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Network of Protected Natural Areas and Endangered Flora in Andalusia (Spain)

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Abstract
Andalusia has one of the highest levels of diversity in Europe in terms of biology, geology and landscape. Its natural heritage is not only extremely diverse but also well preserved. Only the vascular flora of Andalusia consists over 4,000 species, many of which are endemic. Nowadays many of these plants are endangered and therefore registered under one or other of the endangered levels in Red Lists and Red Books.
The aim of this research is to make a qualitative analysis of the main ecological characteristics of the endangered flora in Andalusia contained in Red Lists, Red Books and specific legislation for the Andalusian territory. The most significant results of this study indicate that over a third of the Andalusian flora is endangered or has been previously considered as such. A high percentage of these species are endemic plants. RENPA (the Spanish acronym for Network of Protected Natural Areas of Andalusia) plays a fundamental role in the management of the endangered flora in Andalusia since only 6% of the endangered flora is not included in the network. The highest concentration of endangered taxa occurs in the thermomediterranean and mesomediterranean bioclimatic belts. However, there is still some discrepancy between the percentage (of species) within the whole of the flora representing concrete families and biotopes and the percentage of those species in the category of endangered.

Key words: conservation, endemism, flora, Red List, RENPA.

Introduction

In the last few decades biodiversity has reached crisis level as a result of habitat fragmentation, the disappearance of large areas of natural vegetation, the introduction of exotic invading species and the growing increase in environmental pollution (Leakey & Lewin, 1996). Studies of fossil records reveal that the average duration of a species was about one million years (May *et al*., 1995) in pre-human times. Nowadays, human impact has increased species' extinction rate at least a thousand times (Pimm *et al*., 1995). This context has prompted the development of a large number of scientific disciplines whose aim is to help to understand and evaluate the "mechanisms" governing biological diversity patterns. Conservation Biogeography (Lodle & Whittaker, 2011) is one of these disciplines. Not only is Conservation Biogeography a key tool in understanding how biodiversity is spatially distributed, but it can also provide more efficient conservation measures (Grehan, 1993; Whittaker *et al*., 2005). Floristic richness is an asset that must be protected and preserved for future generations and endangered species must be a priority. The protection of plants not only enhances plant conservation, but also the conservation of animals, communities, ecosystems, biological interactions and ecological processes (Mota *et al*., 2003).

The Mediterranean basin is regarded as one of the 25 world biodiversity hotspots (Médail & Quézel, 1997; Myers *et al*., 2000). The Mediterranean climate exhibits the highest number of bioclimatic subtypes in the world (Rivas-Martínez *et al*., 1997). The Mediterranean area has two main spots of biodiversity: the western Mediterranean (Iberian Peninsula, Morocco, Algeria and Tunisia) and the eastern Mediterranean (Turkey and Greece).

The Spanish flora is comprised of 7,071 species (Aedo *et al*., 2013). Of the total Spanish flora, 60% of the species occur in Andalusia which represents 15% of the area of the Iberian Peninsula. In Andalusia, the Betic Ranges exhibit one the highest biodiversity levels in the Mediterranean region. Together with the mountains in North Africa and Corsica, the Betic ranges represent one of the three main hotspots of diversity in the Mediterranean basin (Sainz-Ollero & Hernández-Bermejo, 1985; Quézel & Médail, 1995; Domínguez *et al*., 1996; Médail & Quézel, 1999) and the Betic ranges have been recognized as one of the most important centres of plant diversity in the world (Blanca, 1993; Mota *et al*., 2002-a).

The floristic richness of Andalusia is estimated at about 4,300 taxa, species and subspecies (Valdés *et al*., 1987; Blanca *et al*., 2009). The Andalusian flora is not only rich but also rare. Over 500 species, about 12.5% of the total, are endemic plants exclusive to Andalusia. This group of endemic plants is accompanied by taxa of paleobiogeographical interest, the so-called "time refugees", on high peaks (boreo-alpine elements), de-

