

BIODIVERSITY AND CONSERVATION VALUES OF THE SERPENTINE ECOSYSTEMS IN SPAIN: SIERRA BERMEJA (MALAGA PROVINCE)

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I. INTRODUCTION

Serpentine ecosystems are considered as topics of great interest in Conservation Biology and in Conservation Biogeography. These original ecosystems are spread by the terrestrial surface and they are experiencing a period of changes as a result of human activity. Part of the exclusive habitats that live in serpentine have been disrupted or destroyed because of mining and building or they have been divided into little fragments of land while others have been transformed by agriculture, livestock or forestry management. Populations of endemic plants and animals have also a high rate of extinction and climate change, boosted by fires, threats these barely studied «biogeographical islands».

In Spain, the serpentine ecosystems are located mainly in Andalusia (Serranía de Ronda) and Galicia (Sierras Capelada and Careón) and show a scarce surface area and irregular and fragmented distribution. These outcrops have unequal degrees of protection and insufficient scientific knowledge. Sierra Bermeja stands out among the most valuable, unknown and threatened peridotite outcrops. This mountain acts as the scenery for the Costa del Sol touristic resort. The massif is the main habitat for taxa and biological-biogeographical processes that deserve conservation measures, especially when adaptation to ultramafic soils is involved. Currently, there is a lack of functional studies that demonstrate the existence of such processes, despite the anthropogenic threats that they face.

Only some endemic species have been analyzed for biogeochemical variability such as *Abies pinsapo*, or nickel hyper-accumulators, such as *Saxifraga gemmulosa* and *Alyssum serpyllifolium*. Nevertheless, serpentine flora and vegetation, unlike in the case of fauna, have attracted the attention of botanist in the last four decades.

The urgent priorities for conserving this complex and threatened ecosystem and the lack of knowledge and awareness in the citizens have moved us on to carry out a search and a synthesis of the bibliographical data about Sierra Bermeja serpentine ecosystems. In this work, we try to contribute with a new and quantitative synthesis about the Biodiversity and conservation values of the peridotite massif. The results will reinforce the previous studies that propose the inclusion of this mountain in the Spanish net of National Parks.

II. METHODOLOGY

According to the concept of ecosystem, a holistic perspective has been adopted to obtain a complete and synthetic view of the conservation values and protection priorities for the biological diversity in Sierra Bermeja. Firstly, an exhaustive search and revision for bibliography about the ecosystems of Sierra Bermeja was made. This search included all the local studies and unpublished works. Secondly, data about conservation strategies for the biodiversity of the outcrop were analyzed and systematized, focusing on endemism, threatened and/or protected species and prioritized habitats. The compilation and synthesis of the previously dispersed information tries to improving the efficacy in the decisions to be made about considering Sierra Bermeja as a National Park (NP) according to legislation (Law 5/2007, Red de Parques Nacionales) and other criteria. Finally, the biodiversity value of the study area is compared to other Natural Protected Areas of Andalusia and the protection status with regard to other ultramafic outcrops in Spain. This comparative analysis is needed to positioning Sierra Bermeja in an adequate context regarding nature conservation policies and to determining whether it presents conservation values higher than those for other protected areas.

III. STUDY AREA

Sierra Bermeja is located in the south of the Iberian Peninsula and constitutes the biggest outcrop in the Ronda and Betic mountain ranges and one of the biggest in the world (more than 300 Km²). This massif includes two mountain of importance: Palmitera y Real. Peridotite, and ultramafic igneous rock with high density and hardness, is composed of ferromagnesian minerals (90% olivine) that, when altered, are classified as serpentine. The peridotites of Malaga are mainly composed of lertzholite and hazburguite. Besides the special lithological nature, among the most important biogeographical aspects that influence on the flora and fauna in Sierra Bermeja is the strategic geographical position between Europe and Africa. Also of note is the topographic configuration as Sierra Bermeja is the westernmost point for the Betic Mountains and the elevation (1.500 m) that stands out in the landscape respect the coastal planes on the foot of its southern slope.

Climate is Mediterranean subhumid-humid, with mean annual rainfall between 800 mm near the coast and 1600 mm in the top of the mountains (probably reaching 2000 mm due to horizontal rainfall because of Levante winds) where snowing is a frequent event in winter.

Mean annual temperature is 14-16 °C and three bioclimatic belts are recognized: thermomediterranean (reaching to 800 m), mesomediterranean (800-1300 m) and supramediterranean (1300-1500 m).

