



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 (Kranter 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) ($\text{MJ cm}^{-2} \text{yr}^{-1}$), 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” (Panariaceae, 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

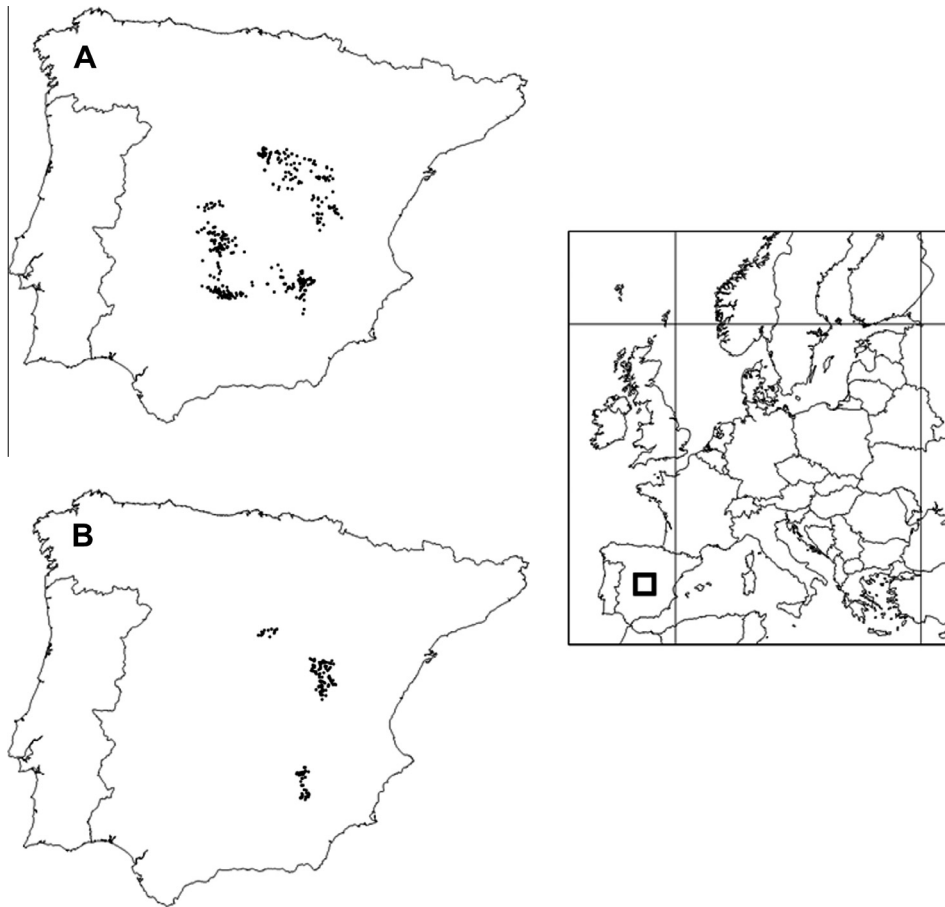


Fig. 1. Map of Spain showing the sites sampled. (A) Oak woodlands and (B) Coniferous woodlands.

Table 1

Environmental parameters for the five different forest types. Means \pm SD for the different parameters, and minimum and maximum values are included in parentheses.

	No. of plots	Elevation (m.a.s.l.)	Tree diameter (cm)	Canopy cover (%)
<i>Quercus ilex ballota</i>	132	904.95 \pm 241.71 (500–1450)	25.01 \pm 9.64 (11.36–61.66)	47.29 \pm 20.33 (10–95)
<i>Q. faginea</i>	147	964.74 \pm 222.32 (550–1460)	26.21 \pm 6.89 (12.19–41.09)	45.93 \pm 19.96 (10–95)
<i>Q. pyrenaica</i>	58	1191.37 \pm 218.31 (824–1650)	24.79 \pm 8.35 (11.91–48.95)	60.64 \pm 19.17 (20–90)
<i>Pinus nigra</i>	110	1352.29 \pm 124.09 (933–1630)	32.74 \pm 9.31 (14.96–61.86)	57.22 \pm 16.62 (20–90)
<i>P. sylvestris</i>	57	1510.66 \pm 102.57 (1279–1670)	34.26 \pm 7.69 (18.62–58.21)	58.24 \pm 15.82 (15–90)

linear models (GENMOD SAS v. 9) (McCullagh and Nelder, 1989). The significance of each predictor was estimated using a deviance test (Guisan et al., 2002). Predictors were excluded from the model when the level of significance was higher than 0.05. We assumed Poisson errors for the response variables.