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sert zones (Iberian-Mauritanian species), saline steppes (Irano-Turanian elements), etc. (Mota *et al*. 2003). There is no doubt that Andalusia exhibits an extremely rich, varied and unique flora (Valdés, 1993, 1994). The large variety of bioclimatic, edaphic, geological and orographical conditions present in the Andalusian territory accounts for this enormous plant diversity. In addition, Andalusian plant richness has been conditioned by Pleistocene glaciations (Blanca, 1993) and by the geographical situation of the territory. Andalusia is a true north-south (Europe and Africa) and east-west (Atlantic and Mediterranean) crossroads which has led to the meeting of various floristic elements (Mota *et al*., 2002-b; Peñas *et al*., 2005). On the other hand, the ecosystems of the Mediterranean basin have undergone intense anthropic pressure for thousands of years to the extent that many authors consider human action as an environmental agent in its own right (Barbero *et al*., 1990; Galdenzi *et al*., 2012). Indeed, Mediterranean ecosystems show very clearly their adaptation to man's presence (Blanca, 1993).

Andalusia has the largest Network of Protected Natural Areas (RENPA, henceforth) in mainland Spain. RENPA is made up of 242 areas which comprise a total of about 2.8 million ha which is 30.5% of the area of Andalusia (Fig. 1).

The flora of this region can represent a clear link to vegetation and environment conservation of the natural areas. Some floristic-vegetational indexes have already been used to assess the environmental quality of a semi-natural area (Giupponi *et al*., 2013). This work is a preliminary investigation about main ecological characteristics of the endangered flora in Andalusia.

Materials and Methods

This research aims at collecting basic and relevant information on all the vascular plant species in Andalusia which appear in Red Lists (or Red Books) or in protection acts. The following information was collected for each of these taxa: inclusion (or not) in a RENPA area, distribution in the biogeographical units under consideration, biotype, altitudinal range and family. This information is useful not only for the study, monitoring and experimental handling of the flora, but also for the development of initiatives aimed at the conservation of the species. In other words, the aim of this research is to catalogue the features of the endangered vascular flora most sensitive to the action of real or potential threat.

