ordination diagram was at the centroid of the sample points where that species occurs. The samples containing the species were thus scattered around that species point in the diagram. The species and samples were separated in the diagrams for easier reading.

Selection of priority areas

The priority conservation areas were selected based on the total number of species threatened in each area, the number of threatened species that behave as strictly orophilous (these appearing only above 1,600 m), the total number of endemic species threatened in the Baetic range, and the number of threatened endemic species that behave as strictly orophilous.

Afterwards, the complementarity criterion was applied to these data to take into account how the addition of a new locality affected the total number of species collected (Vane-Wright et al., 1991; Colwell & Coddington, 1994).

Results

The 17 high-mountain areas assigned within the Baetic range occupied 2,197.5 km^2. Most of the zones were calcareous, except for one part of the Sierra Nevada and Filabres, which were siliceous. Of the 2,197.5 km^2, the protected spaces amounted to 1,654.5 km^2 (75.3%). Noteworthy zones included the mountains Mágina, Tejeda-Almijara, Las Nieves, and Grazalema, with 100% of their surface area protected, and Sierra Nevada with 95.2%. On the opposite extreme were Gádor and Sagra mountains, with a large surface area above 1,600 m a.s.l., but without any protection (Table I).

Threatened flora

In the Baetic high-mountain areas, we counted 82 threatened taxa, 44 of which were strictly orophiles and the rest facultative orophiles. The families with the greatest representation in threatened plants were *Compositae* (19 taxa), *Poaceae* (6), *Rosaceae* (5), *Caryophyllaceae* (5), and *Geraniaceae* (4). In terms of distribution range, the endemic taxa of the Baetic

Table I. Sites studied.

Lithology	Areas	Abbreviation	Maximum altitude (m a.s.l)	Surface area above 1,600 m a.s.l (ha)	Protected surface area above 1,600 m (ha)	% surface area protected
Calcareous	Grazalema	GR	1,665	11.0	11.0	100.0
	Nieves	NI	1,918	1,137.1	1,137.1	100.0
	Loja	LO	1,671	174.6	0.0	0.0
	Lújar	LU	1,824	750.9	0.0	0.0
	Gádor	GA	2,240	11,339.9	0.0	0.0
	Tejeda-Almijara	TEA	2,065	2,649.0	2,649.0	100.0
	Estancias	ES	1,722	92.5	0.0	0.0
	Calcareous Sierra Nevada	SNC	2,201	3,484.5	2,496.6	71.6
	Huétor-Harana	HUH	1,943	2,661.7	678.8	25.5
	Mágina	MA	2,167	3,604.1	3,604.1	100.0
	Cazorla-Segura	CA	2,107	44,587.1	35,833.2	80.4
	La Sagra	SA	2,383	1,813.7	0.0	0.0
	Subbéticas	SB	1,872	743.9	0.0	0.0
	María-Orce	MAO	2,045	3,316.8	2,370.7	71.5
	Baza	BA	2,270	12,929.4	12,611.5	97.5
Siliceous	Filabres	FI	2,168	31,686.7	9,985.6	31.5
	Siliceous Sierra Nevada	SNS	3,482	98,769.2	94,074.7	95.2
				219,752.1	**165,452.4**	**75.3**

range predominated (64); some were restricted to one or two mountain areas (54) while others had a wide distribution (7) but with few populations and individuals (see Table II).

The ecological preferences of the species studied were the calcareous rocky and scree areas (14 taxa), mesophilous woodlands and spiny shrublands (13), and hygrophilous high-mountain pasturelands (8). All these habitats together constituted a small portion of the study area. Also, dolomitic sandy areas were relatively important (7), given that this habitat is exclusive to the Baetic range.

The total number of threatened species clearly tended to decrease with respect to the extent of selected area, this tendency being less pronounced the higher the altitude. For the range of 2,600–2,800 m, the number of threatened species decreased, while for 2,800–3,000 m and 3,000–3,200 m the number increased, coinciding with the siliceous Sierra Nevada high mountain, where many endemic species live and unusual Arctic-Alpine disjunctions occur. With respect to populations, we can highlight the presence of 20 taxa from only one population in the Baetic range (*Alchemilla fontqueri, Arenaria nevadensis, Artemisia umbelliformis, Astragalus tremolsianus, Castrilanthemum debeauxii, Centaurea haenseleri* subsp. *epapposa, Delphinium fissum* subsp. *sordidum, Dryopteris thyrrena, Erodium astragaloides, Festuca clementei, Geranium cazorlense, Hippocrepis prostrata, Holcus caespitosus, Jurinea fontqueri, Moehringia fontqueri, Moehringia intricata* subsp. *tejedensis, Odontites granatensis, Papaver lapeyrousianum, Quercus alpestris, Solenanthus reverchonii*) and 11 with two subpopulations (*Arabis margaritae, Centaurea gadorensis, Euonymus latifolius, Galium pulvinatum, Hieracium texedense, Iberis carnosa* subsp. *embergeri, Leucanthemum arundanum, Salix hastata* subsp. *sierrae-nevadae, Senecio elodes, Seseli intricatum, Teucrium oxylepis subsp. oxylepis*). With regard to the number of individuals, three notable taxa had fewer than 50 individuals (*Alchemilla fontqueri, Dryopteris thyrrena, Salix hastata* subsp. *sierrae-nevadae*) and five taxa had some 50–250 individuals (*Atropa baetica, Centaurea haenseleri* subsp. *epapposa, Delphinium fissum* subsp. *sordidum, Euonymus latifolius, Solenanthus reverchonii*).

