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HIGHER PLANT AND VERTEBRATE SPECIES RICHNESS IN SPANISH AND SOME MEDITERRANEAN MOUNTAINS

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SUMMARY.- This paper reviews the biodiversity of the Spanish and some other Mediterranean mountains. These have some of the richest areas for vascular plants recorded apart from some areas in the tropics. The number of endemic species is substantial. Six areas in Spain and four other Mediterranean areas are described in detail. A special plea is made for a comprehensive detailed vegetation map for European mountains to include the Spanish and Mediterranean mountains.

RÉSUMÉ.-Ce travail porte sur la biodiversité de quelques montagnes méditerranéennes, notamment celle de l'Espagne. Ces dernières montrent une flore vasculaire des plus riches au monde, si l'on excepte les pays tropicaux. Aussi le nombre d'espèces endémiques est très important. Six systèmes montagneux d'Espagne et quatre autres sur le pourtour méditerranéen sont étudiés en détail. Dans une section spéciale on étudie la carte de végétation synthétique des montagnes européennes, de façon à inclure les montagnes de l'Espagne et de la Mediterranée.

RESUMEN.-Se estudia la biodiversidad de las montañas españolas y de otras mediterráneas. Si se exceptúan algunas áreas tropicales, se trata de una de las áreas más ricas en plantas vasculares. El número de especies endémicas resulta sustancial. Se estudian con mayor detalle seis áreas montañosas de España y cuatro áreas más del Mediterráneo. De un modo particular se estudia un mapa sintético de vegetación de las montañas de Europa en relación con las montañas de España y del Mediterráneo.

Keywords: Biodiversity, mountains, Mediterranean, endemic species.

1. Introduction

Whilst species richness will not rank the Mediterranean mountains among the so called megadiversity spots, it can highlight their importance as regional centres, having far higher levels of biodiversity than surrounding areas. Among those with the highest biodiversity, we may list the Baetic Sierras in Spain, the mountains of Corsica, the Pindos and Rhodope chains, the Taurus range in Turkey, and the Rif in Morocco (GASTON & DAVID, 1994). These ranges stand out not only because of their high number of species, but also because of their high percentage of endemics. The number of endemics alone would result in many other chains, from Lebanon to the Iberian range, being classed as macrodiversity spots.

Biodiversity is a term frequently and often incorrectly used by the environmentally conscious. It has become a common household term and as a consequence has lost its original meaning. Scientists attach a more precise meaning to it, but even they often misuse the word. Biological diversity has had a long history of controversy and has even been labelled a «non concept», the word «diversity» being alleged to be void of content and precise meaning (HURLBERT, 1971). However, a careful analysis of the criticisms directed at the biodiversity concept results in a consensus, i.e. «biodiversity» is not a term without a meaning, but one with too many. The plurality of meanings makes it possible to apply it to different situations and use it to describe different things under the same label. This explains the confusion and some of the concern voiced about the common use of the term.

Different definitions of biodiversity can be given according to different conceptual meanings, applications, levels, geographical scales or measurement procedures. With so many dimensions to consider, the possible scenarios and meanings relating to biodiversity are numerous. When discussing the biodiversity of the Mediterranean mountains, it is important that we select a convenient measure. We need a measure which is easy to apply, can be derived from existing data, allows comparisons between different areas, highlights interesting spots, is applicable to a range of geographic regions and which, through close correlation to other biodiversity measures, sums them up.

Of the several measures which satisfy the above requirements, the species richness of the flowering plants and the vertebrates were selected for the present paper. The species composition of these groups in most Mediterranean areas has long been known (although new species are still being discovered, especially in mountain areas). Species richness is usually high when other, more comprehensive measures of diversity are also high. The number of publications using species richness is large, therefore a large body of data is

available for comparisons. Species richness is the most frequent measure that is used in practical conservation, also. We use species richness, without denying that there are better measures of biodiversity, to emphasise that it is the simplest and a most convenient measure of biodiversity.

