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Assessing changes in epiphytic lichen community after 45 years, a study case in white poplars from northern Iberian Peninsula (Jaca, Aragon)

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Abstract

ASSESSING CHANGES IN EPIPHYTIC LICHEN COMMUNITY AFTER 45 YEARS, A STUDY CASE IN WHITE POPLARS FROM NORTHERN IBERIAN PENINSULA (JACA, ARAGON).— Epiphytic lichens are used broadly as bioindicators, as they are sessile organisms with slow growth and different species display a wide range of environmental sensitivity. Most studies on epiphytic lichens focus on their use as indicators of the present environmental conditions, but few studies assess the changes that occur over decades. Comparative temporal approaches in lichens are rare, since there are few old datasets and in most cases substrates have disappeared, especially trees. However, in 1973 one of us (X. Llimona) described the lichen community on urban *Populus alba* in Jaca, and those trees are still alive. Our aim was to study the epiphytic lichen community in 2018 and compare it with the study of 1973. Species richness decreased during these 45 years. While only 36% of species found in 1973 persisted until 2018, these species remaining were observed at a high frequency in the 2018 sampling. Lichens communities from both years were similar on its tolerance to environmental variables, and the locality and their surroundings had the same land use in both years. Thus, the changes in lichen composition between both samplings might be explained by autogenic succession or limitation on dispersion rather than habitat filtering. Our data suggests that, under stable environments, lichen community assembly over decades depends on other traits such as competition rather than lichen sensitivity.

Key words: autogenic succession; biotypes; community assembly; growth forms; photobiont; temporal changes.

Resumen

EVALUACIÓN DE LOS CAMBIOS EN UNA COMUNIDAD DE LÍQUENES EPÍFITOS DESPUÉS DE 45 AÑOS, UN CASO DE ESTUDIO EN ÁLAMOS BLANCOS DEL NORTE DE LA PENÍNSULA IBÉRICA (JACA, ARAGÓN)—. Los líquenes epífitos se usan generalmente como bioindicadores, debido a que son organismos sésiles de crecimiento lento y las diferentes especies muestran un gran rango de sensibilidad ambiental. La mayoría de los estudios sobre líquenes epífitos se centran en utilizarlos como indicadores de las condiciones ambientales actuales, pero hay pocos analizando cambios temporales. La escasez de datos antiguos y la poca persistencia de los substratos, árboles en su mayoría, hacen que los estudios que incluyen una comparación temporal más o menos larga sean bastante raros. Sin embargo, en 1973 uno de nosotros (X. Llimona) describió la comunidad de líquenes de *Populus alba* de la parte urbana de Jaca, y esos árboles aún siguen vivos. El objetivo de este estudio es conocer la comunidad de líquenes de epífitos del 2018 y comparar con el estudio de 1973. La riqueza de especies disminuyó ligeramente durante estos 45 años. Sólo el 36% de las especies encontradas en 1973 persistían en 2018, aunque las persistentes se observaron con alta frecuencia en el muestreo de 2018. La sensibilidad ambiental de la comunidad de líquenes no cambió a lo largo de los años, así como, la localidad y sus alrededores no han cambiado de uso de suelo durante décadas. Los cambios en la composición de los líquenes entre ambos muestreos podrían explicarse por la sucesión autógena o limitación en la dispersión más que por filtraje ambiental. Nuestros datos sugieren que, en entornos estables, el ensamblaje de las comunidades de líquenes epífitos durante décadas depende de otros rasgos como la competencia y no de la sensibilidad ambiental de los líquenes.

Palabras clave: biotipos; cambios temporales; ensamblaje de comunidades; fotobionte; sucesión autogénica.

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INTRODUCTION

Lichens are highly sensitive to environmental conditions due to their unique biology. They have mechanisms to absorb water and nutrients from atmospheric sources, while they have no deciduous parts to avoid pollutants by shedding their parts (Nash, 2008). Lichen species show different grades of sensitivity to environmental changes (Hawksworth, 1971) and for this reason lichens are broadly used as bioindicators of environmental changes (Nimis *et al.*, 2002).