The factors most affecting the threatened orophilous flora were, in this order: natural causes (78) and overgrazing (75), followed distantly by fire (21), and recreational activities (20). The natural causes together with overgrazing affected a very high number of species (see Appendix 1).

It is noteworthy that there was only one extinct species; *Tanacetum funkii*, for which taxonomical doubts remained (Blanca et al., 2002a). With respect to the other categories, 21 taxa were critically endangered (CR), 26 endangered (E), and 32 vulnerable (VU). For one species, *Nepeta hispanica*, there was deficient data for evaluation (DD).

From a legal standpoint, though 62 of the 82 taxa are recognized under regional and national legislation (32 as endangered and 30 as vulnerable), 16 taxa have no protection at all. Of these, eight are critically endangered: *Alchemilla fontqueri, Arabis margaritae, Castrilanthemum debeauxii, Centaurea haenseleri subsp. epapposa, Dryopteris thyrrena, Hippocrepis prostrata, Teucrium oxylepis* subsp. *oxylepis* and *Veronica tenuifolia* subsp. *fontqueri*. Another six are endangered: *Armeria filicaulis* subsp. *trevenqueana, Bupleurum bourgaei, Galium pulvinatum, Koeleria dasyphylla,*

Table II. Relationship between general distribution and distribution in Baetic range, according to threatened categories for the 82 selected taxa.

	Baetic range*										
	Wide					Narrow					
	EX	CR	EN	VU	DD	EX	CR	EN	VU	DD	Total
General											
Wide	–	–	1	3	–	–	1	1	1	–	7
Western Mediterranean	–	–	1	–	–	–	1	–	–	–	2
High European mountains	–	–	–	–	–	–	–	1	–	–	1
S Europena mountains	–	–	–	–	–	–	–	1	1	–	2
Iberian and North African	–	–	1	–	–	–	–	2	–	–	3
Iberian endemism	–	–	–	–	–	–	–	1	–	–	1
S Iberian Peninsula	–	–	–	–	–	–	–	–	1	–	1
E and SE Iberian Peninsula la P. Ibérica	–	–	–	1	–	–	–	–	–	–	1
Endemic Baetic range	–	1	3	6	–	1	19	14	19	1	64
Total	0	1	6	10	0	1	21	20	22	1	82

*Distribution in Baetic range, narrow: inhabit in one or two selected sites, wide: inhabit in three or more selected sites.
Abbreviations: CR: critically endangered; DD: data deficient; EN: endangered; EX: extinct; VU: vulnerable.

Leucanthemum arundanum and Polycarpon polycarpoides subsp. *herniaroides.*

Selection of priority areas

The importance of each orophilous centre as a function of the number of threatened species (revealed by the complementarity analysis) is shown in Figure 1, where the analytical results are presented in three parts (total species, strictly orophilous species, and the most threatened species). The three aspects analysed show that the highest number of species come from the siliceous Sierra Nevada, and Cazorla-Segura mountains. In third place, there were variations, given that when the total number of species was considered, Tejeda-Almijara was the next in importance; nevertheless, when only the strictly orophilous species were considered, Mágina, calcareous Sierra Nevada, and Gádor proved to be the most important. For the most threatened species, Gádor appeared in third place, both for the sum of endangered and critically endangered taxa, as well as for only the critically endangered taxa.

Two fundamental centres for conservation were found: siliceous Sierra Nevada on the one hand, and Cazorla-Segura and Las Villas on the other. These were followed by a group of mountains presenting a relatively high number of threatened species: calcareous Sierra Nevada, Mágina, Tejeda-Almijara, and Gádor. Some of these are of particular interest, such as Tejeda-Almijara or Gádor, given that a good part of their elements are exclusive or strictly exclusive orophiles. The correspondence analysis made on the presence/absence matrix per orophilous centre showed three clearly defined groups (Figure 2), the most numerous group being comprised of a set of calcareous mountains that share many elements. The second group is made up of siliceous Sierra Nevada and Filabres, which share some species (i.e. practically all of the species of the latter are present in the former). Finally, a centre of great originality in terms of threatened flora is Gádor, with exclusive species such as *Astragalus tremolsianus, Seseli intricatum, Centaurea gadorensis, Polycarpon polycarpoides* subsp. *herniarioides,* and *Coronopus navasii.*

The number of threatened species was positively and significantly correlated with altitudes and areas above 1,600 m a.s.l. ($R^2 = 0.7366$; Spearman rank correlation $r = 0.680$, $p = 0.0024$), although many mountain areas had more threatened species than expected in relation to their surface area of the terrain (Grazalema, Las Nieves, Tejeda-Almijara, calcareous Sierra Nevada and Mágina).

Discussion

Considering the 841 taxa inhabiting the oro- and cryoromediterranean belt in Baetic range (Peñas et al., 2005), we conclude that 82 (9.8%) are under extinction risk, in comparison with 191 threatened taxa in southern Spain (Blanca et al., 1999, 2000) or 311 in the entire country (excluding the Balearic and Canary Islands) (Bañares et al., 2003), representing 42.9% and 26.4%, respectively. Having only 0.2% of the total surface area of the country, this hotspot constitutes an important site to optimize the conservation efforts (Médail & Quézel, 1997; Myers et al., 2000). The protection of Baetic high-mountain areas is relatively extensive, although there are zones such as Gádor or Sagra with large orophilous areas that would be advisable to protect. A considerable percentage of threatened taxa are endemic to the

