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NUMERICAL ANALYSIS OF LICHEN ZONES IN KOMÁROM, NW HUNGARY

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Lichen distribution data in the town and the surroundings of Komárom were analysed numerically to support the visually established lichen zones. Three types of hierarchical classification methods were used for grouping the sampling sites based on their species lists. When group structure of the dendrograms were analysed, results obtained by the global optimization method made the most complete interpretation possible. In general, the sampling sites characterized by epiphytic lichens showed more stable, repetitive group structure in the dendrograms than those of having predominantly saxicolous lichen flora. Considerable coincidence with the two, visually established "struggle zones" was obtained when the numerically defined subgroups, characterized by epiphytic lichens, were re-allocated to the map of the study area.

Key words: air pollution, Jaccard-index, Komárom, lichen mapping, numerical analysis, struggle zone

INTRODUCTION

Since the correlation between air pollution and lichens was recognized some 150 years ago, numerous lichen maps were prepared throughout the world (*e.g.* SERNANDER 1926, HAUGSJA 1930, VAARNA 1934, VARESCHI 1936, MATTICK 1937, ALMBORN 1943, SAUBERER 1951, BARBALIC 1953, FENTON 1960, GUTTE *et al.* 1976, NIMIS 1989, KRAVCHUK and KAKAREKA 1995, MALYSHEVA 1996, ERNST 1997, ÖZTÜRK *et al.* 1997, SKIRINA 1998, VOLKOVA and SONDAK 1998), and also in Hungary (*e.g.* FELFÖLDY 1942, GALLÉ 1979, FARKAS 1982, VERSEGHY and FARKAS 1985, KISS 1990, VÁNCSA and VÁNCSA 1990, VÁNCSA 1991, MALATINSZKI 1992, SZABADOS 1993, PALLOS 1996, MOLNÁR 1999). Among the advantages of lichen mapping it is acknowledged that it is relatively cheap and that indicates well the global effect of air pollution on living organisms (KOVÁCS and PODANI 1986). Therefore, despite of its disadvantages (*e.g.* it is time consuming, non-quantitative, etc.) the mapping method is a popular one even today in towns and industrial areas.

The "classical" lichen maps, based on distribution data of the epiphytic lichen species, communities, or particular "indicator" species, composed of a centrally located "desert zone" (where the epiphytic lichens are missing), one or more "struggle zones" (where there is a transitional lichen vegetation), and usually far from the pollution sources the "normal zone" (where the lichen vegetation appears to be almost natural). Certain kinds of indices (IP, IAP, lichen biodiversity index, etc.) were applied for confirmation of the borders of the zones (TRASS 1968, LEBLANC and DE SLOOVER 1970, NIMIS *et al.* 1991), but for individual cities these were not supported by numerical analyses yet.

Preparation of the lichen map of Komárom (MOLNÁR 1999) made it possible to establish lichen zones of the town and its surroundings. The central desert zone seemed to be missing. Two struggle zones and the normal zone were clearly visible. The border of the inner struggle zone almost coincides with the densely built-up area of the town. Based on the species distribution data, these impressions of zone boundaries are supported by multivariate numerical analysis in this paper.

MATERIAL AND METHODS

Altogether, 630 records of 50 (20 epiphytic and 30 saxicolous) lichen species were collected from 84 localities within the administrative boundary of Komárom (NW Hungary) (Fig. 1) between October, 1997 and April, 1999. The majority of the individuals were found on tree barks and on stones. Soil inhabiting lichens were almost missing, only found occasionally on small soil patches in wall gaps of some very old buildings (*e.g.* Fortress Igmánd). Specimens were identified and deposited in the lichen herbarium of the Hungarian Natural History Museum (Budapest, BP), thus serving as a basic reference of this study.