3. Results

A total of 182 epiphytic species were identified, 93 in coniferous forests, 135 in oak forests, and 46 in both types of forest. 47 and 89 species were unique to coniferous and oak forests, respectively. Ninety species were foliose or fruticose (macrolichens) and 92 were crustose (microlichens). The most common families of macrolichens were Parmeliaceae (34 species), followed by Physciaceae (16 species), Collemataceae (16 species), and the rest

of Peltigerales (Lobariaceae, Nephromataceae, Pannariaceae, and Peltigeraceae) (15 species). Teloschistaceae (2 species), Cladoniaceae (4 species), and Ramalinaceae (3 species) were not included in the analyses.

The total species richness in each forest type and the species richness of each suprageneric range selected are listed in Table 2. Parmeliaceae was the most common group in all of the forest types whereas the remaining families were mainly associated with *Quercus* forest stands. The number of species per plot ranged from 10 to 53 (Table 2).

Collemataceae was highly and positively correlated with the “rest of Peltigerales” whereas Physciaceae was negatively correlated with these two families (Table 3). In oak forest plots, the increase in the richness of Collemataceae and the “rest of Peltigerales” was highly and significantly correlated with the increase in the total species richness (Tables 4 and 5, Fig. 2). A similar

Table 2
Species richness of each forest type and the average (\pm SD) at the plot level. Phy = Physciaceae, Par = Parmeliaceae, Coll = Collemataceae, Rest Pelt. = rest of Peltigerales.

Forest type						Plot level	
	Total	Phy	Par	Coll	Rest. Pelt.	Average	Max/min
<i>Quercus ilex ballota</i>	108	16	17	11	9	27.64 \pm 7.53	53/15
<i>Q. faginea</i>	112	14	18	11	10	29.79 \pm 7.23	49/18
<i>Q. pyrenaica</i>	85	10	21	7	12	26.36 \pm 6.14	41/17
<i>Pinus nigra</i>	90	6	22	0	0	22.24 \pm 6.15	37/10
<i>P. sylvestris</i>	75	2	20	0	0	22.77 \pm 6.31	40/13

trend was found for the richness of Parmeliaceae and the total richness in coniferous forests (Tables 4 and 5, Fig. 2). However, Physciaceae was not significantly correlated with the total species richness.

In oak forests, results of the models (GENMODs) showed that species richness of Collemataceae and the “rest of Peltigerales” increased in plots with low management intensity and high canopy cover, whereas the richness of Physciaceae exhibited the opposite pattern. However, there were no relationships between the management intensity and the richness of Parmeliaceae (Table 6). The models for coniferous forests showed that the richness of Parmeliaceae was greater in forest with low management intensity, high average tree diameters and high canopy cover (Table 6). For the macro-climatic conditions, we found that summer rainfall was an important variable that favored the richness of Collemataceae, “rest of Peltigerales,” and Parmeliaceae. However, it was notable that we did not find any effects on coniferous forests.

4. Discussion

Our results showed that we could predict the total species richness of epiphytic lichens in a wide range of forests in the

Table 3
Pairwise correlations among the species richness for each taxonomic group evaluated.