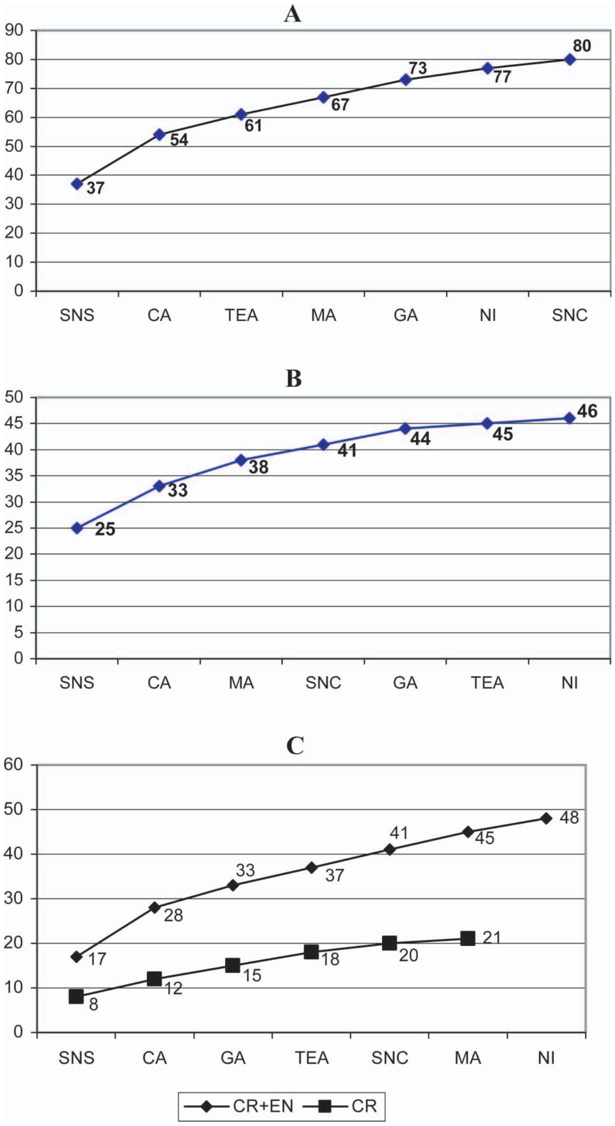

Figure 1. Results of the complementarity analyses, focusing on three aspects: A: total no of species in each centre; B: no of strictly orophilous species in each centre; C: sum of species critically endangered + endangered and only critically endangered. Abbreviations: BA: Sierra de Baza; CA: Sierra de Cazorla-Segura; ES: Sierra de las Estancias; FI: Sierra de Filabres; GA: Sierra de Gádor; GR: Sierra de Grazalema; HUH: Sierra de Huétor; LU: Sierra de Lújar; MA: Sierra de Mágina; MAO: Sierras de María y Orce; NI: Sierra de las Nieves; SA: Sierra de la Sagra; SNC: calcareous Sierra Nevada; SNS: siliceous Sierra Nevada; SU: Sierras Subbéticas Cordobesas; TEA: Sierras de Tejeda y Almijara.

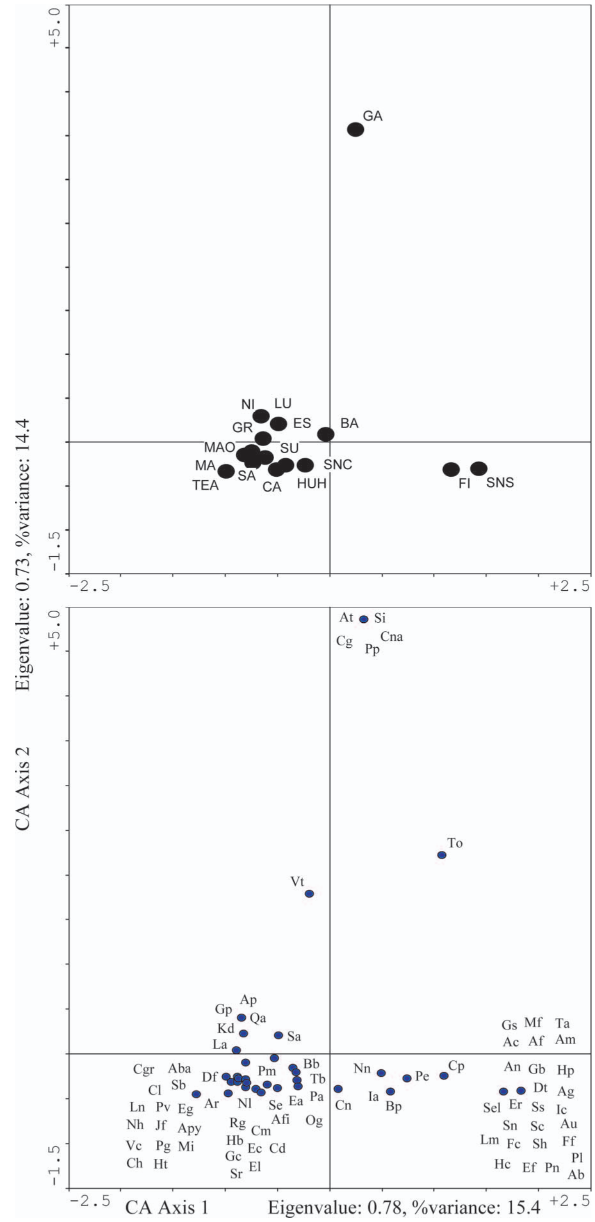

Figure 2. Correspondence analysis ordination biplot showing the position of the high-mountain areas in relation to the presence/absence of the threatened orophilous flora. Abbreviations as for Figure 1. Abbreviations of the species can be consulted in Appendix 1.