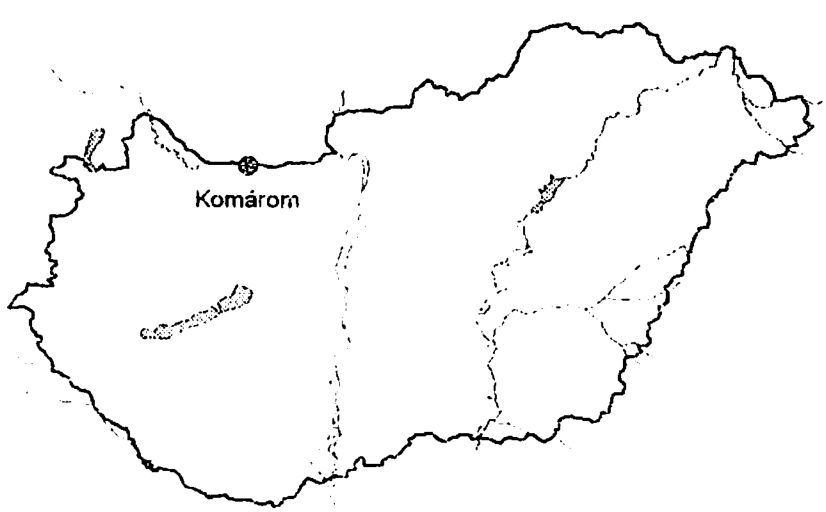

Fig. 1. Location of the study area in Hungary.

Multivariate methods were applied for data evaluation. Based on the attributum duality concept (*cf.* PODANI 1997), both the sampling sites and species were grouped by hierarchical classification methods (cluster analysis), of which results related to the sampling sites are discussed in this paper.

Several similarity functions and coefficients are known to measure the floristic similarity of the sampling sites (based on presence/absence data). Since the average species number of our sites was low compared to the species pool of the whole sample, it is reasonable to omit "mutual absences", when the similarity matrix is calculated (TAMÁS 1997). Among indices using only 3 cells (a, b, and c) of the contingency table, we used the Jaccard-index:

$$J_{i,j} = a/(a+b+c),$$

where a is the number of species present both in samples i and j, b is the number of species present in sample i only, and c is the number of species present in sample j only.

Jaccard-index is the unweighted member of a subgroup of indices often producing topologically identical results (PODANI 1997, TAMÁS 1997).

Three of the clustering algorithms were used: the complete linkage-, the group average- and the global optimization method (PODANI 1989, 1993). It is recommended to use various algorithms in a study for better representation of the general trends in the analysed data set. The SYNTAX program package were used for computation (PODANI 1991, 1993).

Localities with only one species, and species occurred at only one locality were removed from the data set. Thus a binary matrix of 36 species and 65 localities served as raw data set for the multivariate analysis (see Appendix).

RESULTS AND DISCUSSION

Results of the global optimization method

The dendrogram produced by the global optimization method is shown in Figure 2. The two major groups of objects are formed by sites where the majority of the species were found on tree barks (marked by number 1), and sites where saxicolous species dominated the samples (marked by number 2). Further groups can be distinguished, if the dendrogram is cut at 0.736 level of dissimilarity (see broken line on Fig. 2). One of the epiphytic subgroups (number 3) contains the sampling sites of wooded areas relatively far from the built-up areas. The other subgroup (number 4) is formed by localities in small wooded patches and allées near in or to the built-up areas. These subgroups also differed in their average species number, with values 7 and 4, respectively.

The saxicolous subgroups (number 5, 6 and 7) differed less remarkably, however, group 5 tended to hold sites of the edge of the built-up areas, whereas groups 6 and 7 were more characterized by sites from the inner city of Komárom. The results obtained by the global optimization method for the epiphytic subgroups were re-allocated to the map of the study area (Fig. 5).