2. Altitude and species richness

Mountain ecologists are especially interested in knowing how biodiversity values are distributed in mountains. A number of different factors have been invoked as the primary drivers of biodiversity. SCHEINER & REY (1994) have attempted to offer a comprehensive explanation of global patterns of biodiversity distribution and concluded that for plants, species richness was related to biomass production, and therefore to temperature and, to a lesser extent, rainfall. They have shown that the highest landscape diversity was correlated with warm temperatures, high elevations and large seasonal temperature fluctuations, i.e. areas such as the mediterranean and subtropical mountains. In contrast, the highest landscape complexity has been linked to high productivity and warm winters such as those that prevail in the tropical lowlands.

The temperature dependence of species richness explains the latitudinal diversity gradient and it also applies to altitudinal gradients in mountains, where the number of species is usually high in the foothills and low at the summits. As mean temperature appears to be a linear function of altitude, it is safe to say that altitude and temperature are similarly related to species richness. The exact nature of this relationship is much debated, but some common features may be inferred from the numerous case studies. In temperate latitudes, diversity values have been found to be high from the foothills up to the montane belt followed by, at first, a steady decrease, and above the treeline, by a sharp decline. In contrast, in tropical mountains the highest species richness is in the montane zone, the lower and upper belts being poorer.

Species distributions along altitudinal gradients seem to obey different rules in tropical and temperate mountains. In the former, where landscape complexity is greater, the climate is milder and there is no thermic seasonality, the main factor affecting species distribution here appears to be interspecific competition. The absence or presence of a competing species may contribute to the varying altitudinal limit for some species. In temperate mountains, in contrast, climate is harsher and there is a strong seasonality which structures the landscape into a mosaic of different units. The borderlines between the units, the ecotones, are linked to the distribution limits of the species. So, in tropical mountains it is synecological factors that govern distribution

patterns, whilst in temperate climates biogeographical factors are important. When the altitudinal ranges of similar species overlap autecological differences become important. Examples are found in temperate mountains, especially in those at high latitude.

Among the factors contributing to the species richness of a region, we must not neglect the historic ones, especially the role played by glaciations and the action of man. In addition, ancient historic factors are also at play, with important consequences for the formation and extinction of species, and hence for species richness. Mountain regions form a kind of island habitat (a continental archipelago) for cold loving species which occur at high altitudes and are unable to cross the lowland zones separating the summits. These high altitude habitats, similar to other isolated habitats found in mountains (e.g. mountain lakes, cliffs) offer an opportunity for the differentiation of new species. This process is much more pronounced in tropical mountain ranges than in temperate ones. However, in some temperate mountains, particularly in the Mediterranean mountains, it is one of the main factors at work in causing a high species richness.

3. Species richness in Mediterranean Europe

Areas in mediterranean climates have long been known for their high species richness. The South African fynbos, for instance, has 8550 vascular plants, three quarters of them endemics, in only 75000 km^{-2}. This richness is similar or even greater than that of tropical forests on an area to area basis. The mediterranean area of California has over 5000 plant species, a quarter of the total number of species in the whole of the United States. The Mediterranean basin has up to 25000 species of vascular plants, 20 % more than the United States, a country five times larger has, and about half of these species are endemic (MOONEY, 1988).

The European Mediterranean region benefits from many conditions which increase species richness e.g. a high mean temperature and associated high biomass production, a rugged topography, the proximity to Asia and Africa, the complexity of the landscape and the influence of the nearby sea. The result of all these factors is a high landscape and taxonomic diversity. Spain has for example about half of the European moss species, one third of the lichens, three-quarters of the fungus species, more than half of the vascular plant species, over half the invertebrates and sixty percent of the vertebrate species excluding fishes (CRESPO & GOSÁLBEZ, 1995). Other Mediterranean countries have similarly high figures. For instance, among the EU countries, the richest vertebrate fauna is found in Spain, followed by France, Italy and Greece.

