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Biogeographical outline of epiphytic lichens in a Mediterranean area: Calabria (S Italy)

Guido INCERTI and Pier Luigi NIMIS

Abstract: This paper aims to provide a biogeographical analysis of the epiphytic lichen flora of S Calabria by means of chorograms (i.e. distributional maps showing the joint distribution of multiple taxa). Two datasets on both local and Italian distribution were used. Local distribution is described by records of 135 epiphytic species in 14 sampling sites (5 trees per site, boles sampled from the ground to 2 m) representing the main vegetation belts of the survey area. A cluster analysis of the species, based on their commonness-rarity in the 9 main bioclimatic areas and in the 20 administrative regions of Italy, was applied. For each of the 7 clusters of species (chorotypes), a chorogram was produced. The matrix of species and sites was also submitted to numerical classification, and 5 clusters of sites were obtained, corresponding to the main altitudinal belts and tree species. For each group of sites, the frequencies of chorotypes were calculated. The results show a clear relationship between local distribution, mainly related to ecological conditions, and the Italian one. The truly Mediterranean forests of the survey area have the highest incidence of the Tyrrhenian element. Beech forests of the montane belt, dominated by broad-ranging lichens, are the most diverse biogeographically. The pine forests lying above the temperate belt do not host a peculiar lichen flora, being dominated by broad-ranging circumboreal species.

Key words: biogeography, Calabria, chorograms, epiphytic lichen distribution, Mediterranean region

Introduction

The analysis of the relationships between ecology and distribution is a basic topic in biogeography. Hultén (1937) was the first to produce maps showing the joint distribution of plants with similar ecology, in order to identify refugial areas during the glacial period. However, Hultén's method of ''equiformal progressive areas'' was rapidly abandoned, mainly because distributional maps were scarce, and because the taxa to be jointly mapped were selected subjectively (Ritchie 1984). In the last decades, since the works by Proctor (1967), Jardine (1972), and Birks (1976), an operational-quantitative approach in the analysis of phytogeographical data has been adopted by several authors (Birks 1987; Pedersen 1990; Hill 1991; Nimis & Crovello 1991; Carey *et al.* 1995; Lawesson & Skov 2002). A matrix of species and their occurrence in OGUs (Operational Geographic Units, see Crovello 1981) can be submitted to multivariate analysis. Cluster analysis, in particular, permits objectively detecting groups of species with similar distribution patterns. These can be depicted by means of chorograms, that is maps showing the joint distribution of a set of taxa. These developments brought several authors to re-discover Hultén's approach (Phipps 1975; Phipps & Cullen 1976; Andersson 1988; Nimis & Bolognini 1990; Myklestad & Birks 1993). Chorograms were used to study the relationship between ecology and distribution of vascular plants in Alaska-Yukon, Siberia and Europe (Nimis 1982; Nimis & Bolognini 1993; Bolognini *et al.* 1994; Nimis *et al.* 1994; Nimis & Fonda 1997; Marquez *et al.* 1997), based on the assumption that the

G. Incerti & P. L. Nimis: Dipartimento di Biologia, Università di Trieste, via L. Giorgieri, 10—I34127 Trieste, Italy.

distribution of taxa depends on both present and past ecological conditions. Chorograms were also used to evaluate the phytogeographical diversity of a whole flora, that of the Putorana Plateau in N Siberia (Nimis *et al*. 1998). They were also used to study the relationship between species' distribution and climatic requirements within a local flora in NE Italy (Poldini *et al.* 1990), and the centres of differentiation of the genus *Allium* in Siberia and Mongolia (Friesen *et al.* 1993). Malyshev (1991) suggested the use of chorograms in comparative floristics, as a tool to reveal distributional differences, and to plan conservation strategies. According to Ritchie (1984), chorograms, although based on a formally rigorous method, could lead to trivial results if not interpreted on the basis of the ecological knowledge.

Lichens, broad-ranging organisms sensitive to air humidity, can contribute even more than vascular plants to outline the bioclimatic features of an area (Nimis & Losi 1984; Nimis & Tretiach 2004). However, chorograms have been rarely used by lichenologists (e.g. Nimis 1985), probably because reliable distributional maps were not available for most species. A recent study on a continental scale (Otte *et al.* 2005), related the distribution of European species of *Melanelia* Essl. with ecogeographical and historical factors, on the basis of distributional maps produced by the 'areal formula' of Meusel *et al.* (1965). Presently, detailed distributional maps are more available and complete than in the past, both for national floras (e.g. Seaward 1995, 1996, 1998, 1999) and in monographic revisions (Otte *et al.* 2002; Bielczyk *et al.* 2004; Litterski & Ahti 2004). In particular, Nimis & Martellos (2002) included distributional information in their on-line information system on Italian lichens, which now makes possible the use of chorograms for the Italian lichen flora.

This paper analyses, by means of a quantitative approach focused on the production of chorograms, the relation between local and Italian distribution of epiphytic lichens along an altitudinal gradient in Southern Calabria. It is intended as a case-study to show the application of a methodology much used for vascular plants to the analysis of lichen biogeography in the Mediterranean region.

Data

Two datasets were used: the analysis of the local distribution is based on a matrix of 135 species and 14 sites in S Calabria derived from the paper of Bartoli *et al.* (1991), while the analysis of Italian distribution is based on a matrix of the same species, and of 98 subdivisions (OGUs) of the whole of Italy (see below). Nomenclature follows Nimis (2003).

Local distribution

Field data (Table 1) were derived from a study by Bartoli *et al.* (1991) in the northern and western slopes of the Aspromonte Massif in S Calabria, from the Gioia Tauro plain up to *c.* 1300 m (Fig. 1, list of localities in Table 2). The climate of this area is generally Mediterranean, but the summer drought period is rather short owing to high rainfall during spring and autumn. The suboceanic character is still more evident in stations of upland areas, where a fog-belt is frequent. The vegetation has been deeply modified by human activities, above all in the lowlands, where natural forests have been replaced by old, close-canopied *Olea*-plantations. The following main vegetational belts can be recognized: (1) *Olea* plantations: from sea level to *c.* 500 m, which replace the natural evergreen forests; (2) relics of evergreen vegetation dominated by *Quercus ilex* and *Q. suber*: very rare in the lowlands and restricted to refugial sites on south-facing slopes between 400 and 600 m; (3) *Castanea* stands: mainly planted in the fog belt at *c.* 800 m; (4) natural beech and mixed *Abies–Fagus* forests: above 800 m and (5) natural *Pine* stands in the driest areas of the mountain summits. Bartoli *et al.* (1991) sampled a broad spectrum of ecological conditions, especially altitude and dominant tree species. Fourteen sampling sites were selected in such a way as to represent the main vegetation belts (Fig. 1). At each site, 5 trees were randomly selected and the species present on the boles from the ground level to 2 m were recorded. Each site is represented by a vector with the species and their frequencies, ranging from 0 (absent in the sampling site) to 5 (species found on every tree).