	Parmeliaceae	Collemataceae	Rest of peltigerales
<i>Quercus ilex ballota</i>			
Physciaceae	0.139 (0.112)	-0.450 (<0.0001)	-0.459 (<0.0001)
Parmeliaceae		-0.176 (0.044)	0.261 (0.003)
Collemataceae			0.804 (<0.0001)
<i>Q. faginea</i>			
Physciaceae	0.240 (0.003)	-0.429 (<0.0001)	-0.318 (<0.0001)
Parmeliaceae		0.288 (<0.0001)	0.421 (<0.0001)
Collemataceae			0.815 (<0.0001)
<i>Q. pyrenaica</i>			
Physciaceae	0.067 (0.616)	-0.341 (0.009)	-0.494 (<0.0001)
Parmeliaceae		-0.023 (0.863)	0.052 (0.660)
Collemataceae			0.887 (<0.0001)
<i>Pinus sylvestris</i>			
Physciaceae	0.010 (0.943)	No lichens	No Lichens
Parmeliaceae		No lichens	No lichens
Collemataceae			No lichens
<i>P. nigra</i>			
Physciaceae	-0.276 (0.004)	No lichens	No lichens
Parmeliaceae		No lichens	No lichens
Collemataceae			No lichens
<i>Quercus</i>			
Physciaceae	0.000 (0.998)	-0.316 (<0.0001)	-0.420 (<0.0001)
Parmeliaceae		0.014 (0.801)	0.252 (<0.0001)
Collemataceae			0.750 (<0.0001)
<i>Pinus</i>			
Physciaceae	-0.246 (0.001)	No lichens	No lichens
Parmeliaceae		No lichens	No lichens
Collemataceae			No lichens

$\alpha = 0.05/6 = 0.008$.

Table 4

Pearson's correlation coefficients of each family and the total species richness.

	<i>Quercus</i>	<i>Pinus</i>
Physciaceae	-0.055 (0.317)	-0.106 (0.172)
Parmeliaceae	0.293 (<0.0001)	0.730 (<0.0001)
Collemataceae	0.765 (<0.0001)	No lichens
Rest of Peltigerales	0.795 (<0.0001)	No lichens

$\alpha = 0.05/4 = 0.0125$.

Mediterranean region based on the species richness of single taxa (i.e., families). This study reveals that, because lichens are substrate specialists, their composition differs among coniferous and oak forests, and their indicators must also be different. The species richness of Collemataceae and the “rest of Peltigerales” from oak forests, as well as Parmeliaceae from coniferous forests were the best predictors of the total epiphytic species. This is important because the clear formulation of monitoring guidelines for identifying lichen conservation sites should be forest type-specific.

In oak forests, we found that the two groups evaluated within Peltigerales (i.e., Collemataceae and rest of Peltigerales) were highly correlated and were affected by the intensity of management and summer rainfall. This correlation between the groups may have been because they have higher ecological and physiological requirements, as follows.

First, it is widely accepted that, mature and dense forests with unaltered forest interior environments appear to maintain the greatest epiphytic richness in Mediterranean climatic conditions (see Aragón et al., 2010a). The species richness of Peltigerales was also greater in dense and unmanaged forests because their physiology is closely coupled to humidity and they can suffer photoinhibition with excessive radiation (Kranter et al., 2008; Lange et al., 2004). Thus, the habitat features of dense forests may compensate sub-optimal climatic conditions in more xeric areas (Marini et al., 2011).

