Estimating epiphytic lichen richness by single families in Mediterranean forests

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ABSTRACT

The current trend of declining epiphytic richness caused by human activities (forest fragmentation, logging, agriculture, and livestock grazing) and the greater efforts required to sample and identify the most inconspicuous species have necessitated the use of indicators of the species richness. In this study, we examined the potential of predicting epiphytic lichen richness based on the richness of a single taxon (family) of the most conspicuous lichens (macrolichens) in Mediterranean woodlands. Since our working hypothesis is that the richness of some conspicuous elements is tightly connected with the total richness, we expect this connection is maintained even after composition shifts (for instance composition changes between coniferous and oak forests). In order to control the large set of confounding factors at macro- and microclimate scales our present study was conducted in 504 forest stands, which represented a wide range of Mediterranean climates, management intensity levels, canopy cover types, and tree sizes. The presence/absence of epiphytic lichens were determined in 7560 trees, which were dominated by coniferous (*Pinus nigra* and *P. sylvestris*) and oak (*Quercus ilex* ssp. *ballota*, *Q. faginea*, and *Q. pyrenaica*) species. In oak forests, the increased richness of Collemataceae and the complex known as "rest of Peltigerales" was followed by an increase in the overall epiphytic richness, whereas there was a strong positive correlation between Parmeliaceae and total epiphytic richness in coniferous forests. In both cases, the richness of these predictors increased in well-preserved forest stands with dense canopies. Thus, we propose the potential use of Parmeliaceae (for coniferous forests) and the Collemataceae and the "rest of Peltigerales" (for oak forests) as indicators in the Mediterranean region because they have a cosmopolitan distribution, grow in a wide range of environmental conditions, and are correlated with changes in the epiphytic richness caused by forest disturbances.

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1. Introduction

The current trend in declining species richness, as well as the limited time and financial resources available to produce an inventory of all species, have necessitated the use of "indicators" species to estimate species richness as an essential measure of biodiversity (Bergamini et al., 2005; Gaston, 1996). According to Lawton and Gaston (2001), indicator species might be used to estimate the diversity of other species, taxa, or communities within an area, thereby suggesting the possible use of a taxa subset as a surrogate of the total community richness (Magierowski and Johnson, 2006; Oliver and Beattie, 1996; Sebastião and Grelle, 2009). Thus, several authors have suggested the use of a surrogate based on the number of supraspecific taxa, such as genera or families (e.g., Balmford et al., 2000; Bergamini et al., 2005) or the richness within some taxonomic groups (e.g., Beccaloni and Gaston, 1995; Biaggini et al., 2007; Magierowski and Johnson, 2006; Sebastião and Grelle, 2009). In the latter case, Beccaloni and Gaston (1995) found that the richness within a single subfamily of butterflies (Ithomiinae) was highly correlated with the overall butterfly richness in a vast area of central and southern America. A similar pattern was observed in a single order of mammals (Didelphimorphia) and the richness of mammals in Amazonas, Brazil (Sebastião and Grelle, 2009). These approaches are valuable in the case of rapid diversity surveys and especially in the case of communities with inconspicuous or hardly detectable individuals or species (Oliver and Beattie, 1996; Giordani et al., 2009).

Epiphytic lichens are among the most important epiphytic organisms in forests and open woodland in southern Europe (Aragón et al., 2012), however their sampling and identification requires considerable effort, particularly crustose species (microlichens), and in many cases thin-layer chromatography analyses of secondary chemical compounds are necessary for identification (Culberson, 1969). The high costs associated with the assessment of microlichens when nonspecialists are involved in large scale

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surveys, are probably the main reason why they are frequently neglected, although microlichens are more diverse than macrolichens (foliose and fruticose species) in many habitats and regions (Bergamini et al., 2005, 2007; Ellis and Coppins, 2006).

Most previous studies have focused on the major threats that affect lichen diversity: forest fragmentation, forest management, land use, air pollution, and climate change (Moning et al., 2009; Ellis, 2012; Nascimbene et al., 2013a), which have suggested that several lichen species are restricted to old-growth forests with long ecological continuity. Lichens are highly sensitive to small environmental changes (Kranner et al., 2008; Pinho et al., 2012) because their physiology is strongly coupled to humidity, solar radiation, and temperature conditions (Green et al., 2008; Honegger, 2009). Thus, lichens have been used as indicators of ecological conditions and conservation values of forests (Giordani, 2012; Giordani et al., 2012; Pinho et al., 2012). However, there is still limited evidence to support a direct relationship between indicators and lichen species richness in different woodland habitats and their use is still neglected in monitoring programs (Ellis and Coppins, 2006; Ellis, 2012; Nascimbene et al., 2010). In particular, there is a lack of knowledge about Mediterranean woodlands, despite human activities such as clearing and logging, which lead to forest fragmentation (Belinchón et al., 2009; Martínez et al., 2011), and agriculture and livestock grazing (Aragón et al., 2010a; Loppi and Pirintsos, 2000; Pinho et al., 2009), which cause shifts in epiphytic communities, thereby leading to a systematic decline in the species richness and diversity (Aragón et al., 2010a; Loppi and Dominicis, 1996; Nascimbene et al., 2007).