Italian distribution

The distributional maps in Italy are from Nimis (2003). The country was subdivided into several OGUs deriving from the overlapping of two basic subdivisions (Fig. 2): (a) the 21 administrative regions and (b) 9 phytoclimatic areas delimited on the basis of several GIS maps (altitude, precipitation, etc.). Since not all phytoclimatic areas occur in each region, the total number of OGUs is 98. The 9 phytoclimatic areas are:

(A) *alpine* area, above the treeline in the Alps and in the highest peaks of the Apennines;

TABLE 1. *All lichens recorded in the 14 sampling sites together with their frequencies, expressed on a 5-class scale. Data are taken from Bartoli* et al. *(1991)*

Taxon*	Sampling sites†													
	O5	O3	O2	O1	C1	O4	S1	L2	L1	F3	F2	F1	P2	P1
Acrocordia gemmata (Ach.) A. Massal.	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arthonia dispersa (Schrad.) Nyl.	–	–	–	–	–	–	–	1	–	–	–	–	–	–
A. pruinata (Pers.) A.L.Sm.	1	–	2	–	–	–	–	–	–	–	–	3	–	–
Arthopyrenia cinereopruinosa (Schaer.) A.Massal.	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Bacidia rubella (Hoffm.) Massal.	3	2	–	–	–	–	–	–	–	–	–	–	–	–
Bactrospora patellarioides (Nyl.) Almq.	2	2	2	3	–	1	–	–	–	–	–	–	–	–
Biatorella ochrophora (Nyl.) Arnold	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Bryoria fuscescens (Gyeln.) Brodo & D.Hawskw.	–	–	–	–	–	–	–	–	–	–	–	–	2	3
Buellia disciformis (Fr.) Mudd	–	–	–	–	–	–	–	–	–	3	1	–	–	–
B. erubescens Arnold	–	–	–	–	–	–	–	–	–	–	–	–	3	4
B. griseovirens (Sm.) Almb.	–	–	–	–	–	–	–	1	2	–	2	–	–	–
Caloplaca ferruginea (Huds.) Th. Fr.	–	2	–	–	2	1	1	–	–	–	–	–	–	1
C. herbidella (Hue) H.Magn.	1	–	1	–	–	2	–	1	–	–	–	–	–	–
C. lucifuga G. Thor	–	–	–	–	2	–	–	–	–	–	–	–	–	–
C. pyracea (Ach.) Th.Fr.	–	–	–	–	–	–	–	–	2	–	–	–	–	–
Candelariella reflexa (Nyl.) Lettau	–	1	1	–	–	–	–	–	–	–	–	–	–	–
Catillaria nigroclavata (Nyl.) Schuler	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Catinaria atropurpurea (Schaer.) Vězda & Poelt	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Chromatochlamys muscorum (Fr.) H.Mayrhofer & Poelt	–	–	–	–	–	1	–	–	–	–	–	–	–	–
Chrysothrix candelaris (L.) J.R.Laundon	–	2	2	–	–	–	–	–	–	–	–	–	–	–
Cladonia fimbriata (L.) Fr.	–	–	1	–	–	–	–	–	–	–	–	–	–	2
C. parasitica (Hoffm.) Hoffm.	–	–	–	–	–	2	1	–	–	–	–	–	–	–
C. pyxidata (L.) Hoffm.	–	–	–	–	–	–	–	–	–	–	–	–	2	–
Collema ligerinum (Hy) Harm.	–	–	–	3	–	–	–	–	–	–	–	–	–	–
C. nigrescens (Huds.) DC.	4	3	2	–	3	4	1	–	2	–	–	–	–	–
Collema subflaccidum Degel.	–	–	–	–	4	3	–	–	–	–	–	–	–	–
Degelia atlantica (Degel.) P.M.Jørg. & P.James	1	2	–	–	2	–	–	–	–	–	–	–	–	–
D. plumbea (Lightf.) P.M.Jørg. & P.James	–	–	–	–	5	1	1	–	–	–	1	–	–	–
Dendriscocaulon umhausense (Auersw.) Degel.	–	–	–	–	2	2	–	–	–	–	–	–	–	–
Dimerella pineti (Ach.) Vězda	–	–	–	3	–	–	–	1	–	–	–	–	–	1
Evernia prunastri (L.) Ach.	–	1	1	–	–	1	2	2	–	–	2	–	–	–
Flavoparmelia caperata (L.) Hale	3	5	5	–	–	–	4	–	3	–	2	–	–	–
F. soredians (Nyl.) Hale	–	2	1	–	–	–	3	–	–	–	–	–	–	–
Fuscidea stiriaca (A.Massal.) Hafellner	–	–	–	–	–	–	–	–	–	–	1	5	–	–
Fuscopannaria ignobilis (Anzi) P.M.Jørg.	1	1	2	–	5	3	–	–	–	–	–	–	–	–

Table 1. *Continued*

Taxon*	Sampling sites†													
	O5	O3	O2	O1	C1	O4	S1	L2	L1	F3	F2	F1	P2	P1
Graphis scripta (L.) Ach.	–	–	–	–	–	–	–	–	–	4	–	–	–	–
Gyalecta flotowii Körb.	3	1	–	3	–	–	–	–	–	–	–	–	–	–
Haematomma ochroleucum (Neck.) J.R.Laundon	–	–	–	–	–	–	–	2	3	–	1	–	–	–
Heterodermia obscurata (Nyl.) Trevis.	2	3	2	–	–	2	–	–	–	–	–	–	–	–
Hyperphyscia adglutinata (Flörke) H.Mayrhofer & Poelt	–	2	–	3	–	–	–	–	–	–	–	–	–	–
Hypogymnia farinacea Zopf	–	–	–	–	–	–	–	–	–	–	–	–	5	3
H. physodes (L.) Nyl.	–	–	–	–	–	–	–	–	–	–	–	–	3	2
H. tubulosa (Schaer.) Hav.	–	–	–	–	–	–	–	–	–	–	–	–	2	–
Hypotrachyna revoluta (Flörke) Hale	1	1	–	–	–	–	–	–	–	–	–	–	–	–
Imshaugia aleurites (Ach.) S L.F. Meyer	–	–	–	–	–	–	–	–	–	–	–	–	2	–
Lecanographa amylacea (Pers.) Egea & Torrente	1	–	1	3	–	–	–	–	–	–	–	–	–	–
Lecanora argentata (Ach.) Malme	–	–	–	–	–	–	1	–	–	2	4	5	–	1
L. chlarotera Nyl.	–	2	–	–	2	2	2	3	5	4	1	–	–	–
L. horiza (Ach.) Linds.	–	1	–	–	–	–	–	–	2	–	–	–	–	–
L. intumescens (Rebent.) Rabenh.	–	–	–	–	–	–	–	3	3	3	2	5	–	–
L. leptyrodes (Nyl.) Degel.	–	–	–	–	–	–	–	–	2	2	1	–	–	–
L. pulicaris (Pers.) Ach.	–	–	–	–	–	–	–	–	–	–	–	–	4	–
L. saligna (Schrad.) Zahlbr.	–	–	–	–	–	–	–	–	–	–	–	–	–	1
L. varia (Hoffm.) Ach.	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Lecidella elaeochroma (Ach.) M.Choisy	1	3	–	–	–	1	3	5	5	–	2	–	–	1
Lepraria incana (L.) Ach.	–	–	1	–	–	–	1	–	–	2	–	–	–	–
Leprocaulon micoroscopicum (Vill.) Gams.	–	–	3	–	–	1	–	–	–	–	–	–	–	–
Leptogium lichenoides (L.) Zahlbr.	–	–	–	–	–	1	–	–	–	–	–	–	–	–
L. saturninum (Dicks.) Nyl.	–	–	–	–	2	–	–	–	–	–	–	–	–	–
Lobaria amplissima (Scop.) Forssell	–	–	–	–	5	2	–	–	–	–	–	3	–	–
L. pulmonaria (L.) Hoffm.	–	–	–	–	5	–	1	–	–	2	1	5	–	–
Lobarina scrobiculata (Scop.) Nyl.	–	–	–	–	–	–	–	–	2	–	1	–	–	–
Melanelia elegantula (Zahlbr.) Essl.	–	–	–	–	–	2	–	–	–	–	–	–	–	–
M. exasperata (De Not.) Essl.	–	1	–	–	–	–	–	–	–	–	–	–	–	1
M. exasperatula (Nyl.) Essl.	–	–	–	–	–	–	–	–	–	–	–	–	–	2
M. fuliginosa (Duby) Essl. subsp. *glabratula*	–	–	–	–	3	1	1	–	2	2	4	3	2	–
M. glabra (Schaer.) Essl.	–	–	–	–	5	–	–	–	–	–	–	–	–	–
M. laciniatula (H.Olivier) Essl.	–	–	–	–	–	–	–	–	–	–	–	3	–	–
M. subaurifera (Nyl.) Essl.	–	–	–	–	–	1	5	4	2	–	2	–	–	–