Baetic range and should be the first to be protected. In addition, these high-mountain areas are the only habitat for 44 taxa.

In terms of threat status, it is worth noting that only one species was assumed to be extinct, though the situation of many species is worrisome, given that 20 taxa have only one population and nine taxa have less than 250 individuals. In all, 21 taxa are critically endangered. Conservation priorities could be established with an appropriate combination of these three factors, which could receive more or less weight depending on the objectives. Among threat factors, natural causes (scarce available habitat, population fragmentation, etc.) have special weight. In these cases, the possibility of acting is very limited; nevertheless, measures could be taken against other factors, such as overgrazing, fires and recreational activities, which act synergetically. All these factors deserve special consideration in recovery plans. Also, legal protection has major deficiencies, particularly regarding endangered and critically endangered taxa. These require urgent attention in future reviews of the regional and national protection lists.

As priority areas, the siliceous Sierra Nevada and Cazorla-Segura are noteworthy in terms of conservation, given that not only for threatened species, but also for endemic ones these sites constitute the main centre of endemism in the Baetic mountains (Castro-Parga & Moreno-Saiz, 1996; Mota et al., 2002; Peñas et al., 2005). Effective protection in these zones would safeguard the survival of some 67.5% of the all the species, 71.5% of the species evaluated as endangered and critically endangered, and 57.1% of those designated as critically endangered. The protection of seven of the 17 massifs (siliceous Sierra Nevada, Cazorla-Segura, Tejeda-Almijara, Gádor, Mágina, calcareous Sierra Nevada, Tejeda-Almijara and Sierra de las Nieves) would cover 100% of the threatened orophilous flora. To achieve this goal, it is particularly important to protect Gádor, and thus it is of the utmost importance to include this massif in the Network of Protected Natural Areas of Andalusia (Red de Espacios Naturales Protegidos de Andalucía). Also, it would be helpful to include zones such as Sagra, although in this case most of its species are represented in Cazorla-Segura.

From the present work, we may conclude that the main conservation measures are: (i) to complete the regional network of protected areas, with the proposed sites; (ii) to include threatened vascular flora in revisions of the regional protected list; (iii) to prioritize target species and areas in order to implement recovery plans, as we propose in this paper; (iv) to undertake an intensive monitoring programme for population trends and conservation action; (v) to control of human pressure, particularly the overgrazing of mountain areas; and (vi) to perform studies related to the conservation biology of endangered species.

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Appendix 1. Data on threatened orophilous species of the Baetic range (from Blanca et al., 1999, 2000, 2002a,b; Bañares et al., 2003, Lorite et al., 2003).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Ap+	*Abies pinsapo* Boiss.	*Pinaceae*	Eastern Baetic range (GR, NI)	Shady slopes and stony ground	1,000–1,800	M-S	2,000,000	3	1,2,3	VU [B1ab(iv) + 2ab(iv)]	E
Ab*	*Aconitum burnatii* Gáyer	*Ranunculaceae*	S. European mountains (SNS)	Megaforbic high-mountain meadows	1,800–2,500	S-O	15,000–20,000	20	1,2,8,9	VU [D2]	V
Ac+*	*Agrostis canina* subsp. *granatensis* Romero García, Blanca & Morales	*Poaceae*	Sierra Nevada (SNS)	Hygrophilous high-mountain pasturelands	2,000–2,900	O	18,000–22,000	15	1,2,8,10	VU [B2ab(iii,v);D2]	V
Af+*	*Alchemilla fontqueri* Rothm.	*Rosaceae*	Sierra Nevada (SNS)	Hygrophilous high-mountain pasturelands	2,500–2,700	O	25	1	1,2	CR C2a(i, ii);D	–
Apy+*	*Aquilegia pyrenaica* subsp. *cazorlensis* (Heywood) Galiano & Rivas Mart.	*Ranunculaceae*	Sierra del Pozo (CA)	Wet, calcareous rocky	1,800–2,000	S-O	954	3	1,2	EN [B1ab(iii) + 2ab(iii)]	E
Am+*	*Arabis margaritae* Talavera	*Cruciferae*	Sierra Nevada (SNS)	Hygrophilous high-mountain pasturelands	2,200–2,500	O	5,000	2	1,2	CR [B1ab(iii,v) + 2ab(iii,v)]	–
An+*	*Arenaria nevadensis* Boiss. & Reut.	*Caryophyllaceae*	Sierra Nevada (SNS)	Sandy screes and edges of snowfields	2,950–3,300	C	2,500	1	1,2	CR [B1ac(iii,iv) + 2ac(iii,iv)]	E
Ar+	*Arenaria racemosa* Willk.	*Caryophyllaceae*	Sierras de Tejeda-Almijara (TEA)	Dolomitic sandy areas	900–1,600	M-S	?	?	1,3,5,11	VU [B2ab(ii,iii,v); D2]	V
Afi+*	*Armeria filicaulis* subsp. *trevenqueana* Nieto Feliner	*Plumbaginaceae*	Sierra Nevada (SNC)	Dolomitic sandy areas	1,700–1,850	S-O	15,500	3	1,2,10	EN [B1ab(iii) + 2ab(iii)]	–
Ag+*	*Artemisia granatensis* Boiss.	*Compositae*	Sierra Nevada (SNS)	Psychroxerophilous pasturelands	2,500–3,300	O-C	2,000	12	1,2,4	CR [A2ad;B1ab(iv,v)]	E
Au*	*Artemisia umbelliformis* Lam.	*Compositae*	Alps, Apeninnes and Sierra Nevada (SNS)	Rocky fissures and siliceous screes	2,800–3,000	C	500	1	1, 2, 4	EN [B1ab(iii,v) + 2ab(iii,v); C2a(ii)]	E
At+*	*Astragalus tremolsianus* Pau	*Leguminosae*	Sierra de Gádor (GA)	Pasturelands in dolines	2,100–2,250	O	16,000	1	1,2,7	CR [B1ab(iii) + 2ab(iii)]	V
Aba	*Atropa baetica* Willk.	*Solanaceae*	Iberian Peninsula, North Africa (CA, SA, MAO, BA, NI, GR)	Clearings of deciduous shrublands	900–1,800	M-S	117	8	1,2,3,5,11	EN [B2ab(i,iii,iv); C2a(i);D]	E