Researchers have studied extensively the relationship between lichen diversity and abundance and air quality, especially using epiphytic lichens. Most studies have focused on the species distribution along an environmental gradient, such as the distance to pollution source, and which show the spatial distribution but not the temporal distribution. This approach is used to understand lichen adaptation to environmental changes, the sensitivity of species and how environmental filter affects the species (Liška & Herben, 2008). However, in addition to habitat filtering, the changes in lichen community might also be explained by the limitation of dispersion and by autogenic succession (Ellis, 2012). To assess other factors rather than habitat filtering, changes in lichen community should be studied in a temporal framework. Nonetheless, studies with a temporal framework are relatively scarce, since there are few time series about lichen composition. Additionally, there are few old datasets and most of the older studies are irreproducible, usually because the substrates are not available anymore. This is especially true for tree substrates.

In July 1973, a study took place on the lichen communities of the Western Pyrenees (Llimona, 1976). Epiphytic communities on urban white poplars (*Populus alba* L.), in the village of Jaca, were recorded during this study. After 45 years these trees are still alive which provided an opportunity to study the change of lichen community during this period. The aim of this study was to compare epiphytic lichen composition, in the same trees between 1973 and 2018. This study will unravel how lichen composition changes in a temporal framework and will provide evidence if environmental conditions have changed during the last few decades in this location.

MATERIALS AND METHODS

The sampling was done in White Poplars (*Populus alba*) in the street “Paseo de la Cantera” in Jaca (northeast of Spain; 42° 34′ 32.4″ N 0° 33′ 13.4″ W), specifically in the same trees that were selected in the 1973 study. Between July and August of 2018, we gathered all the species to obtain a list of species, reproducing the methodology used on the 1973 study, and adding comments about frequency (rare, common or very common). The collected lichens were identified in the lab using standard techniques for lichen identification and by means of specific literature (Clauzade *et al.*, 1985). The nomenclature used followed the *Index Fungorum*. The specimens identified from the 2018 collections are kept in the Herbarium JACA, of the Instituto Pirenaico de Ecología in Jaca, along with the samples of the 1973 survey.

To describe the list of species of both samplings, we characterized all lichens growth forms, type of photobionts, and its environmental sensitivity based on values of the information on Italian lichens (Nimis & Martellos, 2017). Also, we checked the phytosociological classification of epiphytic lichens (Van Haluwyn, 2010) to associate species with a lichen community based on characteristic taxon. Differences in environmental sensitivity of lichen community between both samplings were assessed based on species occurrence and its sensitivity using Welch *t*-test in R 3.6.0 (R Core Team, 2020).

RESULTS AND DISCUSSION

Firstly, comparing the area between the two samplings we observed that the areas around the trees location had the same land use in the years according to both studies (Fig. 1). Results showed that species richness was lower in 2018 than in 1973; 19 species of lichens were found in 2018, while 25 species in 1973 (Table 1, for more details see Appendix 1). Only nine species were common in both samplings. Consequently, 16 species disappeared from 1973 and 10 species were new.

Disappeared species were seven crustose, eight foliose and a fruticose [*Ramalina fraxinea* (L.) Ach.], which was one of two fruticose found in 1973. Crustose species were *Rinodina exigua* (Ach.) Gray, species of genus *Caloplaca s. l.* [*Athallia pyraceae* (Ach.) Arup, Frödén & Søchting (≡ *Caloplaca pyracea* (Ach.) Zwackh), *Blastenia ferruginea* (Huds.) A. Massal. (≡ *Caloplaca aurantiaca* (Lightf.) Th. Fr.), *Caloplaca haematites*

Table 1. Species richness, functional groups and families in 1973 and 2018 samplings.

	1973	2018
Total species	**25**	**19**
Crustose (%)	36.0	36.8
Foliose (%)	56.0	57.9
Fruticose (%)	8.0	5.3
Chlorolichens (%)	88.0	89.5
Cyanolichens (%)	12.0	10.5
Candelariaceae (%)	–	5.3
Collemataceae (%)	12.0	10.5
Lecanoraceae (%)	16.0	5.3
Lecideaceae (%)	4.0	5.3
Megasporaceae (%)	–	5.3
Parmeliaceae (%)	12.0	21.1
Pertusariaceae (%)	–	5.3
Physciaceae (%)	28.0	26.3
Ramalinaceae (%)	4.0	–
Rinodinaceae (%)	4.0	–
Telochistaceae (%)	20.0	10.5
Verrucariaceae (%)	–	5.3
Total families	8	10

