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Classification of habitats highlights priorities for conservation policies: The case of Spanish Mediterranean tall humid herb grasslands

Ana S. García-Madrid, José A. Molina*, Paloma Cantó

Plant Sciences Department, Complutense University, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain

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ABSTRACT

The Mediterranean grasslands of *Molinio-Holoschoenion* are one of the lesser known natural habitat types of interest for conservation in the European Community. A study on their content with regard to their plant-communities and interest for plant conservation is conducted on a regional scale for the first time. A new comprehensive classification is proposed for this habitat type in Spain (Iberian Peninsula and Balearic and Canary Islands) where they have their highest European diversity. Twenty-five plant-community types are floristically identified by k-means clustering. Cluster analysis reveals a major hierarchical aggregation in two vegetation groups: (i) rush meadows of *Scirpoides holoschoenus* (L.) Soják; and (ii) communities of herbs and forbs dominated by *Molinia caerulea* (L.) Moench subsp. *arundinacea* (Schrank) H. Paul and/or *Schoenus nigricans* L. These groups are associated with different positions along a soil moisture gradient where rush formations occupy the positions farthest from the water table. Cluster Analysis also shows an uneven distribution of species with conservation interest. The highest content in endangered species is found in halophilous rushes. Grasslands on mineralised soils host the highest number of vulnerable species. Spanish *Molinio-Holoschoenion* plant communities were ranked using three criteria (regional responsibility, local rarity and habitat vulnerability) in order to set conservation priorities. The highest conservation values were achieved by coastal rush communities developing on dune slacks, and by forbs and rushes in the Baetic System growing on banks of streams with oligotrophic waters.

Introduction

Tall herb grasslands growing on humid soils and shaped by human influence are known in Mediterranean-climate areas around the world (e.g. Hauenstein et al. 2002; Keeler-Wolf et al. 2007). Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion* represent one of the natural habitat types of European Community interest for conservation (EC 2007, habitat code 6420). They consist of rushes of *Scirpoides holoschoenus* (L.) Soják, and tall grasses and herbs related to outcropping of groundwater and anthropogenic influence (Tchou 1948). Grasslands of *Molinio-Holoschoenion* are subjected to water table oscillations (Molina et al. 2004), and are also partly dependent on extensive agricultural practices (EEA 2009); specifically they are mainly affected by pastoral systems, which contribute to maintaining their characteristics in the intermediate stages of vegetation succession (Moreira et al. 2005). *Molinio-Holoschoenion* vegetation performs certain ecological services (Caballero et al. 2009; Halada et al. 2011; San Miguel 2009). For example, since it grows on moist soils, it avoids the water stress typical of the Mediterranean climate caused by the absence of precipitation in the hot season (Bernáldez 1988; Bernáldez et al. 1989; Grootjans et al. 1988), and constitutes pasture reserves in late summer when most of the grasslands in Mediterranean countries have dried (Bernáldez 1991).

Herb grasslands of *Molinio-Holoschoenion* play a role in various key ecological functions of wetlands such as water filtration and storage, flood prevention, positive contribution to local climate, production of natural products and habitats for rare or endangered species. They provide an important habitat for a wide range of species of butterflies, grasshoppers, voles and birds (Kati et al. 2012). *Molinio-Holoschoenion* grasslands are present throughout Mediterranean countries but they reach their greatest extension and diversity on the Iberian Peninsula (Rivas-Martínez et al. 2011), where very little is still known about the richness and distribution of endemisms and the endangered species that live in this habitat. Iberian *Molinio-Holoschoenion* has the added value of hosting the endemic Cabrera vole, *Microtus cabrerae* Thomas (Landete-Castillejos et al. 2000), classified by the IUCN (2012) as one of the threatened species of rodents in Europe.

Territorial plant diversity classification is a useful aid for biodiversity conservation (Türe & Böcük 2010). In spite of the fact that Iberian *Molinio-Holoschoenion* grasslands include a high

* Corresponding author. Tel.: +34 913941770; fax: +34 913941774.
E-mail address: jmabril@farm.ucm.es (J.A. Molina).

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number of plant-community types (Rivas-Martínez & Penas 2003), they have not been numerically analysed. Hierarchical cluster analyses organise information into discrete floristic-groups and display how the plant diversity is distributed, as well as revealing the floristic and ecological relationships (McGarigal et al. 2000). Furthermore, the distinct groups revealed by cluster analysis can be evaluated by applying the criteria used for conservation priorities. Methods to establish regional-level priorities for the conservation of both plant species and plant communities often include different criteria based on regional responsibility, local rarity and habitat vulnerability (Gauthier et al., 2010; Paal 1998). There are advantages to using a habitat-based multi-criteria evaluation for the assessment of conservation value, as opposed to the traditional species-based criterion (Panitsa et al. 2011).

This study focuses on the classification of Spanish grasslands of *Molinio-Holoschoenion* in order to achieve the following objectives: (a) to provide a comprehensive classification based on floristic data; (b) to report basic information about plant richness and endemic and threatened species in the resulting discrete groups taken here as plant-community types; and (c) to produce a threat categorisation of the community types using three conservation criteria. This knowledge will provide valuable information on Mediterranean humid grasslands which can be: (i) the basis for comparing intra- and inter regional classifications of Mediterranean-climate areas; and (ii) useful tools for European conservation and restoration policies.