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Bp	*Betula pendula* subsp. *fontqueri* (Rothm.) G. Moreno & Peinado	*Betulaceae*	C and SE Iberian Peninsula, North Africa (CA, SNS)	Shady slopes with edaphic wetness	600 – 1,800	M-S	< 500	9	1,2,3,8	EN [B1ab(i,ii,iii,iv,v)]	E
Bb+	*Bupleurum bourgaei* Boiss. & Reut.	*Umbelliferae*	Eastern Baetic range (CA, BA)	Limestone montane cushion scrub	1,500 – 2,270	S-O	1,600	4	1,2,3,5	EN [B1ab(iii,v) + 2ab(iii,v)]	–
Cd+*	*Castrilanthemum debeauxii* (Degen, Hervier & E. Rev.) Vogt & Overprieler	*Compositae*	Sierra de Guillimona (CA)	Annual high-mountain pasturelands	1,700 – 1,800	S-O	494,400	1	1,2,5,10	CR [B1ab(iii)c(iv) + 2ab(iii)c(iv)]	–
Cg	*Centaurea debeauxii* subsp. *nevadensis* (Boiss. & Reut.) Dostál	*Compositae*	E and SE Iberian Peninsula (CA, HUH, SNC)	Hygrophilous meadows on calcareous substrates	900 – 2,100	M, S, O	< 7.000	5	1,2,7,8	VU [B2ab(iii,v); C2a(i);D2]	V
Ch+	*Centaurea gadorensis* Blanca	*Compositae*	Sierra de Gádor (GA)	Shrublands on calcareous substrates	1,300 – 1,900	M-S	15,000 – 25,000	2	1,2,3,5	VU [B2ab(iii,v);D2]	V
Cm+	*Centaurea haenseleri* subsp. *epapposa* G. López	*Compositae*	Sierra de Tejeda (TEA)	Shrublands on calcareous substrates	1,400 – 1,650	M-S	187	1	1,2,3	CR [B1ab(ii,iii) + 2ab(ii,iii); C2a(ii)]	–
Cn+	*Centaurea monticola* DC.	*Compositae*	Baetic range (SNC, MA, SU, HUH)	Shrublands on calcareous substrates	700 – 1,600	M-S	< 100,000	7	1,2,3,5,7, 10,11	VU [B2ab(iii,v);D2]	V
Cp+	*Centaurea pulvinata* (Blanca) Blanca	*Compositae*	Sierra Nevada, Baza, and Filabres (SNS, BA, FI)	Shrublands and thistle patches on siliceous substrates	1,300 – 1,900	M-S	10,000	4	2,3,5,11	VU [D2]	V
Cna+*	*Coronopus navasii* Pau	*Cruciferae*	Sierra de Gádor (GA)	Pasturelands in dolines	1,800 – 2,100	S-O	38,000 – 39,000	5	1,2,5,10	CR [B1b(iv,v)c(iv) + 2b(iv,v) c(iv)]	E
Cl	*Crataegus laciniata* Ucría	*Rosaceae*	Western Mediterranean (CA, MA, SA)	Deciduous thorny plants	1,000 – 1,900	M-S	12 (MA)	1	1,2,5,7	EN [A3cd;C2a(i)]	V
Cgr+*	*Crepis granatensis* (Willk.) Blanca & Cueto	*Compositae*	Sierras de Mágina and la Sagra (MA, SA)	Limestone screes	1,600 – 2,200	S-O	17,400 – 17,500	5	1,2,10	EN [B1ab(iii,v) + 2ab(iii,v)]	E
Df	*Delphinium fissum* subsp. *sordidum* (Cuatrec.) Amich, Rico & Sánchez	*Ranunculaceae*	Iberian endemism (MA)	Mesophilous and thorny woodlands	1,720 – 1,780	S	66	1	1,2,4,5	EN [B2ab(iii,iv) + 2ab(iii,v); C2a(ii)]	E