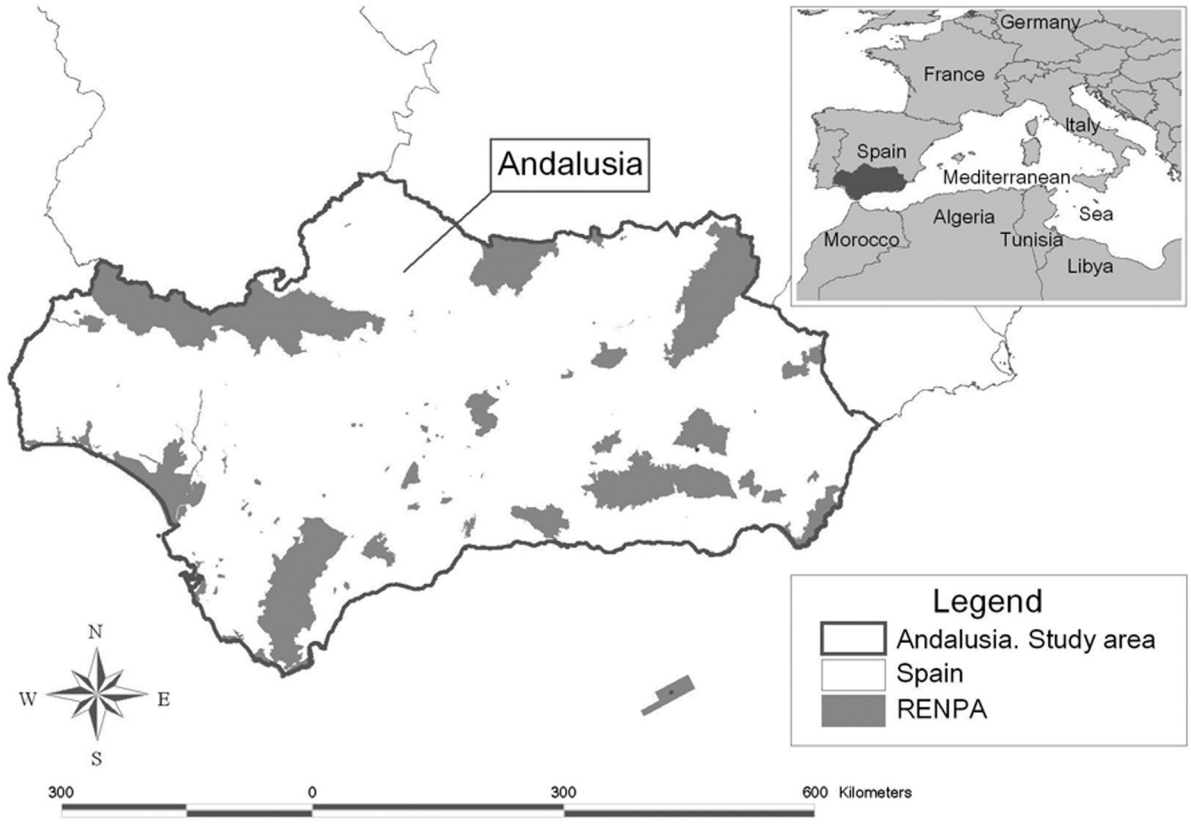

Fig. 1 - Distribution of Protected Natural Areas (RENPA) in Andalusia.

Floristic catalogue

We have set up a data base with the vascular flora species included in Red Lists, Red Books or Catalogues mentioned in Laws, Decretos and Reales Decretos, Directives and Biodiversity Protection Conventions at all levels, either regional, national or international. For this purpose we have reviewed all the technical literature, from the publication of the list by Barreno *et al*. in 1984, to the most recent Andalusian catalogue which is the one included in the Decreto 23/2012. Basically, the technical literature with data on endangered flora in Andalusia is the following:

1. **International**: Laws (Anon., 1973; Anon., 1986; Anon., 1992-a).
2. **National**: Laws (Anon., 1989; Anon., 1990), and Red Lists (VV. AA. 2000; Moreno, 2008; VV. AA. 2010).
3. **Regional**: Laws (Anon., 1992-b; Anon., 1994; Anon., 2003; Anon., 2012), and Red Lists and Red Books (Hernández Bermejo *et al*., 1994; Blanca *et al*., 1999, 2000; Cabezudo *et al*., 2005-b).

Data sources

For the collection of citations of taxa we also consulted scientific literature, such as and revisions on particular families and genera. We reviewed offprints and more specific works (The botanical literature reviewed is detailed in the annex and the flora database can be downloaded at the link: www.scienzadellavegetazione.it/sisv/documenti/Articolo/pdf/331.pdf). The data bases available on the Internet were also consulted, for example, Anthos. Spanish plants information system (Anthos 2.3., 2012), Global Biodiversity Information Facility (Gbif.es, 2013) and SIVIM (Font *et al*., 2012). The research also involved visits to the herbaria of Granada (GDA-GDAC), Almería (HUAL), Jaén (JAEN), Málaga (MGC) and Murcia (MUB), where numerous specimens were examined. In addition, our research incorporates data generated from field samples and plant collecting and recording campaigns conducted by the investigation team RNM-344 from 2005 to 2012. The material collected is stored in the HUAL herbarium (Mota *et al*., 2005; Pérez-García *et al*., 2005; Martínez-Hernández *et al*., 2009; Mota *et al*., 2010; 2011; Pérez-García *et al*., 2011). These campaigns allowed us to validate the information found in the bibliography and to check doubtful cases.

All the data collected, particularly those obtained from the data bases on the Internet, were carefully checked to detect and remove spurious information.

Variables under study

For each taxon mentioned in this study we collected the following information:

RENPA

Using a GIS (ESRI, 2011) we have determined whether all plant populations concerned are included in protected areas (RENPA, 2013), whether none of them are, or whether in some cases there are populations both inside and outside RENPA areas. In other words, if the whole extent of the population is entirely contained in a protected area this species has been qualified as 'included'. On the contrary, we have considered the plant species that have all their populations outside protected area. The number of populations of species that are both inside and outside of protected area has also been studied.

CHOROLOGY

We distinguished four categories according to the information about geographical distribution of the plants species (Castroviejo, 1986-2010; Blanca *et al*., 2009; Valdés *et al*., 1987). Species exclusive to the Andalusian territory were ranked as "endemic". "Iberian-North African" plants are those occurring in the Iberian Peninsula and North Africa. Quasi-exclusive plants (i.e., those present in the Andalusian territory and in areas of the Iberian Peninsula adjacent to Andalucía) were ranked as "subendemic". Finally, species with broad distribution were ranked as "non endemic".