TABLE 1. *Continued*

Taxon*	Sampling sites†													
	O5	O3	O2	O1	C1	O4	S1	L2	L1	F3	F2	F1	P2	P1
Nephroma laevigatum Ach.	1	–	2	–	4	2	1	–	–	–	1	–	–	–
Normandina pulchella (Borrer) Nyl.	–	3	2	–	2	3	2	–	–	–	2	–	–	–
Ochrolechia arborea (Kreyer) Almb.	–	–	–	–	–	2	–	–	–	–	–	–	–	–
O. balcanica Verseghy	–	2	1	–	2	–	–	–	–	–	–	–	–	–
O. pallescens (L.) A.Massal.	–	–	–	–	2	–	–	–	–	–	–	–	–	–
O. subviridis (Høeg) Erichsen	1	–	4	–	3	3	–	–	–	–	–	–	–	–
Opegrapha celtidicola (Jatta) Jatta	2	–	–	3	–	–	–	–	–	–	–	–	–	–
O. rufescens Pers.	–	–	–	–	–	–	–	–	–	2	1	3	–	–
O. viridis (Ach.) Behlen & Desberger	1	–	1	3	–	–	–	–	–	–	–	–	–	–
Pachyphiale carneola (Ach.) Arnold	–	–	–	–	–	–	–	–	2	–	–	–	–	–
Pannaria conoplea (Ach.) Bory	–	–	–	–	3	–	–	–	–	–	–	–	–	1
Parmelia saxatilis (L.) Ach.	–	–	–	–	–	–	–	–	–	–	2	5	2	–
P. sulcata Taylor	2	3	2	–	–	1	3	1	–	–	5	5	–	1
Parmeliella testacea P.M.Jørg.	–	–	–	–	3	3	1	–	–	–	–	–	–	–
Parmelina pastillifera (Harm.) Hale	–	–	–	–	–	–	–	–	–	–	3	–	–	–
P. quercina (Willd.) Hale	–	3	1	–	4	1	–	1	–	–	1	–	–	–
P. tiliacea (Hoffm.) Hale	3	1	1	–	5	3	–	–	–	–	1	–	–	–
Parmeliopsis ambigua (Wulfen) Nyl.	–	–	–	–	–	–	–	–	–	–	–	–	3	1
Parmotrema chinense (Osbeck.) Hale & Ahti	–	5	1	–	–	1	5	–	3	–	3	–	–	–
P. reticulatum (Taylor) M.Choisy	3	5	5	3	–	–	3	–	–	–	1	–	–	–
Peltigera collina (Ach.) Schrad.	–	–	–	–	3	–	–	–	–	–	–	–	–	–
Pertusaria albescens (Huds.) M.Choisy & Werner	2	1	4	–	5	5	–	–	–	–	–3	3	–	–
P. amara (Ach.) Nyl.	1	4	5	–	3	4	3	4	–	3	5	3	–	
P. coccodes (Ach.) Nyl.	–	1	–	–	–	–	–	–	–	3	2	3	–	–
P. flavida (DC.) J.R.Laundon	–	2	–	–	2	–	–	–	–	–	–	–	–	–
P. hemisphaerica (Flörke) Erichsen	–	–	1	–	–	–	1	–	–	–	–	–	–	–
P. heterochroa (Müll. Arg.) Erichsen	–	–	–	–	–	–	–	5	4	–	–	–	–	–
P. hymenaea (Ach.) Schaer.	4	4	5	3	5	5	1	–	–	–	1	–	–	–
P. leioplaca DC.	–	–	–	–	–	–	1	4	2	2	–	3	–	–
P. multipuncta (Turner) Nyl.	–	–	–	–	–	–	–	–	–	2	2	–	–	–
P. pertusa (Weigel) Tuck.	–	2	4	–	5	2	2	–	2	4	5	5	–	–
P. slesvicensis Erichsen	–	–	–	–	–	–	–	–	–	3	4	–	–	–
Phaeophyscia chloantha (Ach.) Moberg	1	1	–	–	–	–	–	–	–	–	–	–	–	–
P. hirsuta (Mereschk.) Essl.	–	–	–	3	–	–	–	–	–	–	–	–	–	–
P. orbicularis (Neck.) Moberg	1	1	–	3	–	–	–	–	–	–	–	–	–	–

TABLE 1. *Continued*

Taxon*	Sampling sites†													
	O5	O3	O2	O1	C1	O4	S1	L2	L1	F3	F2	F1	P2	P1
Phlyctis agelaea (Ach.) Flot.	–	1	–	–	–	–	1	4	2	–	1	–	–	–
P. argena (Spreng.) Flot.	–	3	1	–	–	–	–	5	3	–	2	5	–	–
Physcia adscendens (Fr.) H.Olivier	2	3	1	–	–	–	–	–	–	–	–	–	–	–
P. aipolia (Humb.) Fürnrh.	1	2	–	–	–	–	–	–	–	–	–	–	–	–
P. leptalea (Ach.) DC.	–	3	1	–	2	1	4	1	–	–	2	–	–	–
P. stellaris (L.) Nyl.	–	–	–	–	–	–	–	–	–	–	–	–	–	1
P. tenella (Scop.) DC.	1	1	–	5	–	–	1	1	2	–	–	–	4	–
Physconia distorta (With.) J.R.Laundon	1	–	1	–	3	4	–	–	–	–	1	–	–	–
P. grisea (Lam.) Poelt	–	–	1	3	–	–	–	–	–	–	–	–	–	–
P. perisidiosa (Erichsen) Moberg	–	1	1	3	–	–	–	–	–	–	–	–	–	–
P. servitii (Nàdv.) Poelt	2	3	–	–	–	1	1	–	–	–	1	–	–	–
P. venusta (Ach.) Poelt	–	–	–	–	3	5	1	–	–	–	1	5	–	–
Platismatia glauca (L.) W.L.Culb. & C.F.Culb.	–	–	–	–	–	–	–	–	–	–	–	3	5	1
Porina aenea (Wallr.) Zahlbr.	–	–	–	–	–	–	–	2	–	–	–	–	–	–
Pseudevernia furfuracea (L.) Zopf var. *furfuracea*	–	–	–	–	–	–	–	–	–	–	–	–	5	5
Punctelia subrudecta (Nyl.) Krog	3	5	3	3	–	3	2	1	2	–	1	–	–	–
Pyrrhospora quernea (Dicks.) Körb.	1	–	3	–	–	–	3	–	–	–	–	–	–	–
Ramalina calicaris (L.) Fr.	–	–	–	–	–	–	1	–	–	–	–	3	–	–
R. canariensis J.Steiner	2	3	1	–	–	–	–	–	–	–	–	3	–	–
R. farinacea (L.) Ach.	–	3	3	–	–	–	4	–	2	–	3	5	–	–
R. fastigiata (Pers.) Ach.	–	3	3	–	4	1	3	3	3	–	1	–	–	1
R. fraxinea (L.) Ach.	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Rinodina capensis Hampe	–	–	–	–	–	–	–	–	–	–	–	–	–	1
R. exigua (Ach.) Gray	–	–	–	–	–	–	–	2	2	–	–	–	–	–
Schismatomma decolorans (Sm.) Clauzade & Vězda	2	2	3	3	–	1	–	1	–	–	–	–	–	–
Tephromela atra (Huds.) Hafellner	–	1	–	–	–	–	–	3	5	–	2	–	–	–
Trapeliopsis flexuosa (Fr.) Coppins & P.James	–	–	–	–	–	–	1	–	–	–	–	–	–	3
Tuckermanopsis chlorophylla (Willd.) Hale	–	–	–	–	–	–	–	–	–	–	–	–	2	5
Usnea hirta (L.) F.H.Wigg.	–	–	–	–	–	–	1	–	–	–	1	–	–	1
Xanthoria parietina (L.) Th. Fr.	3	3	2	3	–	–	–	–	–	–	1	–	–	–