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Dt*	*Dryopteris thyrrena* Fraser-Jenk. & Reichst.	*Dryopteridaceae*	Western Mediterranean (SNS)	Fissures in shady schist rocks	2,350–2,550	O	44	1	1,4	CR [B1ab(v) + 2ab(v); C2a(i)]	–
Ef+*	*Erigeron frigidus* DC.	*Compositae*	Sierra Nevada (SNS)	Psychoxerophilous pasturelands and rock fissures	2,900–3,400	C	<25,000	3	1,2,10	VU [B2ab(ii,iii,iv,v); D2]	V
Ea+*	*Erodium astragaloides* Boiss. & Reut.	*Geraniaceae*	Sierra Nevada (SNC)	Dolomitic sandy areas	1,700–1,900	S-O	12,300	1	1,2	CR [B1ab(iii,v) + 2ab(iii,v)]	E
Ec+*	*Erodium cazorlanum* Heywood	*Geraniaceae*	Sierra de Cazorla s.l. (CA)	Low calcareous shrublands	1,600–1,800	S-O	7250	3	1,2	EN [B2ab(iii,v)]	E
Er+	*Erodium rupicola* Boiss	*Geraniaceae*	Sierra Nevada and Filabres (SNS, FI)	Fissures in schist rocks	1,500–2,200	S	<10,000	12	1,2	VU [B2ab(ii,iii,v); C2a(i);D2]	E
Eg+	*Eryngium grosii* Font Quer	*Umbelliferae*	Sierras de Tejeda-Almijara (TEA)	Dolomitic sandy areas	750–1,600	M-S	300	3	1,2,3,5,11	EN [B2ab(i,ii,iii,v)]	V
El	*Euonymus latifolius* (L.) Mill.	*Celastraceae*	Europe, Irano-Turanic region and North Africa (CA)	Riparian mountain forests	1,100–1,900	M, S, O	234	2	1,2,10	CR [B2ab(iii,iv); C2a(i)]	E
Fc+*	*Festuca clementei* Boiss.	*Poaceae*	Sierra Nevada (SNS)	Psychroxerophilous pasturelands	2,400–3,400	O-C	30,000–40,000	1	1,2,10,11	VU [B2ab(ii,iii,iv,v); D2]	V
Ff+*	*Festuca frigida* (Hackel) K. Richt.	*Poaceae*	Sierra Nevada (SNS)	Hygrophilous high-mountain pasturelands	2,200–3,200	O-C	70,000	15	1,2,9,10	VU [B2ab(iii,v);D2]	V
Gp+	*Galium pulvinatum* Boiss.	*Rubiaceae*	Western Baetic range (NI)	Fissures in calcareous-dolomitic rocks	700–1,700	M-S	3,688	2	1,2,11,3	EN [B1ab(iii,iv) + 2ab(iii,iv)]	–
Gb*	*Gentiana boryi* Boiss.	*Gentianaceae*	C-S de la Península Ibérica (SNS)	High-mountain hygrophilous pasturelands	2,300–3,200	O-C	45,000–80,000	16	1,2,9,10	VU [D2]	V
Gs+*	*Gentiana sierrae* Briq.	*Gentianaceae*	Sierra Nevada (SNS)	High-mountain hygrophilous pasturelands	1,800–3,200	S,O,C	150,00–200,000	25	1,2,9,10	VU [D2]	V
Gc+*	*Geranium cazorlense* Heywood	*Geraniaceae*	Sierra del Pozo (CA)	Screes and fissures in calcareous rock	1,800–2,000	O	729	1	1,2,10	CR [B1ab(iii,v) + 2ab(iii,v)]	E
Ht+	*Hieracium texedense* Pau	*Compositae*	Sierra de Tejeda (TEA)	Calcareous-dolomitic rock fissures	1,500–1,800	S-O	442	2	1,2,4,10	CR [B1ab(iii,v) + 2ab(iii,v)]	E
Hp+*	*Hippocrepis prostrata* Boiss.	*Leguminosae*	Sierra Nevada (SNS)	Shrublands over schists	1,800–2,100	S-O	2,265	1	1,2	CR [B1ab(iii) + 2ab(iii)]	–

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Hc+*	*Holcus caespitosus* Boiss.	*Poaceae*	Sierra Nevada (SNS)	Screes and psychroxerophilous pasturelands	2,300–3,400	O-C	>150000	1	1,2,10,11	VU [D2]	V
Hb+	*Hormathophylla baetica* P. Küpfer	*Cruciferae*	Sierra de Cazorla s.l. (CA)	Fissures in calcareous-dolomitic rocks	1,500–1,900	S-O	?	?	1,2	VU [C2a(i);D2]	V
Ic+*	*Iberis carnosa* subsp. *embergeri* (Serve) Moreno	*Cruciferae*	Sierra Nevada (SNS)	Screes and psychroxerophilous pasturelands	2,900–3,200	C	12,000–15,000	2	1,2,10	VU [B1ab(iii,v) + 2ab(iii,v)]	V
Ia	*Ilex aquifolium* L.	*Aquifoliaceae*	Europe, Asia and North Africa (CA, SNS)	Mesophilous and thorny woodlands	1,000–1,800	M-S	?	?	1,2,4	VU [B1ab(i) + 2ab(i)]	V
Jf+*	*Jurinea fontqueri* Cuatrec.	*Compositae*	Sierra Mágina (MA)	Calcareous screes	1,650–1,850	S-O	2,231	1	1,2	CR [A3c;B1ab(iii,v) + 2ab(iii,v)]	E
Kd+	*Koeleria dasyphylla* Willk.	*Poaceae*	Baetic range (GR, NI)	Shrublands over calcareous substrate	1,100–1,800	S	23,000–24,000	4	1,2,3	EN [B1ab(i, ii, iii,iv,v) + 2ab (i, ii, iii,iv,v)]	–
Lm+*	*Leontodon microcephalus* Boiss. ex DC.) Boiss.	*Compositae*	Sierra Nevada (SNS)	High-mountain hygrophilous pasturelands	2,400–3,000	O-C	480,000–640,000	20	1,2,10	VU [B2ab(iii,v);D2]	V
La+*	*Leucanthemum arundanum* (Boiss.) Cuatrec.	*Compositae*	Sierras de Mágina and Nieves (NI, MA)	Gravelly areas and fissures in calcareous rock	1,690–1,830	S	1,363	2	1,2	EN [B2ab(ii,iii,iv) c(iv);C2b]	–
Ln+	*Lithodora nitida* (Ern) R. Fern.	*Boraginaceae*	Subbaetic range, Mágina and Tejeda (SU, MA, TEA)	Dolomitic sandy areas	900–1,900	M-S	612	4	1,2,3,5	EN [B1ab(i, ii, iii,iv,v) + 2ab (i, ii, iii,iv,v)]	E
Mf+*	*Moehringia fontqueri* Pau	*Caryophyllaceae*	Sierra Nevada (SNS)	Fissures in shady schist rock	1,850–2,450	S-O	115,000	1	1,2,3,11	EN [B1ac(iv) + 2ac(iv)]	E
Mi+*	*Moehringia intricata* subsp. *tejedensis* (Willk.) J. M. Monts.	*Caryophyllaceae*	Sierra Tejeda (TEA)	Fissures in calcareous-dolomitic rock	1,750–1,850	S	723	1	1,2,3,4	CR [B1ab(iii) + 2ab(iii)]	E
Nl+	*Narcissus longispathus* Pugsley	*Amaryllidaceae*	Baetic range (CA, MA, SU)	Calcareous wet meadows	1,100–1,700	M-S	23,000–24,000	5	1,2,4,8	EN [B1b(iii,v)c(iv) +2b(iii,v)c(iv)]	E
Nn+	*Narcissus nevadensis* subsp. *nevadensis* Pugsley	*Amaryllidaceae*	Sierra Nevada, Baza and Filabres (SNS, BA, FI)	Wet meadows	1,300–2,500	M, S, O	24,000–25,000	9	1,2,4,8,11	EN [B1b(iii)c(iv) + 2b(iii)c(iv)]	E
Nh+	*Nepeta hispanica* subsp. *hispanica* Boiss. & Reut.	*Labiatae*	Sierras Cazorla and María (CA, MAO)	–	–	–	–	–	–	DD	–