Results of the group average clustering

The dendrogram created according to the group average method (Fig. 3) does not allow a complete interpretation of the clusters, however, some of the clusters are related to certain habitat attributes. Sites in wooded patches far from the

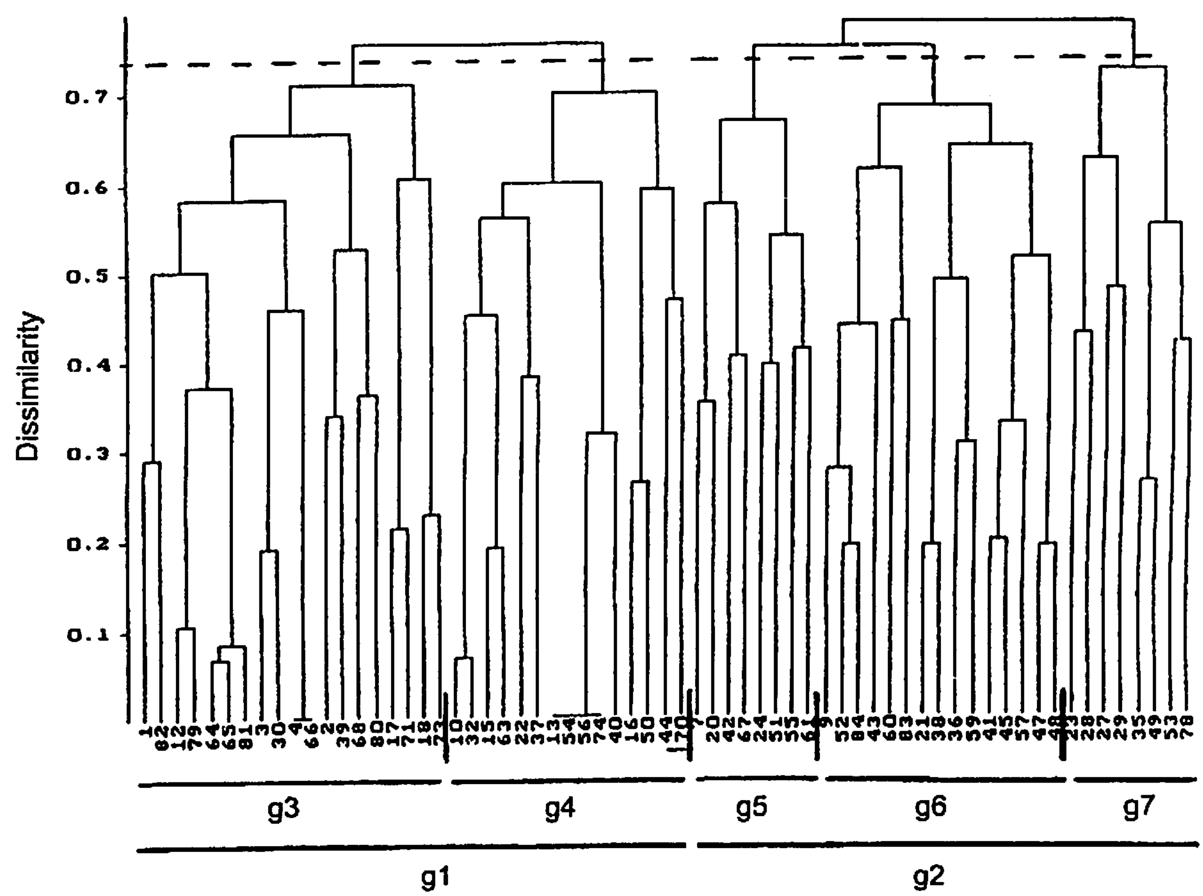

Fig. 2. Dendrogram of the sampling sites according to the global optimization method. Jaccard-index was used to measure dissimilarities. Groups and subgroups (g1–g7) are discussed in the text.

built-up areas are found in the group marked by number 1. This group has a fairly good agreement with group 3 of the global optimization dendrogram (*cf.* Fig. 2), while groups marked by number 2 and 3 correspond to the sampling sites with small group of trees inside the built-up areas.

All sampling sites of the latter two groups are members of group 4 in the global optimization method. Sampling sites found in the city of Komárom and characterized by calcareous stones (either man-made concrete or hewn limestones) can also be distinguished by their lichen flora (see group 4 in Fig. 3).