*Nomenclature is updated following Nimis (2003).
†For details see Table 2.

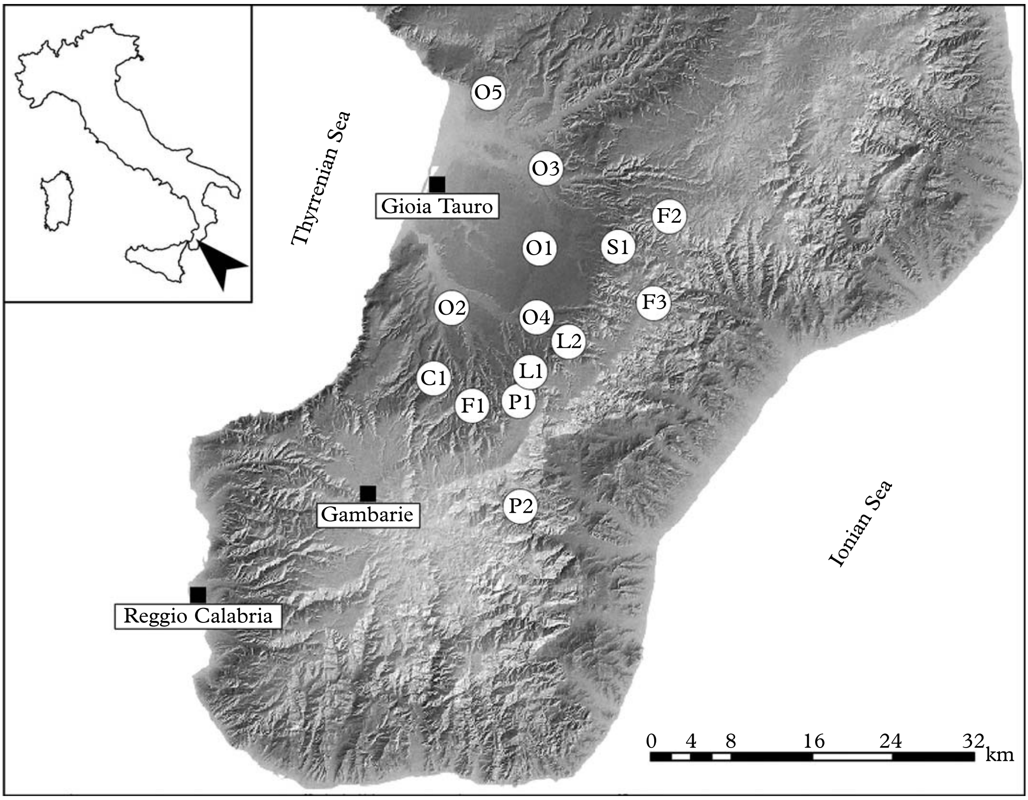

FIG. 1. Survey area, and location of sampling sites (see also Table 1).

(A1) *subalpine-oroboreal* area, near the treeline in the Alps;

TABLE 2. *List of localities, altitudes and tree species of sampling sites*

Site code	Altitude (m)	Locality	Tree Species
O1	240	Cittanova	*Olea europaea*
O2	200	Castellace	*Olea europaea*
O3	200	Anoia	*Olea europaea*
O4	480	Terranova	*Olea europaea*
O5	200	Limbadi	*Olea europaea*
L1	630	Varapodio	*Quercus ilex*
L2	620	Molochio	*Quercus ilex*
S1	650	S. Giorgio Morgeto	*Quercus suber*
C1	790	Sinopoli	*Castanea sativa*
F1	1020	Scido	*Fagus sylvatica*
F2	930	Giffone	*Fagus sylvatica*
F3	1015	Canolo	*Fagus sylvatica*
P1	1080	Piminoro	*Pinus laricio*
P2	1300	S. Luca	*Pinus laricio*

(B) *oromediterranean* area, above the treeline outside the Alps;
(C) *montane* area, from *c.* 600 to *c.* 1600 m;
(D) *submediterranean* area, lying between the montane and the mediterranean areas;
(E) *padanian* area, the plains of the North, separated from D, because of pollution and/or almost complete deforestation;
(F) *humid submediterranean* area (Tyrrhenian, see Nimis & Tretiach 2004), separated from D due to the mild-humid climate;
(G) *humid Mediterranean* area (Tyrrhenian), from 0 to *c.* 100 m (threshold between mediterranean and submediterranean vegetation, see Tomaselli 1973);
(H) *dry Mediterranean* area, separated from G due to the dry-mediterranean climate.

Commonness-rarity scores were assigned by Nimis (2003) to all species in each of the 9 phytoclimatic areas, based on the number of herbarium specimens and on literature records. These are expressed on a 9-classes scale: absent (0), extremely rare (1), very rare (2), rare (3), rather rare (4), rather common (5), common (6), very common (7), and extremely common (8).