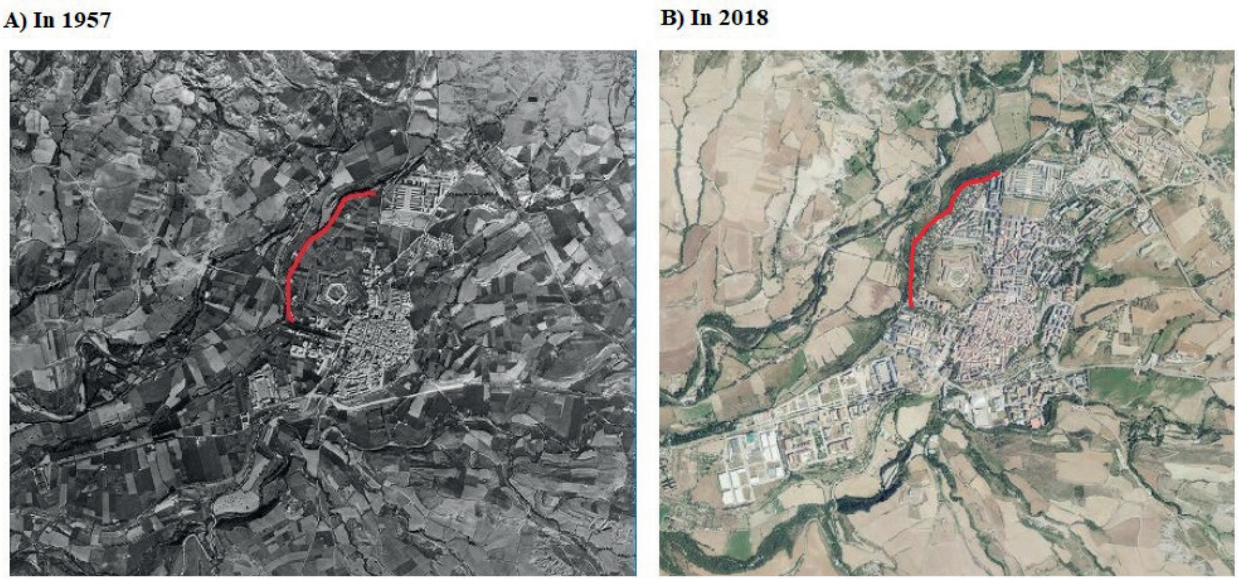

Figure 1. Location of poplar trees studied in Jaca: (A), in 1957; (B), in 2018. Adapted from Gobierno de Aragón.

(Chaub. ex St.-Amans) Zwackh] and species of genus *Lecanora s. l.* [*Lecanora chlarotera* Nyl., *L. glabrata* (Ach.) Malme, *Myriolecis hagenii* (Ach.) Śliwa, Zhao Xin & Lumbsch (≡ *Lecanora hagenii* (Ach.) Ach.)], most of them characteristic of alliance *Lecanorion subfuscae*. Xavier Llimona suggested in 1976 (based on his observations of 1973) that these crustose species, as first colonizers, would disappear in a temporal framework. Disappeared foliose were three species of Physciaceae [*Phaeophyscia orbicularis* (Neck.) Moberg (≡ *Physica orbicularis* (Baumg.) Poetsch), *Physcia aipolia* (Ehrh. ex Humb.) Fürnr., *P. tenella* (Scop.) DC.], three species of Collemataceae [*Blennothallia crispa* (Huds.) Otálora, P. M. Jørg. & Wedin (≡ *Collema crispum* (Huds.) Weber ex F. H. Wigg.), *Collema subflaccidium* Degel., *Scytinium fragrans* (Sm.) Otálora, P. M. Jørg. & Wedin (≡ *Collema fragrans* (Sm.) Ach.)], a Parmeliaceae as *Pleurosticta acetabulum* (Neck.) Elix & Lumbsch [≡ *Parmelia acetabulum* (Neck.) Duby], and a Teloschistaceae as *Polycauliona candelaria* (L.) Frödén, Arup & Søchting [≡ *Xanthoria candelaria* (L.) Th. Fr.]. Most of these foliose had a small thallus size.