A promising approach is to search for taxonomic groups within lichens that could be used as a surrogate of the total epiphytic richness, given that good surrogates should be correlated with changes in biodiversity due to spatial variability, succession, season, or disturbance (Colwell and Coddington, 1994; Gladstone, 2002; Sarkar et al., 2005; Sauberer et al., 2004). Our main goal was to investigate the possibility of predicting epiphytic lichen richness based on the species richness of a single taxon (family) of macrolichens. As lichens are substrate specialists, we hypothesized that indicators should be determined by the host tree species. Thus, the study was conducted using five tree species in >500 forest stands in a wide range of climatic conditions in the Mediterranean region. In the previous work, Aragón et al. (2010a)) found that mature and unmanaged forests maintained the greatest epiphytic richness, and when forest disturbance was increased the number of epiphytes significantly decreased. In this sense, we also investigated whether species richness of the families tested as indicators were affected by the forest structure, particularly the canopy cover, management intensity, and tree size.

2. Material and methods

2.1. Study area

The study was carried out between 2004 and 2009 in different forested areas in Central Spain (Fig. 1). This landscape is highly heterogeneous and comprises a flat area surrounded by mountains, with a mean plot elevation of 600–1670 m.a.s.l (maximum 2274 m.a.s.l). The climate is Mediterranean with a pronounced summer drought (May to September). The mean annual temperature ranges between 6.2 °C and 16.0 °C, but exceeds 30 °C in summer and is below 0 °C in winter. The annual rainfall ranges from 424 to 1112 mm, with summer rainfall of 35–147 mm.

2.2. Sampling design and data collection

The epiphytic richness is highly influenced by macro- and microclimatic variables (Ellis, 2012), so the 504 sampling plots were randomly selected based on habitat type, altitude, and latitude. We selected the following variables for each plot: potential sun direct incident radiation (PDIR) (MJ cm^{-2} yr^{-1}), which was calculated based on the latitude, slope, and plot exposition (McCune, 2007); summer rainfall (mm) and mean annual temperature (°C), which were taken from CLIMOEST a climate simulator for the Iberian Peninsula (Sánchez-Palomares et al., 1999); mean tree diameter at breast height (cm) of the 15 trees measured per plot as a surrogate of the stand forest structure; canopy cover (%); and management intensity (six levels): 0 = no management; 1 = hunting use; 2 = low-intensity cattle use; 3 = intermediate intensity cattle use; 4 = high-intensity cattle use; 5 = highest intensity of agricultural activities (i.e. cultivated dehesas with interspersed trees) (see Aragón et al., 2010a for additional information on the climatic variables).

Data were collected in five forest types (Table 1): oak forests of *Quercus ilex* ssp. *ballota*, which is an evergreen tree; *Quercus faginea* and *Quercus pyrenaica*, which are semideciduous species; and *Pinus nigra* and *P. sylvestris*, which are coniferous trees. At each site, 15 trees (diameter at breast height >9 cm) were randomly selected within 200 m × 200 m plot. To avoid the effects of different environmental conditions, the plots were always located at least 100 m from the forest edge (Rheault et al., 2003). Each plot was georeferenced (GPSmap 60CSx, Garmin GPS).

At tree level, we recorded the presence of all lichen species up to a height of 2 m. We did not consider species within the first 10 cm from the soil to avoid the inclusion of terricolous lichens (Aragón et al., 2010a). A total of 7560 trees were studied.

2.3. Data analyses

The lichen species were classified into two functional groups based on their growth form: macro- (foliose or fruticose species) or microlichens (crustose species), The macrolichens were grouped into suprageneric ranges at the family level. We only selected suprageneric ranges that included common and widespread species we could easily identify in the field, i.e., Physciaceae (Teloschistales), Parmeliaceae (Lecanorales), Collemataceae (Peltigerales), and the complex known as "rest of Peltigerales" (Pannariaceae, Nephromataceae, Lobariaceae, and Peltigeraceae), which were considered together. The latter are represented by families that comprise very few separate species, but they have very similar ecological requirements (Barkman, 1958; Burgaz et al., 1994). However, Collemataceae was considered as a separate group, which includes species with gelatinous dark thalli that are morphologically and ecologically very different from the families included in the rest of Peltigerales (Otálora et al., 2010). The genera in each family are listed in Appendix A.

We used Pearson's linear correlation coefficients to explore the relationships between the species richness of the four macrolichen groups (pairwise tests) and the total richness of species. We tested the use of indicator taxa at the plot level in two different situations: (1) in each forest type, and (2) in coniferous versus oak forests. In each situation, we evaluated the relationship between the richness of the selected families and the total species richness to determine whether a single family could be used as a total species richness predictor. When testing correlation, the number of species of each family was subtracted to the total richness. For example, when testing Collemataceae as potential predictor, the total species richness would be the sum of all species except Collemataceae. To avoid Type I errors, the alpha values were divided by the number of correlations (four correlations) (Sebastião and Grelle, 2009).

In addition, we modeled the effects of the climatic variables (mean annual temperature, annual rainfall, and PDIR) and forest stand variables (canopy cover, mean tree diameter, and management intensity) on the richness of the families by fitting generalized