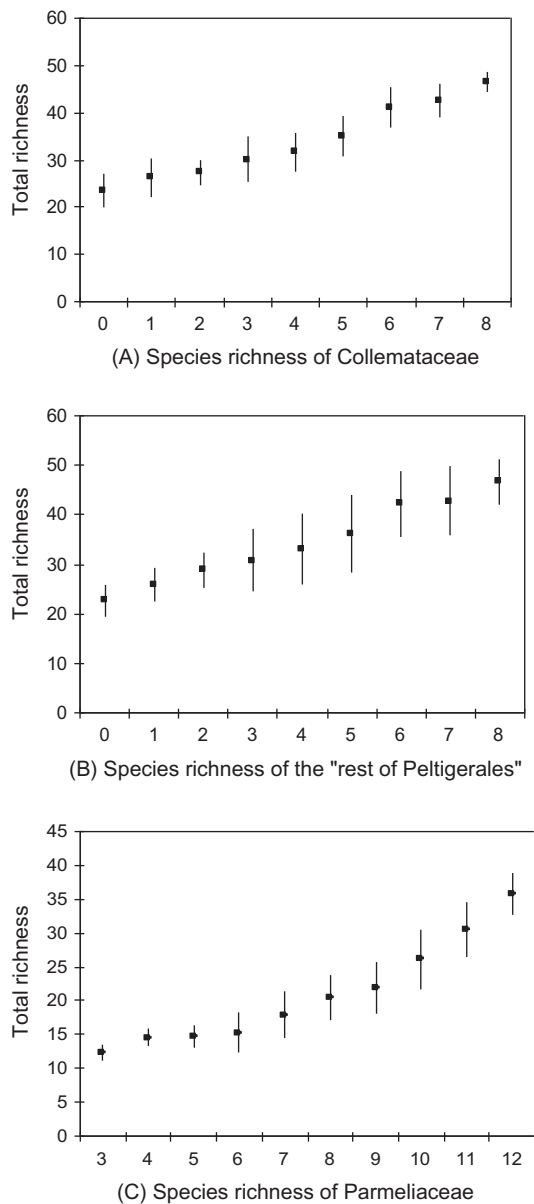
Second, forest management (clearing and logging) can affect the humidity, temperature, and light conditions inside forests, thereby causing the disappearance of the most demanding Peltigerales species (Johansson, 2008; Nascimbene and Marini, 2010). This could be related to the absence of cortical pigments, which protect the thallus from excessive irradiation, and the presence of cyanobacterial photosynthetic partners in most species, which are strongly coupled to liquid water availability (Honegger, 2009; Kranter et al., 2008; Marini et al., 2011). Similarly, the high irradiance in more open woodlands and the high rate of deposition of nutritious dusts related to agricultural and livestock could also lead to the general impoverishment of lichen communities (Aragón et al., 2010b; Hedenäs and Ericson, 2004; Pinho et al., 2009).

Third, forest disturbances may have immediate and negative effects on lichen persistence but there are great variations among species of Peltigerales in their responses to the increased levels of irradiance, water stress, and wind exposure caused by disturbances (Johansson, 2008; Kranter et al., 2008). For example, in a selective cutting experiment that affected evapotranspiration, irradiation, and wind speed, Hedenäs and Ericson (2003) detected

Table 5

Pearson's correlation coefficients of each family and the total species richness.

	<i>Quercus ilex ballota</i>	<i>Q. faginea</i>	<i>Q. pyrenaica</i>	<i>Pinus sylvestris</i>	<i>P. nigra</i>
Physciaceae	−0.197 (0.023)	−0.122 (0.140)	−0.270 (0.040)	0.026 (0.848)	−0.133 (0.165)
Parmeliaceae	0.261 (0.003)	0.543 (<0.0001)	0.243 (0.066)	0.718 (<0.0001)	0.744 (<0.0001)
Collemataceae	0.750 (<0.0001)	0.822 (<0.0001)	0.874 (<0.0001)	No lichens	No lichens
Rest of Peltigerales	0.814 (<0.0001)	0.879 (<0.0001)	0.894 (<0.0001)	No lichens	No lichens

 $\alpha = 0.05/4 = 0.0125$.**Fig. 2.** Relationship between total epiphytic species richness (at plot level) and the species richness of a single family for oak forests (A and B) and coniferous forests (C).

different responses in the vitality, growth, and damage in three cyanolichens. The thalli of *Collema* species grew slowly and were fragmented because of their decreased size, whereas those of *Leptogium saturninum* were less affected (Hedenås and Ericson, 2003). Recently, Aragón et al. (2010a, 2010b) showed that typical forested lichens were present in open woodlands but their

Table 6

Results of the generalized linear models (GENMODs) of the species richness for Parmeliaceae, Physciaceae, Collemataceae, and the "rest of Peltigerales." PDIR = Potential solar direct incident radiation. Coef: coefficient of the variable in the model. SE: Standard error. χ^2 : Chi-square; *P*: level of significance of the model corrected for multiple comparisons using Holm's method ($P < 0.05$). Significant correlations are in bold.