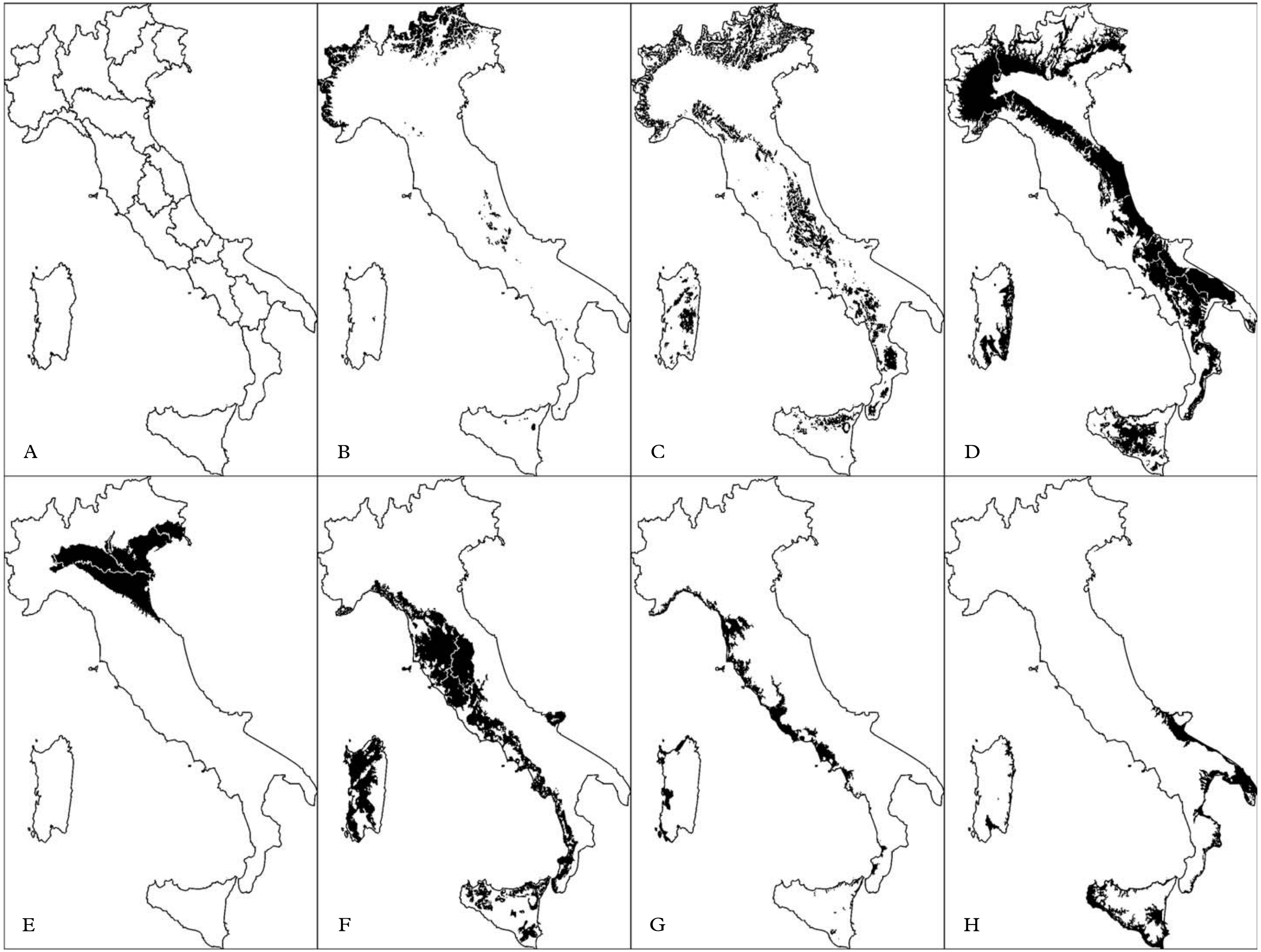

FIG. 2. The regions (A) and main bioclimatic subdivisions (B–G) of Italy. A, the 21 administrative regions; B, alpine, subalpine and oromediterranean; C, montane; D, submediterranean; E, padanian; F, humid submediterranean (Tyrrhenian); G, humid mediterranean (Tyrrhenian); H, dry mediterranean.

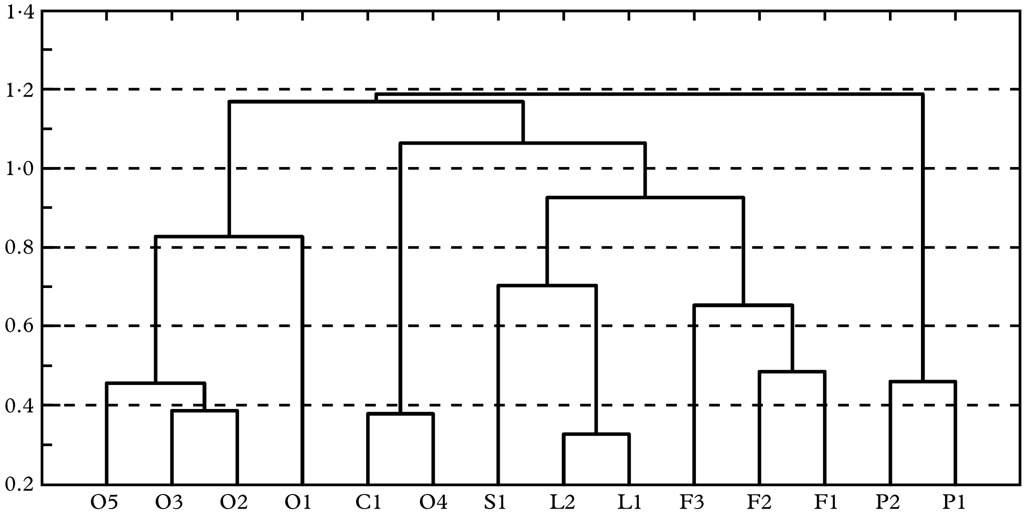

FIG. 3. Dendrogram of the sampling sites. The main clusters are numbered from 1 to 5 (see text). Site codes (see Table 2): O, *Olea europea*; C, *Castanea sativa*; S, *Quercus suber*; L, *Quercus ilex*; F, *Fagus sylvatica*; P, *Pinus laricio*.

In this paper, we have described the Italian distribution of the 135 species found by Bartoli *et al.* (1991, Table 1) by a vector reporting their commonness-rarity scores in the 98 OGUs.

The matrix of the 135 species and the 14 sites (local distribution), and that of the same species and the 98 OGUs (Italian distribution) were submitted to multivariate analysis.

Methods

The matrix of species and sites was submitted to numerical classification, using the Pearson's correlation coefficient as distance measure, and complete linkage as the aggregation algorithm, in order to identify clusters of sites with similar floristic composition, based on local frequencies.

The matrix of species and OGUs was submitted to numerical classification, using the same distance measure and aggregation algorithm, in order to identify clusters of species with similar distribution patterns in Italy (chorotypes).

For each cluster of species a chorogram was produced as follows:

(a) a commonness-rarity score for the cluster (C_j) in each OGU was calculated as the average of the scores of all the species of the cluster in the OGU, according to the formula:

$$C_j = \frac{\sum_{i=1}^{N} C_{i,j}}{N}$$

where C_{ij} is the commonness-rarity score of the *i*-th species of the given cluster in the *j*-th OGU, and N is the number of species in the cluster;

(b) C_j ranges between 0 (all the species of the cluster are absent in the *j*-th OGU) and 8 (all species of the cluster are extremely common in the *j*-th OGU). Each C_j was rounded to the closest integer value, to be expressed on the same scale of the commonness-rarity score used for species.

(c) the Italian distribution of a cluster is described by the vector C reporting its commonness scores in the 98 OGUs. The vector was projected on a GIS-based map of Italy, in which each OGU is coloured with a greyscale value corresponding to the commonness-rarity score of the cluster, from white (C_j=0) to black (C_j=8).

For each cluster of sites, the percent frequencies of the chorotypes was calculated, in order to evaluate the relation between local and Italian distribution.

Results

In the dendrogram of sampling sites (Fig. 3), 5 main clusters were formed:

Cluster 1. *Olea europea* groves at low altitudes. Most frequent are rather hygro- and heliophytic lichens, such as (in order of decreasing frequency): *Parmotrema reticulatum*, *Pertusaria hymenea*, *Punctelia subrudecta*, *Flavoparmelia caperata*, *Xanthoria parietina*, *Schismatomma decolorans*, *Bactrospora patellarioides*, *Collema nigrescens*, *Gyalecta flotowii*, *Heterodermia obscurata*, *Pertusaria albescens*.