Results of the multivariate analysis by complete linkage method

Three groups can be interpreted in the dendrogram of the complete linkage method. The first group is formed by sampling sites where the lichen specimens were found principally on tree barks (number 1 in Fig. 4). In case of groups 2 and 3 the lichen specimens were collected mainly from the concrete substrate or, less frequently, from tombstones (number 2 and 3 in Fig. 4). Though the substrate of

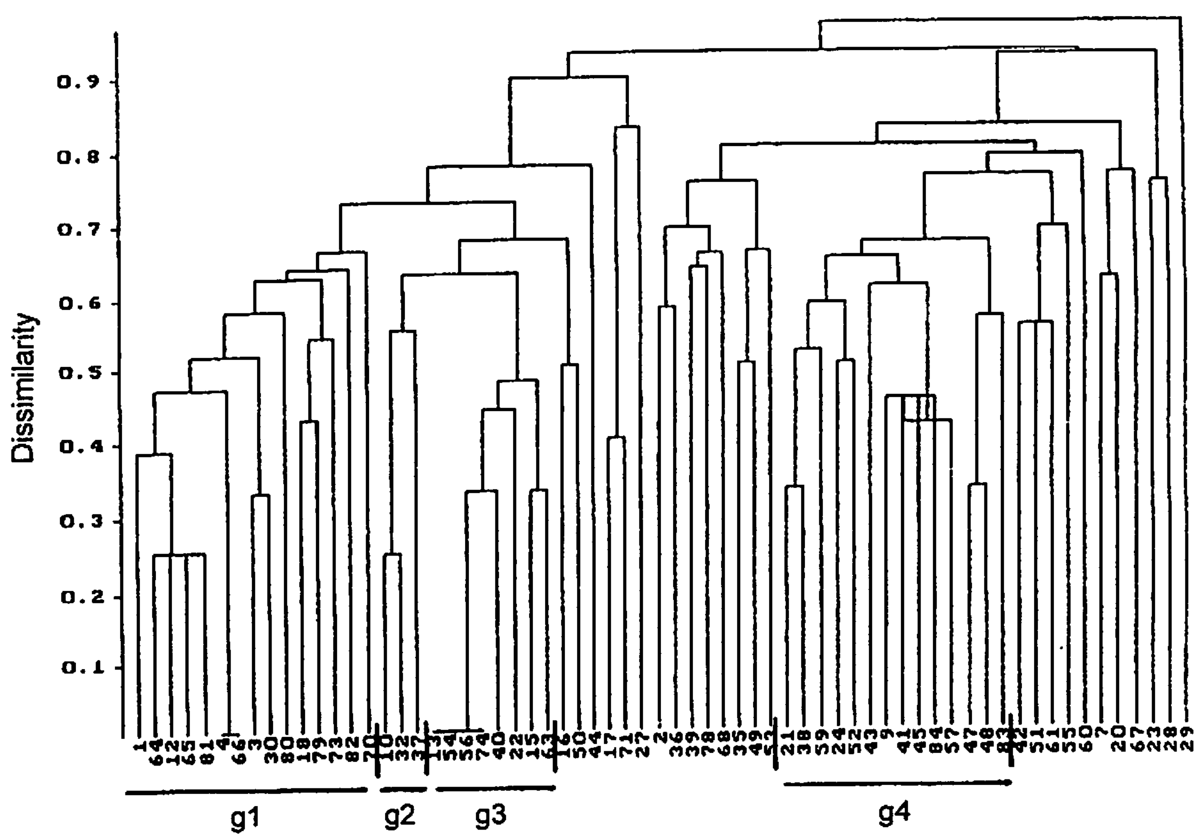

Fig. 3. Dendrogram of the sampling sites according to the group average method. Dissimilarity was measured by the Jaccard-index. Groups (g1–g4) are discussed in the text.

groups 2 and 3 is very similar, they differ in their average species numbers, 4 and 6, respectively.