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Og+*	*Odontites granatensis* Boiss.	*Scrophulariaceae*	Sierra Nevada (SNS)	Juniper-genista patches over calcareous substrate	2,000–2,250	O	104,000	1	1,2,4,11	CR [A2abde;B1ab(iii,v) + 2ab(iii,v)]	E
Pl+*	*Papaver lapeyrousianum* Guterm	*Papaveraceae*	Pyrennes and Sierra Nevada (SNS)	Psychroxerophilous pasturelands	3,200–3,450	C	< 2,500	1	1,2,4,10	EN [B1ab(ii,iii,v) + 2ab(ii,iii,v)]	E
Pn+*	*Pinguicula nevadensis* (H. Lindb.) Casper	*Lentibulariaceae*	Sierra Nevada (SNS)	High-mountain hygrophilous pasturelands	1,900–3,200	O-C	50,000–1,00,000	25	1,2,10	VU [B2ab(iii,v);D2]	V
Pv+	*Pinguicula vallisneriifolia* Webb	*Lentibulariaceae*	Baetic range (CA. TEA)	Wet calcareous walls	600–1,700	M-S	?	?	1	VU [D2]	V
Pp	*Polycarpon polycarpoides* subsp. *herniarioides* (Ball) Maire & Weiller	*Caryophyllaceae*	Sierra de Gádor and north-western Africa (GA)	Fissures in calcareous-dolomitic rock	1,400–2,150	S,O	1,289	5	1,2	EN [B1ac(iii,iv) + 2ac(iii,iv)]	–
Pe+*	*Primula elatior* subsp. *lofthousei* (H. Harrison) W. W. Sm. Fletcher	*Primulaceae*	Sierra Nevada, Baza and Filabres (SNS, BA, FI)	Wet meadows	1,700–2,900	S-O	30,000–40,000	30	1,2	VU [D2]	V
Pa	*Prunus avium* L.	*Rosaceae*	Europe, Asia and North Africa (SNS, CA, SNC, MA, HUH, GR, SU)	Mixed deciduous forests	1,100–2,000	M-S	1,000	?	1,2,5	VU [D1 + 2]	V
Pm	*Prunus mahaleb* L.	*Rosaceae*	C-S de Europa, O de Asia y NO Africa (CA, SNC, NI, BA, GR)	Deciduous thorny shrublands	1,100–1,700	M-S	1,000	2	1,2,5	VU [D1 + 2]	V
Pg+	*Pseudoscabiosa grosii* (Font Quer) Devesa	*Dipsacaceae*	Sierras de Tejeda-Almijara (TEA)	Fissures in calcareous-dolomitic rock	600–1,600	M-S	3,000	?	1,2,3	VU [B2ab(ii,iv,v); C2a(i);D2]	V
Qa+*	*Quercus alpestris* Boiss.	*Fagaceae*	Sierra de las Nieves (NI)	Mesophilous and thorny woodlands	1,600–1,800	S	3,145	1	1,2,3	EN [B1ab(iii) + 2ab(iii)]	E
Rg+	*Rothmaleria granatensis* Boiss. Ex DC.) Font Quer	*Compositae*	Baetic range (TEA, SNC, HUH)	Dolomitic sandy areas	1,100–1,800	M-S	30,000–100,000	14	1,2,11	VU [D2]	E
Sc*	*Salix caprea* L.	*Salicaceae*	Europe and Asia (SNS)	Mixed deciduous forests	1,700–2,100	S-O	< 1,000	5	1,2	EN [B2ab(iii,iv,v); C2a(i)]	E