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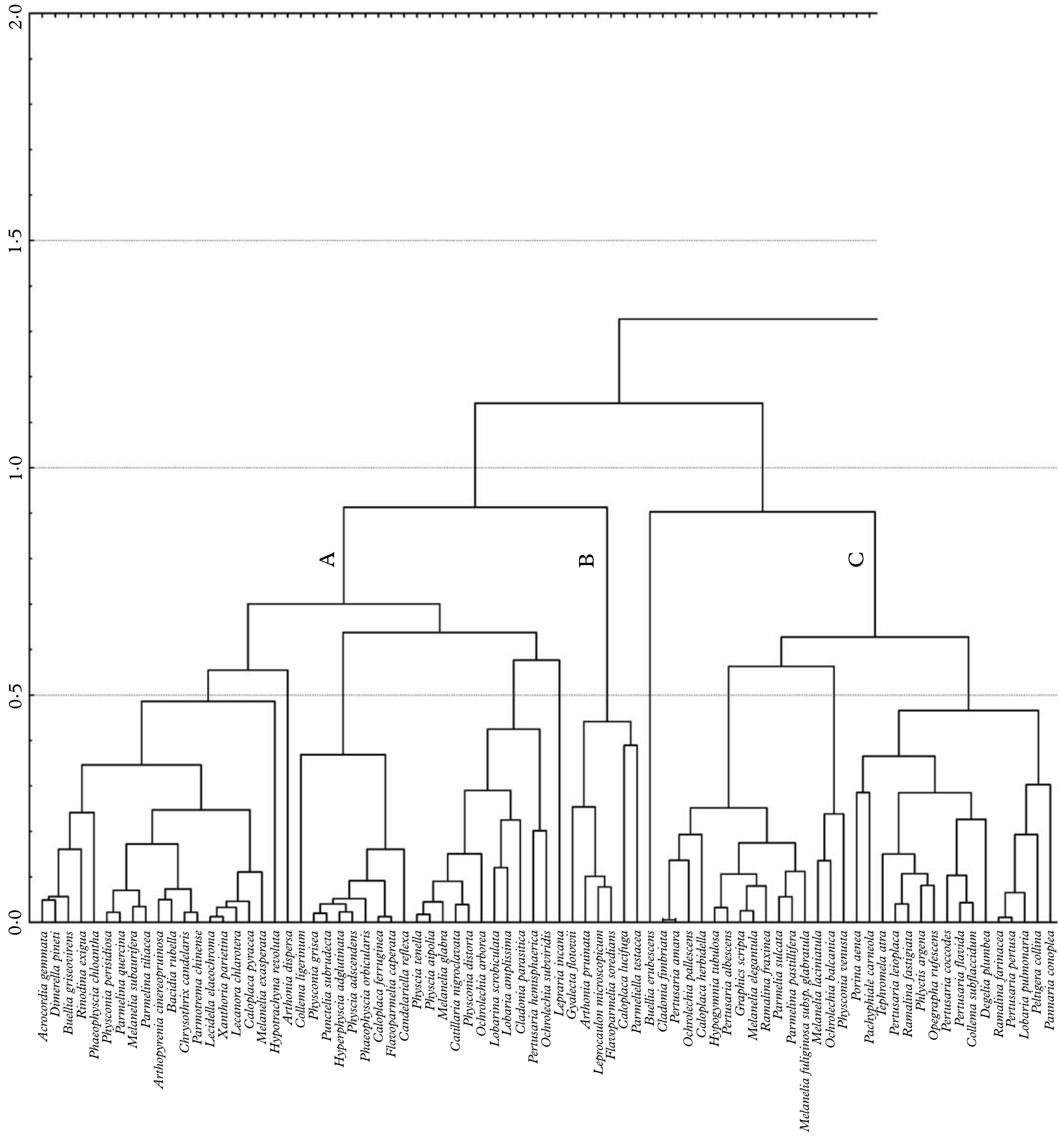

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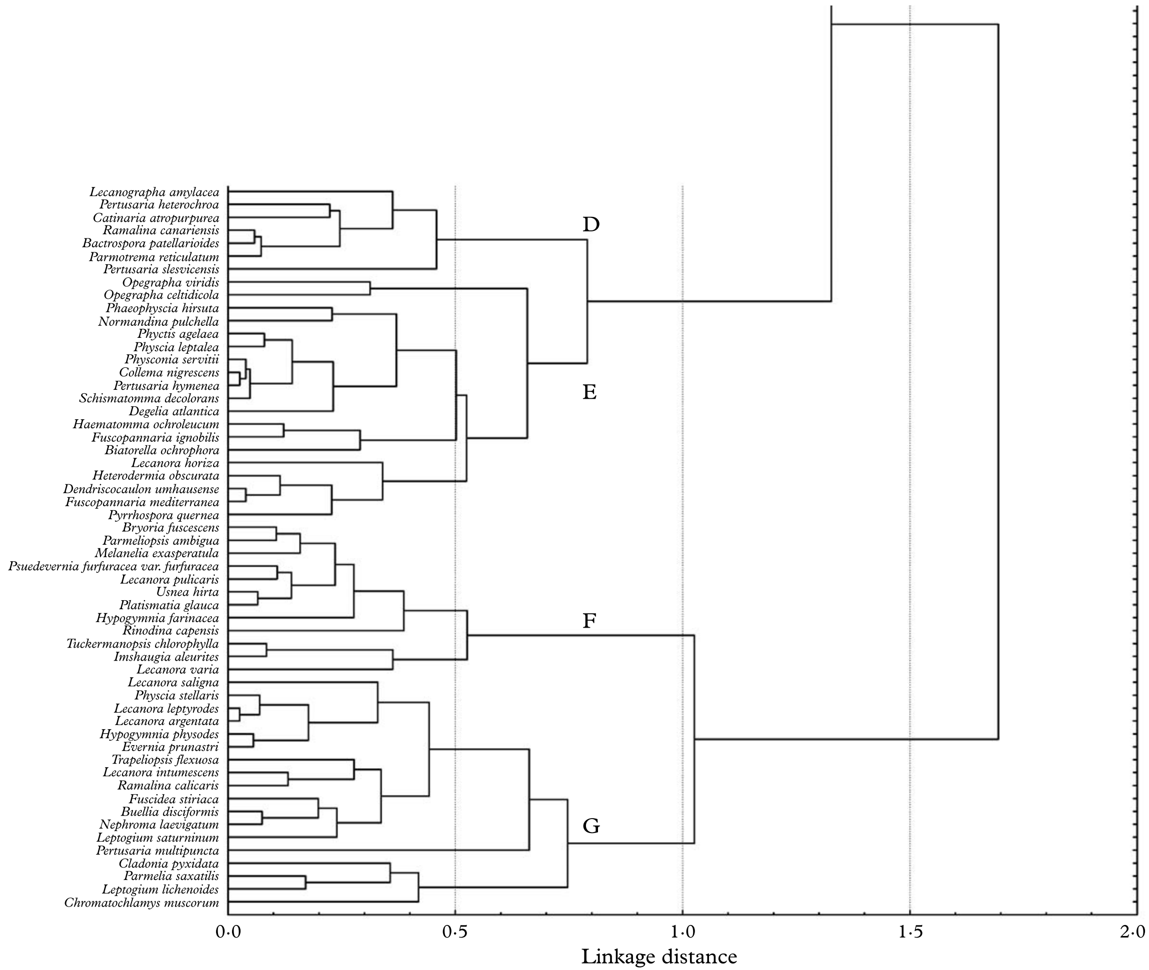

FIG. 4. Dendrogram of the species. The principal clusters are named with capital letters, from A to G (see text).

Cluster 2. *Castanea sativa* and *Olea europaea* stands of the fog belt. Some hygro- and heliophytic species of the previous cluster remain frequent, accompanied by others with even higher moisture requirements (*Collema nigrescens*, *Fuscopannaria ignobilis*, *Lobaria amplissima*, *Collema subflaccidum*), or with a broader ecological range, such as *Pertusaria amara* and *Parmelina tiliacea*.