Interrelation of these unique environmental conditions cause the natural geochemical processes of transformation of the peridotite rocks and the subsequent formation of serpentine soils of Sierra Bermeja which are outstanding when compared to other substrata. Singularities of serpentine soils include: limitation of essential nutrients as N, P and K and basic cations, as well as low proportion of Ca²⁺/Mg²⁺ (0,84), high concentration of heavy metals (Cr, Ni, Co, Cu) (altering metabolism of some plants) and a xerophytic character with high risk of erosion.

Consequences over plants and animals caused by the special edaphical composition are known as «serpentine syndrome» or «serpentinomorphoses» and generates a flora and vegetation different from those living on other substrates non-serpentinic. As a consequence, several endemism are exclusive from Sierra Bermeja and other typically Mediterranean plants are excluded and so are alien plants. Geographical situation of the massif has made it refugia for Tertiary taxa migrating between Africa and Europe and an important location for animals, especially birds.

Geological isolation has helped the existence of a unique biogeographical sector (Bermejense) which put together the exceptional natural values of Sierra Bermeja, representing one of the main speciation centres of the Spanish flora and vegetation. Among the different plant communities, forests of *Pinus pinaster* var. *acutisquama* Boiss. are replaced in the top of the massif by fir forests (*Bunio macucae-Abietetum pinsapi*).

Some civilizations have modified the landscape and the vegetation but this effect has increased since the middle of the 20th century as a result of the creation of the Costa del Sol touristic resort. Since then, traditional exploitations in Sierra Bermeja are being abandoned and fires are increasing with high-recurrence (14.5 years). On the other hand it is of note the strong urban pressure from touristic towns as Casares, Estepona, Benahavís or Marbella, which have based their economies in licensing residences and huge projects linked to golf as one of the Libyan Foreign Bank (480 hectares in La Resinera). A motorway project between San Pedro and Ronda, would divide the peridotite massif into two pieces. In Sierra Bermeja nowadays, prevail forestry and livestock linked to little towns as Genalguacil, Jubrique, Júzcar, Igualeja or Istán.

IV. RESULTS AND DISCUSSION

4.1. A synthesis of the natural values

There is not an exhaustive catalogue of plants from the complete massif considering that a great part of the Andalusian flora does not inhabit on serpentine and there are some important endemism. 317 species of vascular plants have been recorded in the «Los Reales de Sierra Bermeja» Natural Park.

In the complete massif 20 edaphical-endemism have been identified (13 species and 7 subspecies or varieties). Some taxa are also endemic but with a wider distribution (Serrania de Ronda) as *Abies pinsapo* or *Ulex baeticus* subsp. *baeticus*. This serpentine flora is special

due to the abundance in endemics, low diversity, the presence of relicts, the mixed vegetation with acidophilus and basophiles species, the dominance of xerophytes, hemicryptophytes and chamaephytes, the dominance of the Mediterranean floristic element, high presence of Asteraceae and pteridophytes, vicariancy phenomena and serpentynomorphs. Four of the endemism are classified as «vulnerable» in the regional legislation and others are catalogued as «special protection». Only one of the serpentynophytes is protected by state legislation (*Galium viridiflorum*).

Doubts on the existence of *Nolletia chrysocomoides* in Sierra Bermeja are consistent although it is classified as «extinct» in the regional red list. Spanish legislation only protects one of the serpentine endemism but 28 are included in state and regional red lists (24 in LRE and 31 in LRA). Is worthy of note the existence of a large number of taxa with high risk categories in Sierra Bermeja following the red lists as *Nolletia chrysocomoides* («Extinct»), *Allium rouyi*, *Centaurea lainzii* and *Peucedanum officinale* subsp. *brachyradium* («in critical risk of extinction»). At least eight more are catalogued as «risk of extinction» summing up at least nine taxa highly threatened (one extinct) included in red lists.

With regards to vegetation, almost every association described for Sierra Bermeja is a phytosociological endemism including the alliance *Staelino baeticae-Ulicion baetici* that gathers the serpentine shrublands. The pine woods (*Pino pinastri-Quercetum cocciferae*) and fir forests (*Bunio macucae-Abietetum pinsapi*) considered as climatic vegetation are exclusive from peridotites of Malaga.

Bryophytes flora includes two mosses endemic from the Iberian Peninsula: *Isotecium algarvicum* and *Rhynchostegiella durieui*. Both are not still included in the Atlas of threatened bryophytes of Spain.

The fauna of Sierra Bermeja includes 216 species with 18 endemism most of them protected by European, Spanish or Andalusian legislation. As a 50% of endemism have been described in the last 10 years and an 80% in the last 20 years, there could be a not evaluated threaten risk. This fact could give a major importance to Sierra Bermeja as a centre of origin for species, especially invertebrates, with 13 species included in the Andalusian Red Book of Invertebrates (LRIA), 9 species are included in the Spanish Red Book of Invertebrates (LRIE), 6 included in international agreements and 4 in the Andalusian Catalogue of Protected Species. Sierra Bermeja is included in the LRIA as an «important area for conservation of threatened species» for Odonata (area 3), Coleoptera (area 10) and terrestrial Mollusca (area 8) and so is a part of the top ten areas with a higher number of threatened species. In relation to vertebrates, Andalusian environmental Agency has carried out cartography (1:400.00).