It is important to stress that high species richness in the Mediterranean is due partly to local geographic conditions and partly to the climatic changes during the Quaternary. Mediterranean peninsulas served as safe havens, offering a refuge to thermophylic species driven south by the advance of the ice. Separate populations of the same species on different peninsulas have acquired taxonomic differences through isolation. Thus, several secondary speciation centres have been recognised in the Mediterranean basin. In addition, the above populations did nod spread uniformly throughout the refugia, but remained restricted to narrow coastal bands. With the retreat of ice and the subsequent elevation of sea level these bands became fragmented into small isolated areas, where the small size of populations prompted an accelerated speciation through genetic drift (MÜLLER, 1972). The mountain summits acted as islands of refuge for arctic-alpine species during the interglacial periods, thus further contributing to speciation.

4. Human pressure in the Mediterranean mountains

Before the Middle Ages, the state of the environment in the Mediterranean mountains was reasonably good. By the end of the Roman Empire, the decline of the war-torn lowland settlements, plagues and consequent population decrease have led to the abandonment of vineyards on the hill sides. The abandoned terraces, ditches and fence systems failed to prevent heavy erosion, which has left a mark in sedimentary areas. Swamps and marshes expanded in the lowlands and malaria became widespread (MCNEIL, 1992). This, in turn, caused a migration of the population up the hills to seek protection from wars and malaria, but not so high as to prevent farming.

Over the centuries, the Mediterranean mountains have become colonised and their forests were cleared to support a growing population. In the Pyrenees for example, the mountains were only used for transhumance before the ninth century. The Arab domination of the lowlands from the ninth century forced the indigenous population into the mountains which led to the disappearance of forests through conversion to pastures or used for shifting cultivation until the soil lost fertility. This pattern of extensive husbandry and shifting agriculture has been common in Spanish mountains —and also in some other countries— until recently. Demographic pressure peaked at the beginning of the 20th century and has decreased since. The mountains nowadays are depopulated, except for tourism related activities. Forest re-growth is happening in many places, where there is still enough soil left.

5. Species rich mountains in Spain and in some other Mediterranean regions

5.1 *Spain*

The South Spanish Sierras form a group of mountain ranges running from south of the Iberian System near to the Gibraltar Strait, a long mountain arch across the south east of Spain. The main ranges are the Sierras de Ronda and Grazalema, and to the east, the Sierras Nevada, de Gador, de los Filabres, Cazorla and Segura. The highest peaks reach an altitude of c. 2000 m, except in the Sierra Nevada, which with its nearly 3500 m is the highest peak in Western Europe outside the Alps. All the above ranges have been heavily impacted by human actions, but still have several original plant formations, particular habitats and numerous endemic species. Most of the 25 nature reserves of Andalusia are found in these mountain ranges.

The Sierra de Grazalema is unique because of the high rainfall (2200 mm $year^{-1}$) it receives compared to the surrounding dry areas. The only fir forests (*Abies pinsapo* Boiss.) are found here, though having a very restricted distribution today. *Abies pinsapo* Boiss. is the only endemic tree, but at least a dozen species of flowering plants are endemic to these mountains. The landscape is rich, although impoverished in comparison with its natural state. Although large areas of the nearby Serranía de Ronda are barren, enough forest cover remains to shelter large animal species, such as golden eagle (*Aquila chrysaetos* L.), ibex (*Capra hispanica* Schinz), roe deer (*Capreolus capreolus* L.), otter (*Lutra lutra* L.) and lynx (*Lynx pardina* Temminck) and there are vast, among the largest in Europe, colonies of bats (Chiroptera).

The Sierra Nevada is special in many aspects. It has remained isolated through the lack of access roads until the 1930s. From a species richness point of view it is of very high value, particularly its upper vegetation belts. About 80 % of the plant species in the cryo-oromediterranean zone are endemics, several of them being on the verge of extinction. Recent intensive ski and leisure industry developments pose a threat to this vulnerable high altitude system.