Cluster 3. Evergreen oak stands at *c.* 600 m. Most frequent are lichens with a wide ecological range: *Lecidella elaeochroma*, *Lecanora chlarotera*, *Pertusaria amara*, *Flavoparmelia caperata*. Some frequent species reflect high moisture, such as: *Pertusaria heterochroa*, *Parmotrema chinense* and *Phlyctis argena*.

Cluster 4. Beech forests of the montane belt. The flora is typical of these forests in the humid mountains of southern Italy. Most frequent are: *Pertusaria pertusa*, *Lecanora argentata*, *Lecanora intumescens*, *Parmelia sulcata*, *Melanelia fuliginosa* ssp. *glabratula*, *Ramalina farinacea*, *Lobaria pulmonaria*, *Pertusaria coccodes*, *Phlyctis argena*, *Parmelia saxatilis*, *Pertusaria slesvicensis*.

Cluster 5. *Pinus laricio* stands above 1000 m. Some of the most frequent lichens are acidophytic, such as *Pseudevernia furfuracea* var. *furfuracea*, *Hypogymnia farinacea*, *Buellia erubescens*, *Tuckermannopsis chlorophylla*, *Platismatia glauca*, *Lecanora pulicaris*, *Parmeliopsis ambigua*, *Trapeliopsis flexuosa*. Others have a wider ecological range (*Bryoria fuscescens*, *Hypogymnia physodes*, *Physcia tenella*, *Melanelia fuliginosa* ssp. *glabratula*, *Parmelia saxatilis*, *Cladonia pyxidata*), most of them having a "northern" distribution in Europe.

The clusters of sampling sites correspond with the main vegetation belts, which suggests that the principal ecological factors underlying the variation of the epiphytic flora are related to an altitudinal-climatical gradient.

In the dendrogram of species based on their Italian distribution (Fig. 4), 7 clusters are formed, plus an outlier, *Buellia erubescens*. The chorograms of the seven clusters (Fig. 5) are:

(A) *common submediterranean*: relatively common from the coasts to the montane belt, less frequent at higher altitudes and in the Mediterranean OGUs;
(B) *rare submediterranean*: generally rare, mostly found in submediterranean OGUs, absent from the montane belt;
(C) *common broad-ranging*: relatively high frequencies throughout the country from sea level to subalpine areas, with a maximum in humid Submediterranean OGUs and lower frequency in the dry Mediterranean ones;
(D) *rare Tyrrhenian*: rare, essentially restricted to the Tyrrhenian part of the country, with higher frequency in humid Mediterranean OGUs;
(E) *common Tyrrhenian*: common in the Tyrrhenian part of Italy, mainly along the coasts, much rarer elsewhere;
(F) *narrow-ranging montane*: most frequent in montane OGUs, much rarer at lower altitudes; and
(G) *broad-ranging montane*: most frequent in montane OGUs, but not rare below and sometimes above this belt.

The maximum frequency of species is: (a) in the coastal humid areas of Tyrrhenian Italy, (b) in the humid submediterranean part of the country and (c) in the montane belt.

Figure 6 relates the local with the national data, showing the incidence of the 7 chorotypes (Fig. 4) in the 5 clusters of sites (Fig. 2):

Cluster 1: olive-groves: it mainly hosts broad-ranging or submediterranean lichens, with an important component of Tyrrhenian species, while the montane element is almost absent.

Cluster 2: holm-oak and cork-oak woods: biogegraphically, there is a somehow higher incidence of the montane and broad-ranging elements, and a lower incidence of the submediterranean element.

Cluster 3: chestnut stands: with a still higher incidence of the montane and

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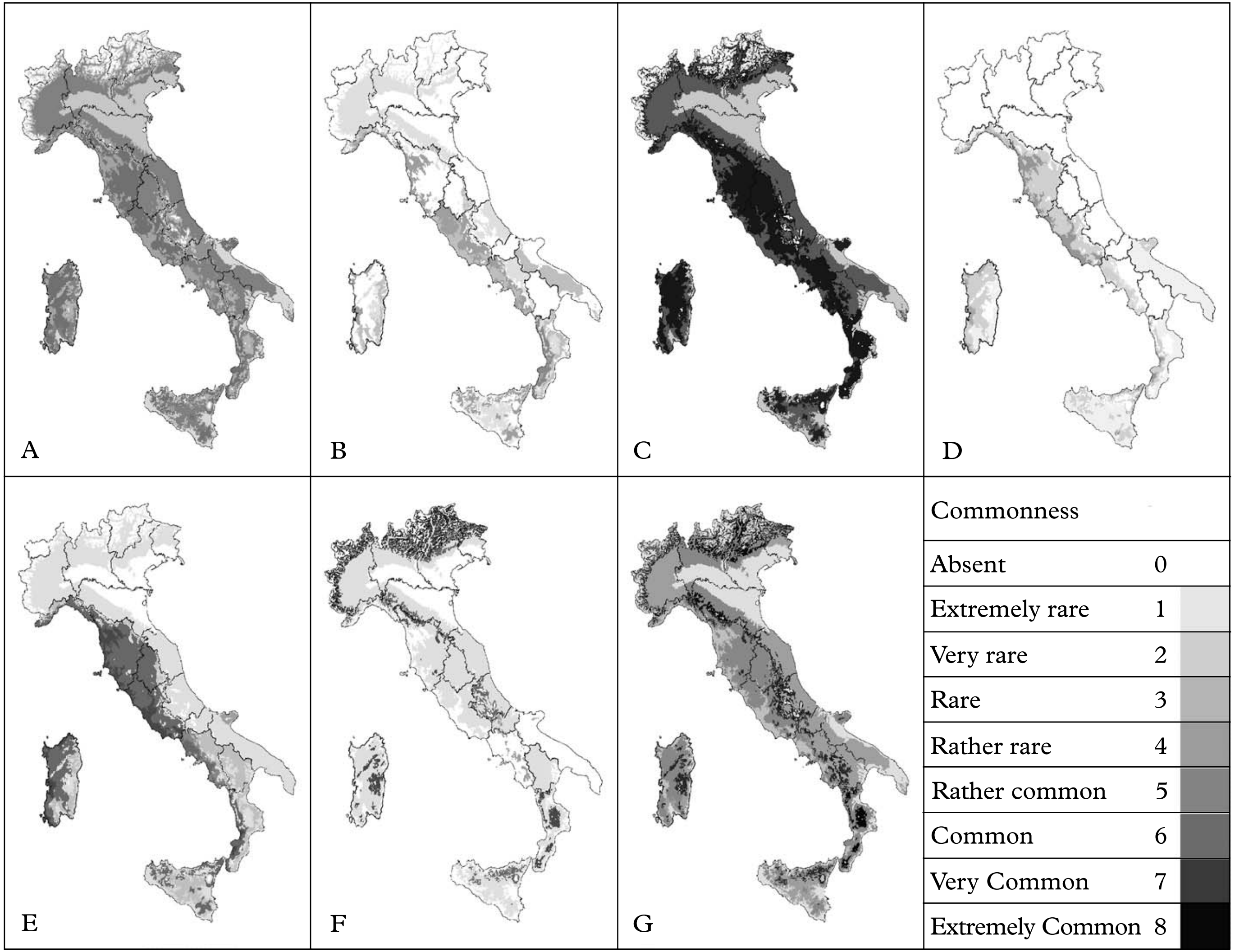

FIG. 5. Chorograms of the local flora, corresponding to the clusters in Fig. 4. A, common submediterranean; B, rare submediterranean; C, common broad-ranging; D, rare Tyrrhenian; E, common Tyrrhenian; F, narrow-ranging montane; G, broad-ranging montane.