BIOTYPES

Following the life forms classification suggested by Raunkiaer and the definitions of P. Font Quer (1982), we distinguished these six biotypes: Phanerophyte, Chamaephyte, Hemicryptophyte, Geophyte, Hydrophyte and Therophyte.

ALTITUDINAL DISTRIBUTION

We indicate the bioclimatic belt (or belts) where each taxon occurs (Rivas-Martínez, 1996-2009), from thermomediterranean to cryoromediterranean (Rivas-Martínez *et al*., 2002). The analysis of the altitudinal distribution of endangered taxa is made at intervals of 100 m altitude.

FAMILY

We also indicate the family of each taxon, according to Flora de Andalucía Oriental (Blanca *et al*., 2009; 2011) and Flora iberica (Castroviejo, 1986-2010).

Results

The data base set up for the investigation included a total of 1,399 taxa. This number represents about 35% of the Andalusian flora. Below we present the results obtained in relation to the variables under consideration. The results are shown in charts for better comparison.

RENPA

Data analyses revealed that 1,313 endangered taxa (about 94% of the total) had at least one population within protected areas. We found 1,019 species (about 73%) with some populations outside RENPA areas. A total of 380 endangered flora species have all their populations inside protected areas, whereas 86 plant species have all of them outside RENPA areas. A total of 933 species have populations both inside and outside RENPA areas (Fig. 2).

CHOROLOGY

Figure 3 shows the results of the analysis of endangered vascular flora according to chorology. Endemic species had a total of 518 endangered taxa. Iberian-North African species had 191. A total of 274 taxa were described as subendemic. Finally, 416 species were widely distributed non endemic plants mentioned in the flora protection lists.

BIOTYPES

The analysis of endangered species classified by biotypes (Fig. 4) revealed that 40% were Hemicryptophytes, whereas Geophytes, Phanerophytes and Hydrophytes show an abundance percentage below 10% in the lists.

The analysis of each biotype in relation to its total number of taxa revealed that 59.19% of the endangered plants were Chamaephytes, 41.54% were Hemicryptophytes and 43.18%, Hydrophytes. The Geophyte, Phanerophyte and Therophyte biotypes showed percentages below 30%.

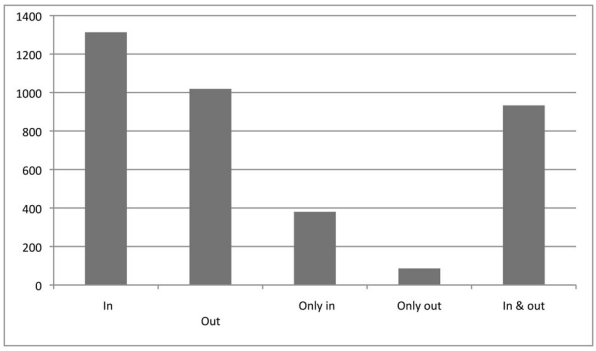

Fig. 2. Abundance of endangered flora in Andalusia according to the distribution inside/outside protected areas of RENPA.

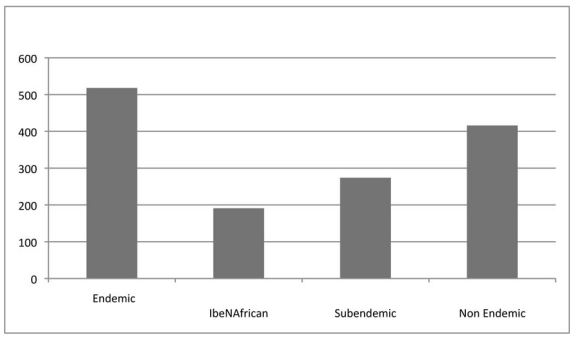

Fig. 3. Classification of endangered flora in Andalusia in the protection lists under study according to chorology.