The expansive forest clad ranges of the Sierras of Cazorla and Segura, at the intersection of the southern Iberian and the Baetic Systems, are home to a rich wildlife. The area has been a Wildlife Reserve since 1960, Biosphere Reserve since 1983 and Nature Park since 1988. The high local species richness is a result of these mountains straddling a biogeographical boudary allowing the co-existence of endemics and eurosiberian species, which reach here their southernmost limit. Wildlife richness is notable and species include Spanish ibex, red deer (*Cervus elaphus* L.), fallow deer (*Dama dama* L.), muflon (*Ovis musimon* L.), otter, genet (*Genetta genetta* L.), golden eagle and vulture

(*Gyps fulvus* Hablizle). There is even an endemic vertebrate, the small Valverde lizard (*Algyroides marchi* Valverde). The area's species richness has contributed to its being made the largest protected area in Spain (and has justified the building of a small research station).

The mountains flanking the Ebro Valley form the Iberian System on the south side and the Pre-Pyrenees on the north side. These are high mountains, often over 2000 m. In the Iberian System the main mountain groups are those of Javalambre and Gúdar, Albarracín, Moncayo and Demanda; in the Pre-Pyrenees the Sierras of Guara, Montsech and Boumort are the highest. Although these mountains are not so rich in endemics as the Baetic Sierras and their landscape complexity is also lower, they nevertheless rank quite high in both respects. Two biogeographic regions, the eurosiberian and the mediterranean meeting along the Pre-Pyrenees, four biogeographic provinces, nine sectors and five bioclimatic belts result in the region's high landscape and taxonomic diversity. Earlier high human pressure in the Pre-Pyrenees has eased and today is only localised, but high impact cultivation areas remain in both ranges. Several national parks and reserves protect the best places.

The Pyrenees are the largest mountain range in Spain, almost as high as, and with much larger high mountain area than the Sierra Nevada. The highest peak is Mount Aneto at over 3400 m and there are about 40 other peaks over 3000 m. It is important to recognise that large parts of the Pyrenees are not in the mediterranean bioclimatic region, but belong to the alpine. Species richness is high, with 3500 species of plants, almost half of the Iberian flora. About 4 % of the plants are endemic, whilst the corresponding figure for amphibians and reptiles is 11 %. At least six species of land vertebrates are endemic of the range, three of them recently discovered. Despite the complex topography, landscape diversity has decreased through deforestation and the expansion of pastures. There are current signs of recovery including forests moving slowly up the mountains, but they will probably never reach the potential timberline in most places because of recent developments such as road building, tourism and amenities in the high mountain areas. There are over 60 protected areas on the Spanish side of the Pyrenees (VILLAR, 1999).

The Eastern Pyrenees belong to the main chain of the Pyrenees but they show stronger mediterranean features. Through the Cevennes area they are connected to the Maritime Alps thereby forming a biogeographic corridor allowing the pass of many species to the north and south. This is true for the coastal areas in general, however this corridor has also allowed the arrival in the mountains of species of African or Tyrrhenic origin, further increasing species richness. There are several high diversity spots in the eastern Pyrenees, some of them undesignated such as Mount Canigou (2987 m). Its plant species diversity with 1100 taxa is nearly one-third of the Pyrenean

flora. Using average figures, a comparable area in Europe would be expected to contain c. 600 species at most. The high diversity at Mount Canigou is due, of course, to the presence of a group of c. 400 mediterranean taxa.

5.2 *Other Mediterranean regions*

Mountain areas, mostly belonging to the Appenine chain, occupy about 80 % of the Mediterranean bioregion in Italy. Plant species richness with its approximately 3500 species is similar to that in the Pyrenees. There are several different types of mountain forest, some of them formed by endemic species. Over the centuries, natural forest cover has decreased and the decline still continues. In comparison with montane grasslands above 2000 m which have lost about 20 % of their original area, of some sclerophyllous forests between 1000 and 2000 m less than 5 % remains. In Sicily, forest loss since 2500 B.C. has been estimated at over 93 % (BRANDMAYR, pers. comm.). Animals have suffered a comparable or even greater loss. For example the chamois (*Rupicapra rupicapra* L.), formerly present all over the Italian high mountains, is now restricted to the Abruzzi Park.