In case of some sampling sites, a completely identical lichen flora was found. These sites were characterized by tree groups and the specimens were collected from barks. Such pairs were amalgamated in the first step and found at zero dissimilarity level in the dendrograms as it is seen for sites 4 and 66 (with the species list: *Amandinea punctata*, *Phaeophyscia orbicularis*, *Physcia tenella* and *Xanthoria parietina*). Another, floristically identical group was formed by sampling sites 13, 54, 56 and 74.

CONCLUSIONS

Considering the results of the three different analyses, a better correspondence with habitat characteristics was found for sampling sites with epiphytic lichens than those of having a predominantly saxicolous lichen flora. One reason for

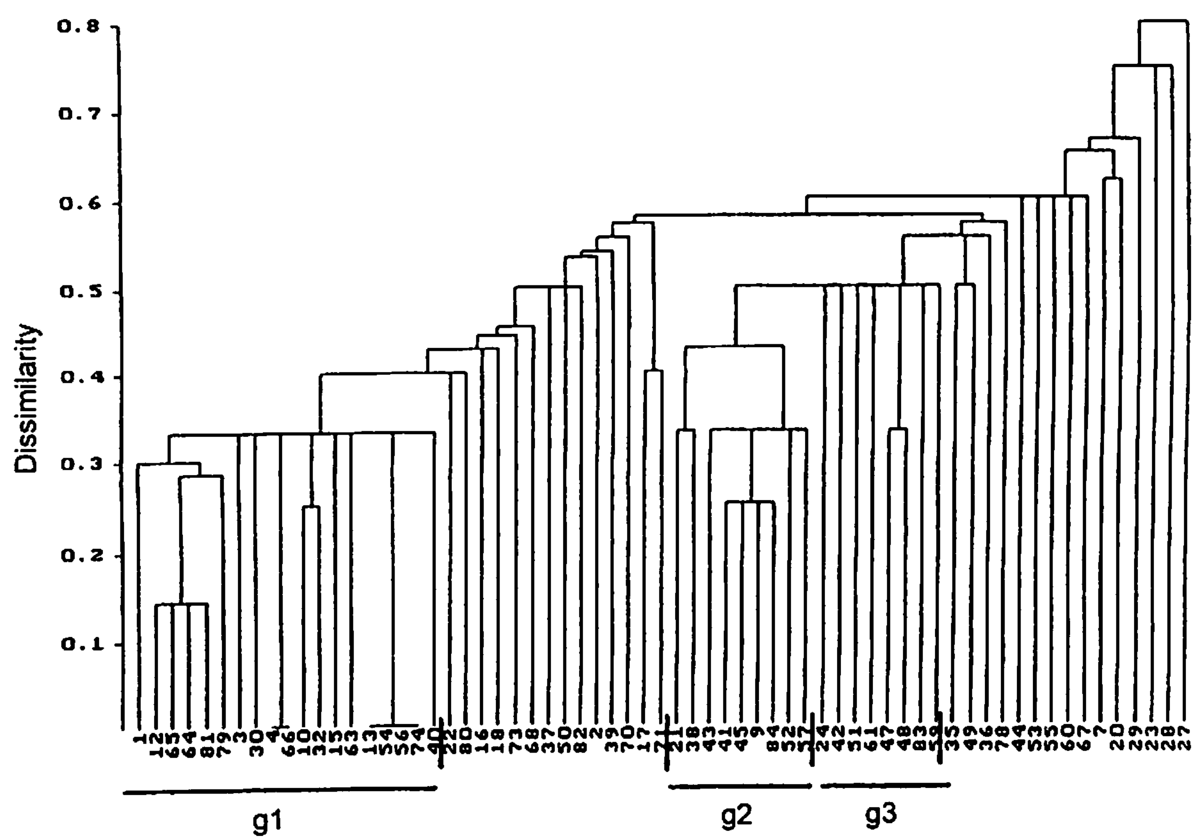

Fig. 4. Dendrogram of the sampling sites according to the complete linkage method. Dissimilarity of the species composition of lichens was measured by the Jaccard-index. Groups (g1–g3) are discussed in the text.