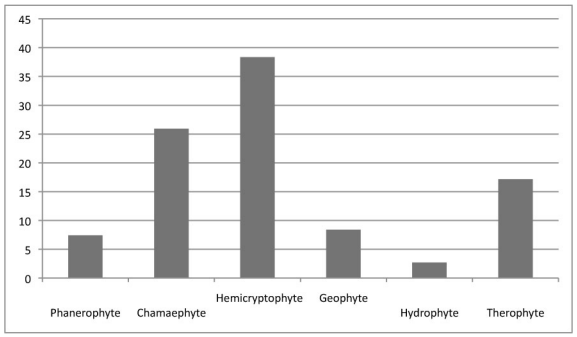

Fig. 4. Percentage abundance of biotypes of endangered vascular flora in the Andalusian protection lists under study.

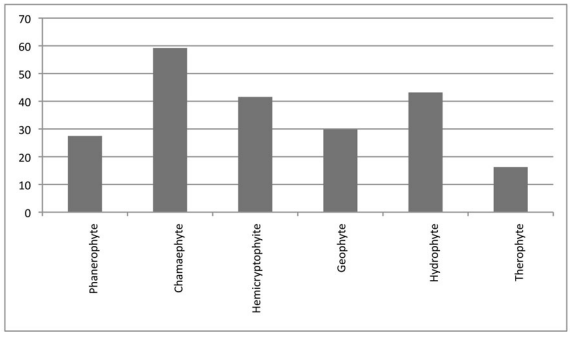

Fig. 5. Proportion of endangered biotypes in Andalusia (compared to the total number of taxa in each biotype).

ALTITUDE

The study of the altitudinal distribution of the endangered taxa revealed that the highest number of them occur in the altitudinal range between 500 and 1,500 m asl. This interval corresponds to the thermomediterranean and mesomediterranean bioclimatic belts (Fig. 5). An abrupt decrease in the number of endangered species was recorded in the interval 150-250 m asl. Above 300 m asl, the number of endangered species increases progressively, reaching its maximum value at 900 m asl. The endangered species curve began to descend until it became stable between 2,500 and 3,100 m asl. Finally, the number of endangered taxa decreased with a slope similar to that of the previous intervals.

FAMILY

The study of the endangered taxa grouped by family revealed that a total of 109 taxonomic families had representation in the protection lists of endangered flora. That means that 66% of the families that make up the vascular flora in Andalusia are represented. The families with the highest numbers of endangered taxa were *Composite* (186 species), *Leguminosae* (121), *Labia-*

tae (110), *Cruciferae* (98), *Scrophulariaceae* (98), *Caryophyllaceae* (79) and *Gramineae* (70). The rest of the species belong to families with less than 5 species and are not shown in Figures 7 and 8.

Clear unbalances between percentages of endangered flora by family and total abundance of each family were found. *Composite*, with 34.31% endangered species, and *Leguminosae* with 26.94% were not the groups with the highest values. *Lamiaceae, Cruciferae* and *Scrophulariaceae* families obtained intermediate values (ca. 50% of species). Some families stood out such as *Plumbaginaceae* (with 81.35% of its species considered endangered), *Saxifragaceae* (with 84%) and *Amaryllidaceae* (with 68.96%).

Discussion

The large number of species of Andalusian vascular flora included in protection lists since 1984 is a clear confirmation of the biodiversity crisis which the Mediterranean basin is undergoing at present. The inevitable and extreme consequence of this crisis is the extinction of species.

The high proportion of endangered flora species included in protected areas testifies to the crucial role of the RENPA network in the preservation and restoration of natural ecosystems. Bruner *et al*. (2001) commented on the relevance of protected areas as a tool for biodiversity preservation. Nevertheless, the mere fact of being a population within the in situ conservation strategy is not protective enough for its long term maintenance. Other measures such as cultivation, reinforcement or reintroduction, are necessary to guarantee the viability of wild populations (Moreno *et al*., 2003). Other authors (Laguna *et al*., 2004; Mendoza *et al*., 2009, 2010, 2014) suggested the creation of a network of flora micro reserves complementary to the current RENPA and aimed at developing conservation initiatives and other compatible useful activities. This proposal could be interesting because some populations of endangered flora still have no protection status (despite the fact that RENPA is the largest protection network of natural habitats in mainland Spain). Species with no population inside the protected areas must be considered top priority. In this way, useful information is provided for the Important Plant Areas program (Langhammer *et al*., 2007), which is part of the Strategy for Plant Conservation (CBD 2002), which aims to identify priority areas in order to improve plant conservation strategies.