	Coef. (SE)	χ^2	<i>P</i>
<i>Quercus</i> (Oak forests)			
Rest of Peltigerales			
Mean annual temperature	−0.0097 (0.0320)	0.09	0.7624
Summer rainfall	0.0108 (0.0034)	10.20	0.0014
PDIR	−0.1677 (0.2956)	0.32	0.5705
Canopy cover	0.0268 (0.0028)	88.42	<0.0001
Mean tree diameter	0.0041 (0.0067)	0.38	0.5393
Management intensity	−0.1709 (0.0506)	11.39	0.0007
Collemataceae			
Mean annual temperature	0.0025 (0.0015)	2.97	0.0846
Summer rainfall	0.0085 (0.0022)	15.53	<0.0001
PDIR	1.2566 (0.3193)	15.48	<0.0001
Canopy cover	0.0205 (0.0028)	53.47	<0.0001
Mean tree diameter	0.0270 (0.0069)	15.42	<0.0001
Management intensity	−0.2723 (0.0514)	28.09	<0.0001
Parmeliaceae			
Mean annual temperature	−0.0002 (0.0007)	0.07	0.7965
Summer rainfall	0.0028 (0.0007)	14.73	0.0001
PDIR	0.2451 (0.1467)	2.79	0.0947
Canopy cover	0.0040 (0.0011)	12.71	0.0004
Mean tree diameter	−0.0171 (0.0026)	44.29	<0.0001
Management intensity	−0.0192 (0.0175)	1.20	0.2724
Physciaceae			
Mean annual temperature	−0.0000 (0.0005)	0.01	0.9259
Summer rainfall	0.0003 (0.0007)	0.15	0.6988
PDIR	0.7825 (0.1478)	28.03	<0.0001
Canopy cover	−0.0052 (0.0010)	25.37	<0.0001
Mean tree diameter	−0.0023 (0.0022)	1.11	0.2920
Management intensity	0.0467 (0.0153)	9.36	0.0022
<i>Pinus</i> (coniferous forests)			
Parmeliaceae			
Mean annual temperature	0.0012 (0.0019)	0.37	0.5440
Summer rainfall	0.0009 (0.0009)	0.88	0.3477
PDIR	−0.0819 (0.1122)	0.53	0.4653
Canopy cover	0.0028 (0.0011)	6.46	0.0110
Mean tree diameter	0.0083 (0.0016)	26.18	<0.0001
Management intensity	−0.0993 (0.0247)	16.16	<0.0001
Physciaceae			
Mean annual temperature	0.0180 (0.0639)	0.08	0.7785
Summer rainfall	−0.0191 (0.0271)	0.50	0.4809
PDIR	5.8763 (3.3737)	3.03	0.0815
Canopy cover	−0.0467 (0.0349)	1.79	0.1805
Mean tree diameter	0.1173 (0.0555)	4.46	0.0347
Management intensity	0.1319 (0.5201)	0.06	0.7999

moisture retention was greater in more favorable habitats (tree bases, northern sides of tree trunks, or linked to bryophytes) where direct solar radiation was lower.

However, we recommend using the complex known as “rest of Peltigerales” rather than the family Collemataceae because (1) the species are taxonomically more stable, and (2) they can be more easily recognized in field by nonspecialists (e.g., forests service crews). For example, minutely foliaceous species of Collemataceae such as *Collema fragrans*, *Leptogium intermedium*, *L. subaridum* or *L. subtile*, can be hardly identifiable in field, while small thalli of *Fuscopannaria mediterranea* or *F. ignobilis*, included in “rest of Peltigerales”, are easily sampled.