New species for the community in 2018 were five crustose: *Megaspora verrucosa* (Ach.) Arcadia & A. Nordin and *Lepra albescens* (Huds.) Hafellner, either characteristic from old trees (Nimis & Martellos, 2017), *Caloplaca cerina* (Hedw.) Th. Fr. *s. l.*, *Candelariella aurella* (Hoffm.) Zahlbr. and undetermined *Agonimia* sp. Also, five foliose appeared in 2018, two cyanolichens [*Collema subnigrescens* Degel., *Enchylium ligerinum* (Hy) Otálora, P. M. Jørg. & Wedin], two Parmeliaceae [*Parmelia carporrhizans* (Taylor) Poelt & Vězda, *P. tiliacea* (Hoffm.) Hale], and *Physconia grisea* (Lam.) Poelt, which has an optimum below the montane belt, locally common also in urban areas (Nimis & Martellos, 2017), as our locality.

Species that persisted in both samplings were observed frequently in the 2018 sampling. There were two crustose, *Lecanora horiza* (Ach.) Röhl. and *Lecidella elaeochroma* (Ach.) M. Choisy [≡ *Lecidea parasema* (Ach.) Ach.]. There were also six foliose lichens, some of them macrofoliose, such as *Melanelixia glabra* (Schaer.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch [≡ *Parmelia glabra* (Schaer.) Nyl.], *M. subargentifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch (≡ *Parmelia subargentifera* Nyl.), *Physconia distorta* (With.) J. R. Laundon [≡ *Physica pulverulenta* (Lam.) Boistel], *Xanthoria parietina* (L.) Th. Fr., which could over-top other tiny lichens, and *Physcia adscendens* H. Olivier and *P. stellaris* (L.) Nyl. Many of them belong to the association *Physcietum adscendentis*. This community is characterized as photophile, aereoxerophile and nitrophile (Barkman, 1958) and it was observed by X. Llimona in 1973 too (Llimona, 1976). Also in 2018, we only found a fruticose species, *Anatpychia ciliaris* (L.) Körb. ex A. Massal., which it was hardly visible like was observed in 1973. Llimona (1976) suggested that the presence of *Anatpychia ciliaris* and *Pleurosticta acetabulum* (found in 1973) could indicate the initial association *Pleurostictetum acetabuli*, which would mean better air quality. Remarkably, *Pleurosticta acetabulum* was present in the same street in 2018, but only on *Quercus ilex* L. and not on *Populus alba*.

Lichen communities from both years were similar on its tolerance to environmental conditions, because we did not find significant differences in any of the environmental variables between both samplings (Table 2, and for more details see Appendix 2). Species found in both samplings were acid tolerant to subneutral (range between 2 to 4/5), to high solar radiation and aridity (values > 3/5), to weak values of eutrophication (values close to 3/5) and slightly sensitive to disturbance (values < 2/3). These values of tolerance were according to the environment of the locality. Trees were isolated, allowing high solar radiation, and the locality has a temperate Mediterranean climate without dry season and with hot summer (AEMET–IM, 2011). Furthermore, the locality was slightly eutrophicated, so on average in 2009 there were 3 $\mu g/m^3$ of SO_2, when 20 mg/m^3 is the critical value (following Spanish legislation), 5.4 $\mu g/m^3$ of NO_2, when 30 $\mu g/m^3$ is the critical value (measured on 0.5 km of the street "Paseo de la Cantera", data provided by Ayuntamiento de Jaca).

The results found in this study showed that the studied locality was almost stable for 45 years and both samplings had a close lichen community, since they showed similar values of sensitivity to environmental variables. However, specific lichen composition changed between both samplings. It was found that only 36% of species from 1973 persisted, with crustose and small foliose species disappearing. Thus, this change on lichen composition between both

Table 2. Means and standard deviation of environmental values. *P*-values of Welch *t*-test from differences on environmental values between studied years.

	1973	2018	Welch *t*-test (P value)
pH (minimum)	2.2 ± 0.5	2.4 ± 0.6	0.316
pH (maximum)	3.5 ± 0.8	3.6 ± 0.8	0.841
Solar radiation (min.)	3.6 ± 0.5	3.5 ± 0.5	0.478
Solar radiation (max.)	4.7 ± 0.6	4.8 ± 0.4	0.414
Aridity (min.)	3.0 ± 0.5	2.8 ± 0.4	0.300
Aridity (max.)	3.6 ± 0.8	3.7 ± 0.8	0.879
Eutrophication (min.)	2.6 ± 0.9	2.2 ± 0.8	0.182
Eutrophication (max.)	3.8 ± 0.8	3.6 ± 0.7	0.452
Poleotolerance (min.)	1.1 ± 0.3	1.0 ± 0.0	0.333
Poleotolerance (max.)	2.1 ± 0.7	2.4 ± 0.6	0.260

samplings seems to be related to the autogenic succession described by Ellis (2012). Finally, this study has been a good opportunity to understand changes in lichen communities and reveal the importance of assessing lichen communities in a long-term survey.