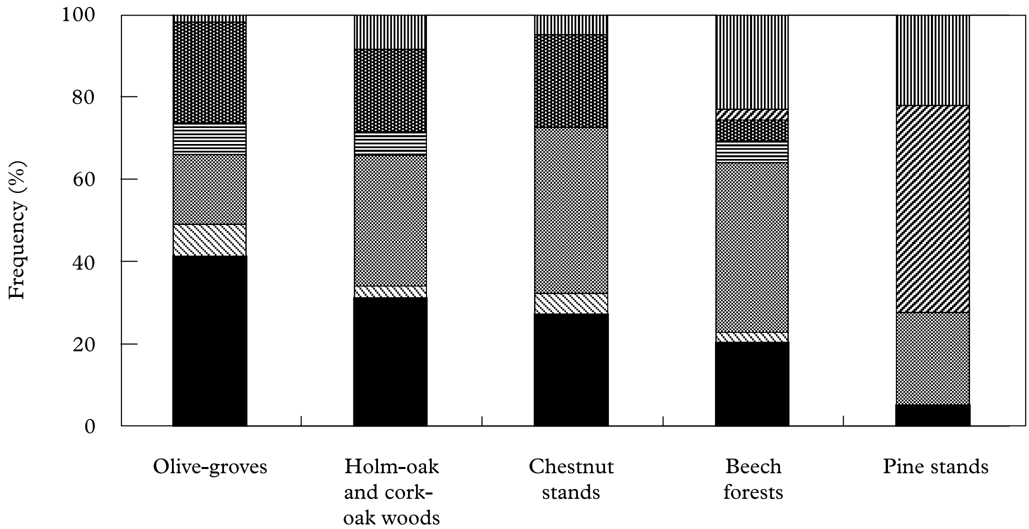

FIG. 6. Frequencies of the 7 chorotypes in the 5 clusters of sampling sites. A, common submediterranean (■); B, rare submediterranean (▧); C, common broad-ranging (▩); D, rare Tyrrhenian (▤); E, common Tyrrhenian (▦); F, narrow-ranging montane (▥); G, broad-ranging montane (▨).

broad-ranging elements, a lower incidence of the submediterranean element and the disappearance of the rare-Tyrrhenian species.

Cluster 4: beech forests: with a clear dominance of broad-ranging and montane species, while the submediterranean and Thyrrenian elements are strongly reduced.

Cluster 5: pine stands: the biogeographically most peculiar cluster, dominated by montane species, with the complete disappearance of the Tyrrhenian element.

Discussion

The results show a clear variation of chorotype frequencies along the altitudinal gradient of S Calabria: Tyrrhenian taxa are most frequent at low altitudes, being progressively substituted by submediterranean taxa. The sharpest transition concerns the pine stands, in which the lichen flora is basically different from that of the underlying belts, as it includes several montane taxa which are common even in the oroboreal belt of the Alps. The results for the main altitudinal belts are discussed in the following sections, Mediterranean, Temperate and Oromediterranean.

Mediterranean belt

Calabria lies in the centre of the Mediterranean region. The most striking result of our analysis is the scarcity of truly "Mediterranean" species in the flora investigated. Several authors (e.g. Nimis & Poelt 1987) implicitly assumed the existence of a "Mediterranean element" in lichens, whose distribution patterns would be consistent with those of steno- or eurimediterranean vascular plants. According to Nimis (1996), however, the "Mediterranean" element among lichens is difficult to define and quite heterogeneous, as it includes: (a) several, often not very well-known, coastal species restricted to the Mediterranean region, (b) those species with a Macaronesian-Mediterranean distribution not bound to a particularly humid climate, (c) a few species extending into other parts of the world with a Mediterranean climate, especially California, and (d) some species restricted to the humid belt of the

Mediterranean mountains. Perhaps the richest habitat for truly "Mediterranean" lichens are humid rock outcrops, along the coasts (see e.g. Roux 1991). The epiphytic vegetation, on the contrary, is much more homogeneous throughout the Mediterranean region. According to Nimis (1993) the scarcity of truly "Mediterranean" lichens might be explained by two main reasons: (a) a summer drought period does not result in a sufficiently strong selective pressure for the evolution of a truly Mediterranean lichen flora, many lichens being anyhow able to withstand long periods of drought, (b) the evolution of a Mediterranean-type climate in southern Europe is too recent to permit the differentiation of a specialized flora in a group of organisms such as lichens which, supposedly, have a very low rate of evolution. Our analysis shows that the truly Mediterranean forests of the survey area are characterized by the highest incidence of the Tyrrhenian element. This, according to Nimis & Tretiach (2004), includes several suboceanic to oceanic species with more or less evident subtropical to tropical affinities, confined to humid climates, which makes up *c.* 20% of the Italian lichen flora. This element is more important in western Europe, while in southern Europe and the Mediterranean region it is tied to humid coastal areas (Tyrrhenian and Dalmatian coasts, Colchis, etc.).

Temperate belt

Our analysis shows that beech forests of the montane belt, although dominated by broad-ranging lichens, are the most diverse from the biogeographical point of view. This is not always the case in Italy: beech forests especially in the north of the country may be quite lichen-poor and biogeographically homogeneous. In the northern part of the Mediterranean region deciduous forest form a belt just above the sclerophyllous vegetation, and the two biota often intermingle. In Italy *Fagus sylvatica* forms the tree-line from the northern Apennines south to the mountains of Sicily. The occurrence of several broad-ranging lichens, which are admittedly not the most characteristic example of "Mediterranean" vegetation, is however of great biogeographical interest. Southern Europe was the principal refugial area, during the glacial period, for the temperate nemoral flora of Europe (Nimis & Bolognini 1993). What may now appear to be a typical example of "Central European" vegetation, such as a German beech forest, is in reality a very much impoverished version of a type of biome that has its roots, and maintains its maximum diversity, in the mountains of the Mediterranean region (Nimis 1996). This holds true for vascular plants and for lichens alike. Many species of the deciduous forest belt, "Central European" or "submediterranean" species, as they are often called, colonized central and northern Europe from the south.

Oromediterranean belt

The highest peaks of the Mediterranean mountains have neither a truly Mediterranean climate, nor do they host a sclerophyllous vegetation. However, they are biogeographically so peculiar that the existence of an "Oromediterranean" vegetation belt is accepted by most authors, albeit under different denominations. Similar considerations apply to intermediate vegetation belts, such as the *Cedrus* forests of the mountains of Mediterranean Asia and North Africa. They show little affinity to evergreen sclerophyllous vegetation, yet they are a typical, unique feature of the Mediterranean region in the wide sense. Our analysis, however, shows that – at least in Calabria, the pine forests lying above the temperate belt do not host a peculiar lichen flora, being dominated by broad-ranging circumboreal species. In the Mediterranean region this element, which in northern and central Europe is generally bound to the arctic-alpine or boreal-oroboreal vegetation belts and which includes many species with a northern, holarctic distribution, reaches far more southern latitudes than the corresponding element in vascular plants. In Italy, the limit of most boreal vascular plants lies somewhere in the N Apennines, with the relevant exception of the Gran Sasso-Majella Massives in the Central Apennines. As far as lichens are concerned, however, the mountains of Calabria and even those of Sicily (Nimis 1996) do still host several so-called ''boreal'' lichens.

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