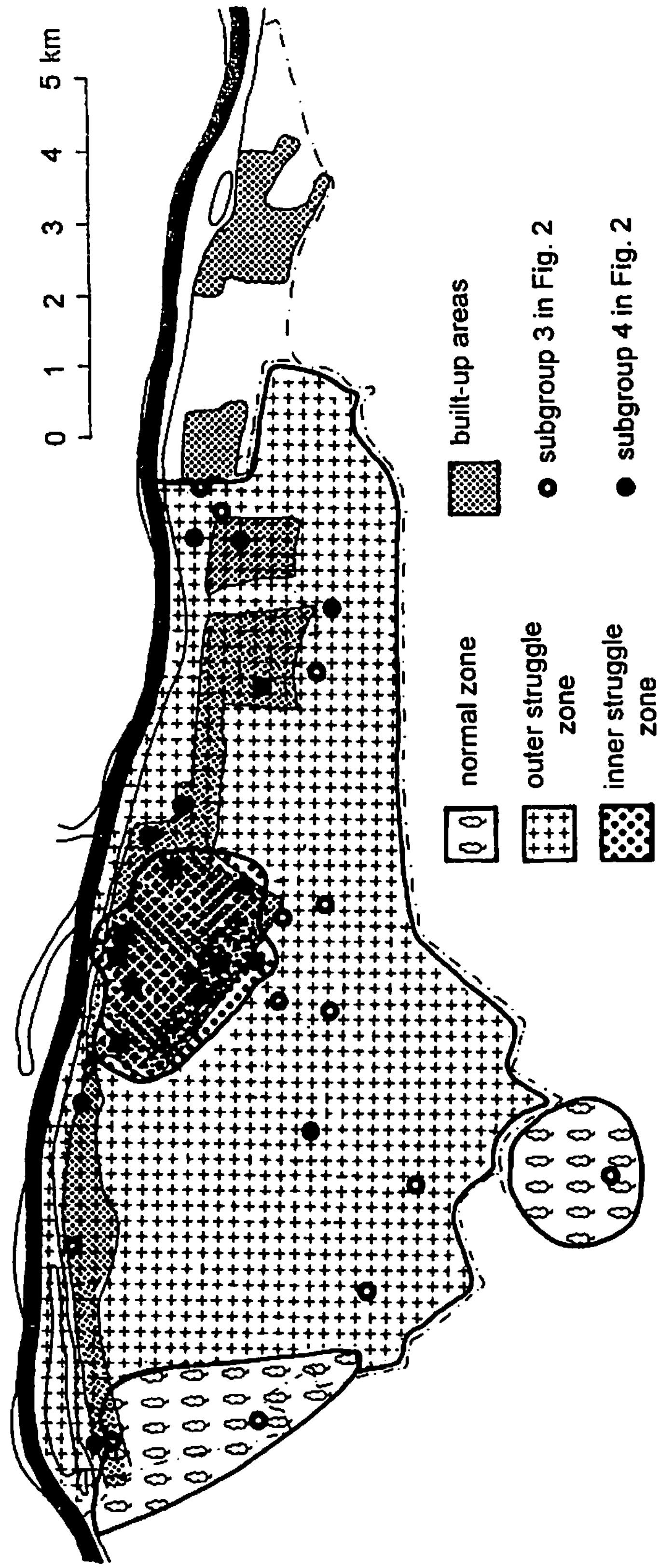

Fig. 5. Map of the study area with the re-allocated epiphytic subgroups obtained by the global optimization method.

this is that trees are found both in the built-up area and outside the settlement (certainly with different frequency), whereas stones or stone-like surfaces are found in the built-up area only. Therefore, epiphytic lichens could perform their habitat preferences in the whole study area, while the saxicolous ones were restricted to the built-up areas. The other reason may be that the saxicolous lichens tolerate more air pollution, consequently, they are distributed rather evenly among the sampling sites with stony substrates.