Similar to oak forests, old-growth and dense coniferous forests possess a higher epiphytic richness than managed or younger forests (Essen et al., 1996; Hauck, 2011; Lesica et al., 1991) because many epiphytic lichens are bound to old forests with long continuity (Coppins and Coppins, 2002; Hauck, 2011; Rose, 1992; Tibell, 1992). Inconspicuous specialist species are frequent in these environmental conditions and some groups have been proposed for use in assessing the epiphytic diversity (Coppins and Coppins, 2002). For example, calicioid species (Caliciales s.l.) have been assessed as high species diversity indicators in pine forests (Selva, 1994, 2002; Tibell, 1992), although previous researchers have emphasized the time demands of investigating the potential microsites of these species and the difficulties of identifying species in the field (Tibell, 1992; Marmor et al., 2011).

Our results showed that the species richness of Parmeliaceae was significantly correlated to the total epiphytic richness in coniferous forests. Parmeliaceae encompasses strong to moderate photophilous species, which live in almost all environmental conditions and they are usually moderately sensitive to eutrophication (see Hauck, 2011). In oak forests, the Parmeliaceae group was composed mainly of generalist species belonging to *Melanelixia*, *Melanohalea*, and *Parmelia* (Nimis and Martellos, 2008). In coniferous forests, however, the Parmeliaceae comprised a subset of rather frequent specialist species belonging to *Bryoria*, *Cetraria*, *Letharia* or *Usnea*, which were favored to the environmental conditions in dense forests (e.g., high humidity and low light levels) (Essen et al., 1996; Hauck, 2011) and to the effect of tree size (i.e., a longer time period available for colonization, see Hauck, 2011; Moning et al., 2009).

Finally, as expected, Physciaceae were not correlated with the increase in the total species richness. Physciaceae includes several nitrophytic species belonging to *Phaeophyscia*, *Physcia*, and *Physconia*, which are favored by the increased deposition of nutrient-bearing dust (Aragón et al., 2010b; Motiejūnaitė and Faūtynowick, 2005). They are linked to open and managed woodlands (that contain agriculture and livestock) where the species richness is lower compared with undisturbed stands (Aragón et al., 2010a).

From a conservation perspective, our approach supports the requirement of using scientific results in applied conservation biology by identifying “easy lichen groups” that can be used to detect areas of high lichen biodiversity. This is the case of the both groups proposed: the “rest of Peltigerales” and Parmeliaceae for oak and coniferous forests respectively. This may allow land managers or administrators who lack a deep knowledge of lichenology to become active partners in conservation programs. The economic resources available for research projects are decreasing at present so it is necessary to find alternative methods that will allow us to continue the identification of priority areas for conservation.

Species richness is a fundamental measure of the biodiversity to be considered for practical conservation, although its usefulness is not always desirable because its interpretation entails difficulties (Magurran, 2004). For example, in areas with various forms of disturbance could coexist a mixture of species of many communities, and the total species richness might be higher than the original habitat type (Hambler, 2004; Nordén et al., 2007). Moreover, species richness is often not recommended to evaluate habitat conservation because a high value in many areas, not always involve the

presence of endemic or threatened species (Prendergast et al., 1993). Thus further studies are needed to find indicators for other community traits such as the species abundance–dominance, species turnover or the presence of rare and threatened species.

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Appendix A.

Genera within each family that were considered as potential predictors of the total species richness. The number of species within each genus is shown in parentheses.

Physciaceae

Anaptychia (1)
Phaeophyscia (2)
Physcia (6)
Physconia (7)

Parmeliaceae

Bryoria (3)
Cetraria (1)
Evernia (1)
Flavoparmelia (2)
Flavopunctelia (1)
Hypogymnia (3)
Imshaugia (1)
Melanophaea (4)
Melanelixia (4)
Parmelia (3)
Parmelina (2)
Parmeliopsis (1)
Parmotrema (1)
Platismatia (1)
Pleurosticta (1)
Punctelia (1)
Pseudevernia (1)
Usnea (3)

Collemataceae

Collema (8)
Leptogium (8)

“Rest of Peltigerales”

Pannariaceae

Degelia (2)
Fuscopannaria (3)
Parmeliella (1)

Peltigeraceae

Peltigera (3)

Nephromataceae

Nephroma (3)

Lobariaceae

Lobaria (3)

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