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Sh+*	*Salix hastata* subsp. *serrae-nevadae* Rech. Fil.	*Salicaceae*	Sierra Nevada (SNS)	Edges of mountain stream borders	2,300–2,600	O	40	2	1,2	CR [B1ab(iii) + 2ab(iii); C2a(i);D]	E
Se+*	*Santolina elegans* Boiss. ex DC.	*Compositae*	Baetic range (SNC, HUH, CA)	Dolomitic sandy areas	1,700–2,000	S-O	?	?	1,2,11	VU [D2]	V
Sb+	*Sarcocapnos baetica* subsp. *intergrifolia* (Boiss.) Nyman	*Papaveraceae*	Baetic range (MA, CA, SA)	Calcareous rocky areas and shady drop-offs	600–2,000	M,S,O	> 5,500	6	1	VU [B1ab(iii,v) + 2ab(iii,v)]	V
Ss+	*Sarcocapnos speciosa* Boiss.	*Papaveraceae*	Sierra Nevada (SNS)	Siliceous rocky areas and drop-offs	1,500–2,000	M-S	< 5,000	10	1	VU [D2]	E
Sel+*	*Senecio elodes* Boiss.	*Compositae*	Siliceous Sierra Nevada (SNS)	Siliceous wet meadows	2,000–2,500	O	1,224	2	1,2	EN [B1ab(iii,v) + 2ab(iii,v)]	E
Sn+*	*Senecio nevadensis* Boiss. & Reut.	*Compositae*	Siliceous Sierra Nevada (SNS)	Siliceous screes	2,600–3,300	O-C	10,000–15,000	3	1	VU [B2ab(ii,iii,v);D2]	V
Si+	*Seseli intricatum* Boiss.	*Umbelliferae*	Sierra de Gádor (GA)	Mesophilous and Holm oak woodlands	1,500–2,200	S-O	2,000	2	1,2,3,5,11	EN [B1ab(iii) + 2ab(iii)]	E
Sr+*	*Solenanthus reverchonii* Degen	*Boraginaceae*	Sierra de la Cabrilla (CA)	Cushion scrubs over calcareous substrate	1,700–1,800	S	62	1	1,2	CR [B1ab(iii,v) c(iv) + 2ab(iii,v) c(iv); Ca(i,ii) b;D]	E
Sa	*Sorbus aria* L.	*Rosaceae*	Europe, Asia and North Africa (CA, SA, NAO, MA, SU, FI, BA, ES, HUH, SNC, SNS, GA, LU, TEA, NI, GR)	Mixed deciduous forests	1,100–2,000	M,S,O	?	?	1,2,3,5,11	VU [D2]	V
Tf+	*Tanacetum funkii* Sch. Bip. *ex* Willk.	*Compositae*	Calcareous Sierra Nevada (SNC)	Annual high-mountain pasturelands	–	S	–	–	1,2,7,11	EX	–
Tb	*Taxus baccata* L.	*Taxaceae*	Europe, Asia and North Africa (CA, MA, BA, SNC, SNS, TEA, NI)	Mesophilous and thorny woodlands	1,300–2,000	M-S-O	?	?	1,2,3,5	EN [C2a(i)]	E
To+*	*Teucrium oxylepis* subsp. *oxylepis* Font Quer	*Labiatae*	Western Sierra Nevada and Gádor (SNS, GA)	Shrublands over schist substrates	1,700–1,850	S	657	2	1,2,3,4	CR [B1ab(i,ii,iv,v) + 2ab(i,ii,iv,v)]	–
Ta+*	*Trisetum antonii-josephii* Font Quer & Muñoz Medina	*Poaceae*	Siliceous Sierra Nevada (SNS)	Screes and fissures in siliceous rocks	2,900–3,150	O-C	9100	3	1,2,10	EN [B1ab(iii) + 2ab(iii)]	E

(*continued*)

Appendix 1. (*Continued*).

Abbreviation	Taxon	Family	Distribution[a]	Habitat	Altitudinal range	Therm.[b]	No individuals in study region	No populations	Threat[c]	IUCN[d]	Legal status[e]
Vt+*	*Veronica tenuifolia* subsp. *fontquerii* (Pau) M.M. Mart. Ort. & E. Rico	*Scrophulariaceae*	Baetic range (NI, BA, GA)	Cushion scrub over calcareous substrates	1,680 – 2,000	S-O	4770	3	1,2,5,11	CR [B2bc(iv)]	–
Vc+	*Viola cazorlensis* Gand.	*Violaceae*	Baetic range (CA, MA)	Fissures in calcareous-dolomitic rocks	700 – 1,900	M, S, O	?	?	1,2	VU [B1ab(i,ii,iii,iv,v) + 2ab(i,ii,iii, iv,v)]	E

Notes: +: taxa exclusive to the Baetic range; *: Strictly orophilous taxa (all their populations in areas > 1,600 m. a.s.l.). [a]General distribution of the species, in parenthesis the distribution in the Baetic range (see abbreviations in Table I). [b]Thermotypes in which the species appears (according to Rivas Martínez et al., 2002); C: cryoromediterranean; O: oromediterranean; S: supramediterranean; M: mesomediterranean. [c]Threats against the species (1: natural causes; 2: overgrazing; 3: fire; 4: collection; 5: deforestation and inappropriate forestry practices; 6: introduction of exotic species and foreign genetic material; 7: changes in agriculture and agricultural practices; 8: drying of wetlands and water pollution; 9: pollution; 10: recreational activities; 11: infrastructure, construction, quarries, gravel beds). [d]Category of threat and criteria (according to the UICN, 2001, 2003). [e]Legal status (Anonymous, 2003); V: vulnerable; E: in danger. ?: data unavailable.