Methods

A composite table was built with 264 relevés and 550 species corresponding to 39 *Molinio-Holoschoenion* associations described or recognised in the Iberian Peninsula, and in the Balearic and Canary Islands (Appendix 1). This selection reasonably covers the lithological and climatic diversity of the study area. The ecological characteristics of the associations were considered using references. Most of the relevés were taken from the SIVIM Database (Information System of the Iberian and Macaronesian Vegetation, www.sivim.info/sivi/). The remaining relevés were taken from the literature (de Bolòs 1957, 1962; Esteso 1992; Esteve 1968; Salazar et al. 2001). Phytosociological data were introduced in the QUERCUS programme (B-VegAna; Font 2005). After a nomenclatural revision, a refined table was obtained, and species with a frequency of less than four relevés were deleted, obtaining a final table with 223 species. Abundance coefficients were transformed into the ordinal scale of Van der Maarel (1979). The resulting matrix was analysed by means of clustering techniques.

A polythetic divisive non-hierarchical clustering such as the k-means clustering was used in order to obtain a reasonable estimate of how many groups to expect in the data. k-Means clustering performs optimally when the objective is to minimise within-cluster variation for a specified number of clusters (McGarigal et al. 2000). k-Means partitions considering values from 15 to 40 groups were calculated using the GINKGO programme (B-VegAna; De Caceres et al. 2003). Partitions were compared to the partition of the data corresponding to the 39 initial associations, taken here as a hypothesis, using the Rand index in order to obtain an optimal grouping of the relevés. Indicator species analysis using Indicator Value Index (IndVal, Dufrêne & Legendre 1997) evaluated the taxonomic consistency of the new groups, taken here as plant-community types, obtained from the k-means partition by calculating species fidelity to each cluster (software PC-ORD 4). Agglomerative hierarchical clustering was performed to detect relationships among and between the new entities and latent environmental factors (McGarigal et al. 2000; Van Tongeren 1995) using the SYN-TAX programme (Podani 2000). Ward's method and Euclidean distance were used as algorithms, as an effective strategy for displaying relationships among clusters (McGarigal et al. 2000). Environmental factors such as chemical composition of soil and groundwater and soil moisture regimen have been considered as primarily influencing the floristic composition in Mediterranean herbs of *Molinio-Holoschoenion* (Bernáldez et al. 1989; García-Madrid et al. 2010; Muñoz-Reinoso 1995; Tzialla et al. 2006).

A preliminary study of the conservation value of the groups obtained by agglomerative clustering was made by analysing their content in plant-community types, species richness, endangered plants, and endemic taxa. The conservation status of the 550 taxa was checked in nine regional documents containing legislation on threatened or protected plant species, three regional red lists (Álvarez 2010; Cabezudo & Talavera 2005; Palacios et al. 2010) and the Spanish red list of vascular flora (Moreno Saiz 2008) and its addenda (Bañares et al. 2011).

A prioritisation exercise was done in order to propose a precise and useful indication of conservation measures for *Molinio-Holoschoenion* community types in Spain. For the choice and quantification of criteria, we followed a method combining three attributes (regional responsibility, local rarity and habitat vulnerability) based largely on Gauthier et al. (2010) for the priority setting of rare species. We introduced certain modifications in this method in order to adapt it to the plant communities that are the object of our study. Regional responsibility is a geographical criterion associated with distribution range, and refers to the proportion of the studied region that contains the plant-community distribution at the European level. We quantified regional responsibility based on the numbers of Mediterranean countries outside Spain and continental Portugal in which each plant-community occurs. The wider the plant-community distribution, the lower the regional responsibility. Owing to the lack of a European *Molinio-Holoschoenion* vegetation monograph, plant-community distributions have been inferred from regional European references or by cross-referencing the distributions of their characteristic species. Local rarity refers to the abundance of areas or localities where a plant community is present in the study area. It is quantified by means of two sub-criteria: (a) the number of Spanish biogeographical provinces where a plant community occurs; and (b) the number of local endemic species contained in the plant community. The smaller the number of provinces where a plant community is reported and the higher the content in endemic plants, the rarer the plant community is in the study area. Habitat vulnerability provides information on the likelihood of habitat loss for a plant community in the study region. We have included within this criterion the following two sub-criteria: (a) a value for the content in threatened plants in each plant community; and (b) the occurrence of the plant community in coastal or island ecosystems, since these are among the most threatened ecosystems in Spain (Campos et al. 2004; Díez et al. 2000). The first sub-criterion was quantified by adding the content of characteristic species belonging to the Spanish red list, with the following scores (Critically Endangered CR = 5, Endangered EN = 4, Vulnerable VU = 3, Near Threatened NT = 2, Least Concerned LC = 1). The second sub-criterion was quantified as follows: plant community occurring both in islands and coastal ecosystems = 2.5; plant community occurring in islands or in coastal ecosystems = 2; plant community occurring in inland and in coastal ecosystems = 1. The core of our classification is the weight of each criterion. Each one was awarded a maximum value of 5, with a possible maximum total score of 15. The final value of each criterion was weighted in relation to the maximum possible value, considering this value as the maximum score for each criterion, and ranking all other values downwards from this point. A final ranking value was obtained with which to order the plant-community types. The potential areas of the groups at the top of the ranking were examined and compared with areas having some type of protection status under Spanish