When subgroups of the sampling sites with mainly epiphytic lichens were re-allocated to the map of Komárom and its surroundings, a fairly good coincidence occurred between the distribution of the two subgroups and the visually established boundary of the two "struggle zones" of the lichen map. Thus the existence of an inner and an outer "struggle zone" is clearly supported by the numerical multivariate analyses.

In correspondence with previous surveys by several investigators (HAWKSWORTH and ROSE 1976, KIRSCHBAUM and WIRTH 1997), in our study also the epiphytic lichens proved to be better for construction of air pollution maps.

* * *

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Appendix. The data matrix of 36 lichen species and 65 localities in and around Komárom (NW Hungary). Column numbers correspond to the sampling sites reported in MOLNÁR (1999).

	1	2	3	4	7	9	10	12	13	15	16	17	18	20	21	22	23	24	27	28	29	30	32	35	36	37	38	39	40	41	42	43	44
Amandinea punctata	1	1	1	1	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0
Aspicilia contorta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Caloplaca citrina	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Caloplaca crenulatella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
Caloplaca decipiens	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca saxicola	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candelariella aurella	0	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	0	1	1	1	0
Candelariella medians	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candelariella xanthostigma	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladonia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Endocarpon pusillum	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypogymnia physodes	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecania erysibe	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora albescens	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0
Lecanora conizaeoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lecanora dispersa	0	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	1	1	0	1	1	0	1	1	0	0
Lecanora hagenii	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	1

Appendix (cont.)

	1	2	3	4	7	9	10	12	13	15	16	17	18	20	21	22	23	24	27	28	29	30	32	35	36	37	38	39	40	41	42	43	44
Lecanora muralis	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1
Lecanora saligna	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
Lepraria incana	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptogium plicatile	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmelia sulcata	1	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Phaeophyscia nigricans	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaeophyscia orbicularis	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1
Physcia adscendens	1	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0
Physcia caesia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Physcia dimidiata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia stellaris	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia tenella	1	1	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0
Sarcogyne regularis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Scoliciosporum chlorococcum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Strangospora pinicola	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Verrucaria muralis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Verrucaria nigrescens	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
Xanthoria elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthoria parietina	1	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1

Appendix (cont.)

	45	47	48	49	50	51	52	53	54	55	56	57	59	60	61	63	64	65	66	67	68	70	71	73	74	78	79	80	81	82	83	84
Amandinea punctata	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	0
Aspicilia contorta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca citrina	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca crenulatella	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Caloplaca decipiens	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca saxicola	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Candelariella aurella	1	1	1	1	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Candelariella medians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candelariella xanthostigma	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Cladonia spp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Endocarpon pusillum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypogymnia physodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lecania erysibe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora albescens	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Lecanora conizaeoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora dispersa	1	1	1	1	0	1	1	1	0	1	0	1	1	0	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1
Lecanora hagenii	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	1	1	0	1	1	0	0	0	1	1	0	1	1	0	0	0

Appendix (cont.)

	45	47	48	49	50	51	52	53	54	55	56	57	59	60	61	63	64	65	66	67	68	70	71	73	74	78	79	80	81	82	83	84
Lecanora muralis	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Lecanora saligna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Lepraria incana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Leptogium plicatile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmelia sulcata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0
Phaeophyscia nigricans	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0
Phaeophyscia orbicularis	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	1	1	0	0	1	1	0	1	1	1	0	0
Physcia adscendens	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	0
Physcia caesia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia dimidiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Physcia stellaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Physcia tenella	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0	1	1	0	0	1	1	1	1	0	0
Sarcogyne regularis	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Scoliciosporum chlorococcum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Strangospora pinicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Verrucaria muralis	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Verrucaria nigrescens	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Xanthoria elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Xanthoria parietina	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	1	1	0	0