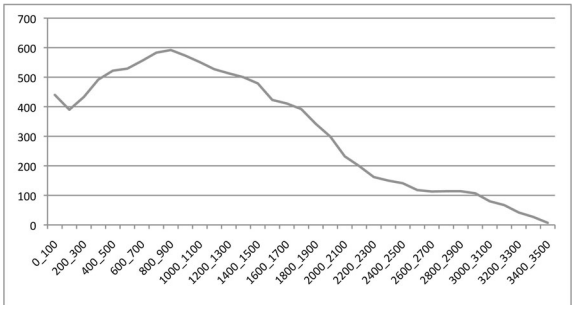

Fig. 6. Distribution of endangered taxa according to altitude in Andalusia.

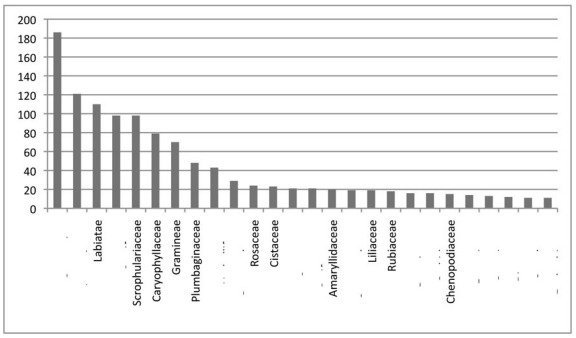

Fig. 7. Abundance of endangered taxa by family in Andalusia.

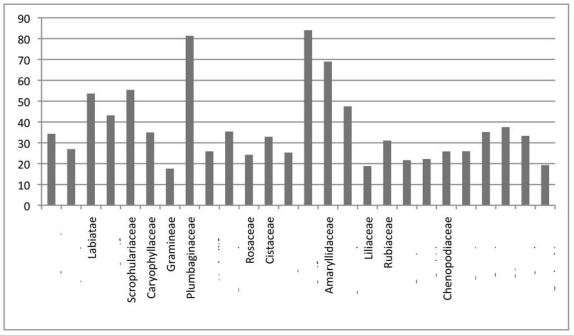

Fig. 8. Percentage of endangered taxa by family in Andalusia.

As for the chorology of endangered taxa, there are noteworthy differences between species of wide and restricted distribution. Endangered endemic species are the most abundant group. This result clearly indicates priority in the protection of endemic flora, priority which can be interpreted in terms of level of stewardship responsibility (Dunn *et al*., 1999). This concept takes into account the situation of a species, for example, if a species is exclusive to an area which is the responsibility for conservation of a given administrative body. The concept represents the ethical and political accountabilities taken on by administrations as guardians of the most important genetic resources of their territory (Jiménez-Alfaro *et al*., 2007). Especially since now it is paying increasing attention to inter-population genetic diversity as a source of evolutionary potential and as a resource for managing wild populations (Salmerón-Sánchez *et al*., 2014).

The grouping by biotype of endangered taxa revealed that Geophytes and Hydrophytes are the least abundant biotypes among this endangered flora. In some cases,

the information on the state of conservation of these species is incomplete, because plants are often cryptic species, with specific ecological requirements or a very short phenological cycle. Despite these inconveniencies, these are very interesting plants for scientists and managers and they are often used as emblematic or flag species for the natural areas they inhabit (Andelman & Fagan, 2000; Bruno *et al*., 2012). Although in absolute terms the presence of Hydrophytes in all endangered flora is very small, over 43% of Hydrophytes in the Andalusian flora are endangered species. By contrast, Hemicryptophytes and Chamaephytes are the most extensively quoted biotypes in protection lists which reflect their greater number and representation in this flora.

As for the distribution of endangered taxa by altitudinal intervals, the results revealed that the thermomediterranean and mesomediterranean bioclimatic belts have the highest number of endangered taxa.