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Appendix 1. Species found in 1973 and 2018. On frequencies 2018: CC: very common, C: common, R: rare.

Species	**Date**	**Herba-rium**	**Freq. 2018**	**Family**	**Growth form**	**Photobiont**
Athallia pyracea (Ach.) Arup, Frödén & Søchting	1973			Teloschistaceae	Crustose	Green algae
Blastenia ferruginea (Huds.) A. Massal.	1973			Teloschistaceae	Crustose	Green algae
Blennothallia crispa (Huds.) Otálora, P. M. Jørg. & Wedin	1973			Collemataceae	Foliose	Cyanobacteria
Caloplaca haematites (Chaub. ex St.-Amans) Zwackh	1973			Teloschistaceae	Crustose	Green algae
Collema subflaccidum Degel.	1973			Collemataceae	Foliose	Cyanobacteria
Lecanora chlarotera Nyl.	1973			Lecanoraceae	Crustose	Green algae
Lecanora glabrata (Ach.) Malme	1973			Lecanoraceae	Crustose	Green algae
Myriolecis hagenii (Ach.) Śliwa, Zhao Xin & Lumbsch	1973			Lecanoraceae	Crustose	Green algae
Phaeophyscia orbicularis (Neck.) Moberg	1973			Physciaceae	Foliose	Green algae
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	1973			Physciaceae	Foliose	Green algae
Physcia tenella (Scop.) DC.	1973			Physciaceae	Foliose	Green algae
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	1973			Parmeliaceae	Foliose	Green algae
Polycauliona candelaria (L.) Frödén, Arup & Søchting	1973			Teloschistaceae	Foliose	Green algae
Ramalina fraxinea (L.) Ach.	1973			Ramalinaceae	Fruticose	Green algae
Rinodina exigua (Ach.) Gray	1973			Rinodinaceae	Crustose	Green algae
Scytinium fragrans (Sm.) Otálora, P. M. Jørg. & Wedin	1973			Collemataceae	Foliose	Cyanobacteria
Anaptychia ciliaris (L.) Körb. ex A. Massal.	both	L2300	R	Physciaceae	Fruticose	Green algae
Lecanora horiza (Ach.) Röhl.	both	L2301	CC	Lecanoraceae	Crustose	Green algae
Lecidella elaeochroma (Ach.) M. Choisy	both	L2302	CC	Lecanoraceae	Crustose	Green algae
Melanelixia glabra (Schaer.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	both	L2303	CC	Parmeliaceae	Foliose	Green algae
Melanelixia subargentifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	both	L2304	CC	Parmeliaceae	Foliose	Green algae
Physcia adscendens H. Olivier	both	L2305	C	Physciaceae	Foliose	Green algae
Physcia stellaris (L.) Nyl.	both	L2306	C	Physciaceae	Foliose	Green algae
Physconia distorta (With.) J. R. Laundon	both	L2307	CC	Physciaceae	Foliose	Green algae
Xanthoria parietina (L.) Th. Fr.	both	L2308	CC	Teloschistaceae	Foliose	Green algae
Agonimia sp.	2018	L2309	R	Verrucariaceae	Crustose	Green algae
Caloplaca cerina (Hedw.) Th. Fr. *s. l.*	2018	L2310	C	Teloschistaceae	Crustose	Green algae
Candelariella aurella (Hoffm.) Zahlbr.	2018	L2311	C	Candelariaceae	Crustose	Green algae
Collema subnigrescens Degel.	2018	L2312	R	Collemataceae	Foliose	Cyanobacteria
Enchylium ligerinum (Hy) Otálora, P. M. Jørg. & Wedin	2018	L2313	R	Collemataceae	Foliose	Cyanobacteria
Lepra albescens (Huds.) Hafellner	2018	L2314	R	Pertusariaceae	Crustose	Green algae
Megaspora verrucosa (Ach.) Arcadia & A. Nordin	2018	L2315	C	Megasporaceae	Crustose	Green algae
Parmelina carporrhizans (Taylor) Poelt & Vězda	2018	L2316	RR	Parmeliaceae	Foliose	Green algae
Parmelina tiliacea (Hoffm.) Hale	2018	L2317	R	Parmeliaceae	Foliose	Green algae
Physconia grisea (Lam.) Poelt	2018	L2318	R	Physciaceae	Foliose	Green algae

Appendix 2. Values of lichen sensitivity in Italy. Extracted from Nimis & Martellos (2019).