With regards to vertebrates, the Andalusian government has mapped (1:400.000) the species diversity: continental fishes (64), amphibians (34), reptiles (89), birds (309) and mammals (105). Shannon-Wiener index was applied and values between 0 (null) and 1 (maximum) were obtained. The value of this index for Sierra Bermeja is more than 0.9 «very high». *Squalius malacitanus* among all the vertebrates must be highlighted as endemic from Sierra Bermeja, together with other species which are living in «refugia» as relicts (*Salaria fluviatilis*) in the rivers Verde and Guadaíza.

Summarizing the diversity of the biota, Sierra Bermeja holds several habitats of the Natura 2000 European net of protected spaces and more than 60 threatened species (UICN). In

Sierra Bermeja are found 15 habitats of the 230 European included in the Appendix I of the Habitats Directive 92/43CEE, constituting 6,52% and 3 classified as «priority».

4.2. Comparative analysis of natural values and protection regimes

We have compared several natural Mediterranean areas (Biodiversity Map of Andalusia) in terms of number of endemic plants and vertebrates. Sierra Bermeja has been catalogued as an «important area for Spanish threatened flora» with an «exceptional» qualification, the highest in the classification. In this study, the endemism rate, threaten risk and concentration of species and communities were taken into account. Among these areas, Sierra Bermeja is ranked number 20 for Spain but number 4 in the Iberian Peninsula, only surpassed by Sierra Nevada and satellite mountains (Gádor, Cazorla). This remarkably high significance of the natural values of Sierra Bermeja also reflects an insufficient knowledge of this massif because the endemic species of invertebrates were not selected for conservation studies. None of the compared areas reaches the geological exclusivity of Sierra Bermeja.

Ultramafic areas are unequally considered in the legislation for protected areas with a disperse net of protected spaces which do not consider the diversity and originality of the serpentine ecosystems (Andalusian and Galician) as a whole in Spain.

Ultramafic massifs are included generally in the Natura 2000 net except for Sierra Alpujata and satellites peridotite mountains in the Guadalhorce valley. This fact does not give an effective protection to these areas because fires, alien species, urbanization and motorways affect them severely.

Sierra Capelada is classified as SCI «Costa Ártabra» (COD: ES1110002), together with a coastal area in the north of La Coruña province with more than 100 km long (Ferrol and Ortegal). The Sierra de Careón, (La Coruña, Lugo and Pontevedra provinces), has been recognized as a SCI «Serra do Careón» (COD: ES1110014) and partially included in the Biosphere Reserve of Terras do Miño (Friol municipality). In Malaga province, the Sierra de Aguas is declared as SIC «Sierras de Alcaparaín y Aguas» (COD ES6170009). The Sierra Parda de Tolox is totally included in the SIC «Sierra de las Nieves» (COD ES6170006) and in the Natural Park and UNESCO's Biosphere Reserve as well as in the «Intercontinental Mediterranean Biosphere Reserve Andalusia (Spain)-Morocco», and so it is the best protected ultramafic outcrop in Spain.

Finally, Sierra Bermeja has been unequally recognized with different conservation regimes that affect it partially: two European SIC Natura 2000 (SIC «Los Reales de Sierra Bermeja» (COD ES6170004) and SIC «Sierras Bermeja y Real» (COD ES6170010)) (2 Andalusian SAC), one Natural Site (Los Reales de Sierra Bermeja), a part of the Natural Park «Sierra de las Nieves», one SPA and it is integrated in the Biosphere Reserves forwardly cited.

As well as for the late implementation of the net of Andalusian Natural Protected Spaces (RENPA) in Sierra Bermeja, it is of note the absence of coordination of environmental politics that affect this mountain, with several areas without effective protection: the serpentine outcrops reaching the coast (nowadays under urbanization) or two of the three unique fir forest in the World (Cerro Abanto and Sierra Real) vaguely protected.

Taking into account those deficiencies, in the last years there have been an increase in the scientific and social sensibilities on the need of protecting the natural values of the Span-

ish ultramafic outcrops and particularly Sierra Bermeja, the most valuable and threatened. Recently, different NGO and scientists have proposed for this mountain the category of National Park, the highest Spanish rank for a net of representative natural areas in good conservation state. With any doubt, the conservation of the serpentine ecosystems is a priority for Spain.