The chain of Pindos, peaking at about 2500 m, continues to the south in the Dinaric Alps and is related to nearby massifs such as the Taygetos and Olympos. Species richness in the Pindos chain is quite high, having as many flowering plants as the much larger Appenines, about 3500 species. The percentage of endemic species is also quite high, 35% being endemic to Greece and 11 % to the Pindos-Taygetos range. In addition, there are some interesting westernmost populations of some Anatolian species. There are also endemic populations of vertebrates, such as *Rana epeirotica* Schneider, Sofianidou & Kyriakopoulou-Sklavounou, together with disjunct extreme populations of Anatolian species, just as in the case of plants.

Mount Olympos does not belong to the Pindos chain, being about 100 km northwards of it, but can be included in the same biogeographic province. Its floristic diversity is perhaps the highest of all the European mountains and has about 26 endemic species, also.

The Balkans and Rhodope chains form two parallel ranges in Bulgaria and Greece. The former, just reaching 2000 m, has a central European type of vegetation with some mediterranean features, while the Rhodope chain, forming the border between Bulgaria and Greece and peaking at 2900 m, is mostly mediterranean. An increase in species richness is caused by the eurosiberian and mediterranean biogeographic regions meeting at the Rhodope. The number of plant species in the Rhodope is near 3000, with about 5 % of them endemics. In the east, the Rhodope chain reaches Thrace where many Asiatic and Pontic species form isolated marginal populations.

6. Biodiversity research in Mediterranean mountains. An outlook

6.1 *Indicator species and populations*

For the scientist studying biodiversity in the Mediterranean mountains the fundamental species are those which can be used as biogeographical, ecological, or evolutionary indicators. They are to be identified as a first step in assessing biodiversity in mediterranean mountains and the effects of global change on it. Examples include k-strategists high up in the trophic webs in complex stable ecosystems, such as birds of prey, or snakes. Another example is endemic mountain plants with their specialist adaptations and restricted areal distribution. Species, which indicate biogeographical and evolutionary trends and sensitive to environmental change, are to be found among amphibians, reptiles and land snails.

A word of caution is appropriate at this point. The classical approach to nature conservation has been to protect endangered species, which without the appropriate protection of habitats can but fail. It should also be mentioned that the selection of species to be protected is biased towards large mammals and birds and less attention is paid to smaller sized species, lower vertebrates, invertebrates and plants. Such an approach ignores most components of biological diversity and may overlook the above mentioned indicator species groups.

When studying populations, it is the extreme ones near the limit of a species' areal distribution, which are likely to be of most interest for biodiversity researchers. Marginal or extreme populations are subject to a range of environmental factors which require adaptation to. Natural selection usually results in more efficient genotypes with a higher ability to cope with limiting conditions and intraspecific competition. Limits to a species' areal distribution are not well-defined. Often they are geographically convoluted, resulting in isolated or semi-isolated populations, where genetic differentiation may proceed at an accelerated rate. In complex mountain environments the number of ecotones and mosaics of ecologically defined units is large and so is the number of interesting marginal populations.

6.2 *Ecological diversity and vegetation mapping*

Ecological diversity is aptly summed up by vegetation maps for given areas. Vegetation mapping has been widely used in many countries. Examples of applications include an European Union-wide classification of habitats (CEE Council, 1992), the setting up of a comprehensive network of reserves (Natura 2000) to include every listed habitat, and its implementation

at the national level, together with the numerous local and regional vegetation maps available in Europe. A continent-wide comparison of regional vegetation maps confirms the point already made i.e. landscape and biodiversity are highest in the Mediterranean mountains.

There is an evident gap in the mapping of European ecosystems as there is no general-purpose vegetation map is yet available for the whole of Europe at a detailed scale. The existing general maps (OZENDA, 1979) have a scale of between 1:2,000,000 and 1:5,000,000, which is not enough for a detailed study of biodiversity highspots. An appropriate map could be compiled from the many existing vegetation maps available for different countries or regions by a co-ordinated effort complementing the national vegetation mapping plans of Mediterranean countries.

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