Species	**pH**		**Solar irradiation**		**Aridity**		**Eutrophication**		**Poleotolerance**	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Agonimia sp.										
Anaptychia ciliaris (L.) Körb. ex A. Massal.	2	3	4	5	3	3	2	3	1	2
Athallia pyracea (Ach.) Arup, Frödén & Søchting	3	4	4	5	3	4	2	4	1	2
Blastenia ferruginea (Huds.) A. Massal.	2	3	4	5	3	3	1	3	1	2
Blennothallia crispa (Huds.) Otálora, P. M. Jørg. & Wedin	3	4	4	4	3	3	2	4	1	2
Caloplaca cerina (Hedw.) Th. Fr. *s. l.*	3	4	3	5	3	4	3	4	1	3
Caloplaca haematites (Chaub. ex St.-Amans) Zwackh	3	4	4	5	4	5	4	4	2	3
Candelariella aurella (Hoffm.) Zahlbr.	4	5	3	5	3	5	2	4	1	3
Collema subflaccidum Degel.	2	3	3	4	2	2	2	3	1	2
Collema subnigrescens Degel.	3	3	3	4	2	2	2	3	1	2
Enchylium ligerinum (Hy) Otálora, P. M. Jørg. & Wedin	2	3	3	5	3	3	1	3	1	2
Lecanora chlarotera Nyl.	2	3	3	5	3	4	2	5	1	3
Lecanora glabrata (Ach.) Malme	2	3	3	3	3	3	2	3	1	1
Lecanora horiza (Ach.) Röhl.	2	3	4	5	3	4	2	3	1	2
Lecidella elaeochroma (Ach.) M. Choisy	2	4	3	5	2	5	2	4	1	3
Lepra albescens (Huds.) Hafellner	2	3	3	4	2	3	1	3	1	2
Megaspora verrucosa (Ach.) Arcadia & A. Nordin	3	4	4	5	3	4	1	3	1	1
Melanelixia glabra (Schaer.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	2	3	4	5	3	4	2	3	1	2
Melanelixia subargentifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	2	4	4	5	3	4	2	3	1	2
Myriolecis hagenii (Ach.) Śliwa, Zhao Xin & Lumbsch	3	5	4	5	3	5	2	4	1	3
Parmelina carporrhizans (Taylor) Poelt & Vězda	2	3	4	5	3	4	2	3	1	2
Parmelina tiliacea (Hoffm.) Hale	2	2	3	4	3	3	2	3	1	3
Phaeophyscia orbicularis (Neck.) Moberg	2	5	3	5	3	4	4	5	1	3
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	2	3	4	5	3	3	3	4	1	3
Physcia adscendens H. Olivier	2	5	4	5	3	4	3	5	1	3
Physcia stellaris (L.) Nyl.	2	3	4	5	3	3	2	4	1	2
Physcia tenella (Scop.) DC.	2	4	4	5	3	4	3	4	1	2
Physconia distorta (With.) J. R. Laundon	3	4	4	5	3	4	3	4	1	3
Physconia grisea (Lam.) Poelt	3	4	3	5	3	3	4	5	1	3
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	2	3	4	5	3	4	2	3	1	2
Polycauliona candelaria (L.) Frödén, Arup & Søchting	2	4	4	5	4	4	4	5	1	2
Ramalina fraxinea	2	3	4	5	2	3	2	3	1	1
Rinodina exigua (Ach.) Gray	1	2	3	5	3	4	3	3	1	2
Scytinium fragrans (Sm.) Otálora, P. M. Jørg. & Wedin	2	3	3	4	3	3	3	3	1	1
Xanthoria parietina (L.) Th. Fr.	2	4	3	5	3	4	3	4	1	3