Species inhabiting the thermomediterranean belt are exposed to numerous threats. This region, located between 0 and 800 m asl, is the largest and most densely populated in the Andalusian territory. The area covers the coastal and pre-coastal rim of Andalusia with its inland depressions. Very frequently these areas are devoted to farming activities, with extensive and varied exploitation of land and ensuing habitat fragmentation. These man-induced activities have a heavy impact on biodiversity. Most of the arid SE territories of the Iberian Peninsula are in the thermomediterranean belt. These zones are characterized by a high proportion of endemic and Iberian-North African plants of great botanical interest, as already shown in much research work (Rivas Goday & Rigual, 1959; Peinado *et al*., 1987; Alcaraz *et al*., 1991; Mota *et al*., 2003; etc.). Despite the richness, rarity and high number of their endemic plants, a recent study has highlighted that the arid steppes have been relegated to second place compared to mountain areas in the conservation policies adopted (Mendoza *et al*., 2014). According to some investigations, the arid regions will probably suffer the effects of global change to a lesser extent in terms of species loss and turnover, since they have previously endured dramatic episodes of environmental change (Allen *et al*., 1999; Thuiller *et al*., 2005). On the other hand, this flora includes flexible and stress-tolerant taxa, in particular endemic plants which have undergone abrupt changes and population bottle-necks (Blanca, 1993). It has been suggested that from an ecological point of view these natural regions are more resilient to environmental upheaval (Mota *et al*., 2004; Suárez *et al*., 1991). For this reason, their preservation could yield profits.

High mountain areas represent the opposite end of the altitudinal zonation. Mountain peaks are island-like ecosystems for species endemic to upper vegetation belts (Peñas *et al*., 2005; Pérez-García *et al*., 2007; Mota *et al*., 2008), where any threat can bring about devastating effects on account of the high sensitivity of these ecosystems. The upper altitudinal belts are characterized by a high number of endemic plants. These are often exclusive plants and, in some cases, with disjunct distribution, whose origin is a result of ancient geological periods. The most obvious case is that of taxa with alpine distribution, which have remained isolated in the high mountains of Sierra Nevada, Sierra de Baza, Sierra de Cazorla or Sierra de la Sagra (Blanca & Morales, 1991; Negrillo, 2001; Lorite *et al*., 2003; Mota *et al*., 2008). The supramediterranean belt of the Betic chorological province has also produced forests associated with conditions of high environmental humidity. Here we can find unique floristic elements (Mota *et al*., 2002-a; Pérez-García *et al*., 2012).

Finally, the grouping of endangered flora species by taxonomic family suggests a direct relationship between the abundance of taxa of the different families and the percentage of them that is considered endangered. Of the vascular flora families in Andalusia, 66% have at least one taxon included in one Red List. Even infrequent families have representatives mentioned in a protection list. However, there are unbalanced records in terms of percentages by family. *Plumbaginaceae, Saxifragaceae* and *Amaryllidaceae* are the groups with the highest proportions of endangered species. Sainz & Moreno (2002) agree with this conclusion and, in addition, pointed to the idea that best represented families in the Iberian flora are also typical constituents of both the Mediterranean and Euro-Siberian landscapes.

To sum up, the most significant data of this investigation are as follows:

1. Over a third of the Andalusian flora is endangered or has been previously considered as such. According to the last Decreto issued, the percentage of endangered species is 6,7%. By contrast, the most recent Red List speaks of 21,5%. This significant divergence requires investigation as to the cause. Two reasons emerge as plausible explanations of the discrepancy. On the one hand, it could have something to do with qualitative and quantitative changes in the endangered level of many of the species as a result of the positive effect of conservation measures. The creation of protected areas and the protection provided by Decretos and Laws would be the most significant measures adopted. On the other hand, it could be attributed to discrepancies in the drawing up of lists and Laws as a result of the lack of data necessary to implement an accurate diagnosis in the growing, but still new, discipline of Conservation Biology.

2. The RENPA leaves a little over 6% of endangered flora unprotected. Although there is room for improvement, protected areas cover a population of at least

1,313 species. The question now is: do RENPA areas perform their role of preserving plant biodiversity efficiently?

3. The criterion of stewardship responsibility is reflected in the high percentage of endemic plants considered under protection.

4. There is some discordance between the percentage (of species) which represents the flora of some families and the percentage of species of those families which are considered endangered. Similar discordance can be seen in biotypes.

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