Terricolous lichen communities of *Corynephorus canescens* grasslands of Northern Italy

Erdflechtengesellschaften von *Corynephorus canescens* Trockenrasen in Norditalien

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Abstract

In Italy most of the habitats hosting terricolous lichens are found in the Alps and along the coasts, but some lichen-rich plant communities are also present in the Po Plain. We report a study of terricolous lichen communities found in dry grasslands attributed to *Spergulo vernalis*-*Corynephoretum canescentis* in the western Po Plain (Northern Italy), in accordance with the Braun-Blanquet approach. Relevés (138) were carried out in several developmental stages of the *Corynephorus* grassland. They were sorted manually and analyzed using ANOSIM, non-parametric MANOVA and PCA. Indicator species of the groups were found by means of INDVAL and SIMPER analyses and literature. Seven lichen vegetation types were distinguished. These were attributable to 4 described associations: *Stereocauletum condensati*, *Cladonietum foliaceae* (in which we found 3 subassociations: *typicum*, *cladonietosum furcatae* and *cladonietosum subrangiformis*), *Cladonietum mitis* and *Cladonietum rei*, and to one impoverished community (*Cetraria aculeata* community). Ordination of floristic variables showed several overlaps between communities, underlining the depleted floristic conditions found in the study area, where several species occur in many communities and other species are very rare, and thus play a minor role in the differentiation of the lichen vegetation types. Overlaps are also referable to intermediate conditions between one community and another, reflecting dynamic relationships, with *Stereocauletum condensati*, *Cetraria aculeata* community and *Cladonietum foliaceae typicum* having the most distinct pioneer character and *Cladonietum mitis* being the most evolved. Ordination of ecological variables based on the indices of substrate pH, light and humidity requirements and tolerance to eutrophication showed several overlaps between the communities, found to be from acidophytic to subneutrophytic, from rather to very photophytic, from mesophytic to rather xerophytic and from anitrophytic to slightly nitrophytic. Rarity in Italy and conservation needs are discussed in detail, also in comparison with the situation of the same communities in central European *Corynephorus* grasslands. These grasslands and their typical lichen communities are rare in Italy and, though somewhat depleted, they are the habitat of several threatened lichen species at the southern margin of their distribution range. Therefore management plans should always consider both the cryptogamic and the vascular plant communities.

Keywords: *Cladonietum foliaceae*, *Cladonietum mitis*, *Cladonietum rei*, lichen vegetation, phytosociology, Po Plain, *Spergulo-Corynephoretum*, *Stereocauletum condensati*

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Terricolous lichens constitute a rather heterogeneous ecological group that includes not only mineral soil-dwelling lichens, but also species with preferences for more humic substrates (SCHEIDEGGER & CLERC 2002, NIMIS & MARTELLOS 2004, VUST 2011).

Like vascular plants, terricolous lichens and bryophytes can form vegetation types, which have been framed into the same sort of syntaxonomical schemes. Terricolous lichen vegetation has been very well studied in Northern and Central Europe (e.g. KRIEGER 1937, TOBLER & MATTICK 1938, LANGERFELDT 1939, KLEMENT 1949, 1955, ZIELIŃSKA 1967, DANIËLS et al. 1993, DREHWALD 1993, PAUS 1997, BÜLTMANN & DANIËLS 2001, GÜNZL 2005, BÜLTMANN 2005a, b, 2006a) and on the Alps, but rather less in Southern Europe (see NIMIS & MARTELLOS 2004 for a review). In spite of the great variety of habitats and environmental conditions found throughout its territory, Italy is decidedly understudied from this point of view. Theoretical outlines of the terricolous lichen vegetation found and expected to be found in Italy were compiled by NIMIS (1986) and NIMIS & MARTELLOS (2004), and a few vegetation studies on terricolous lichens have been carried out in the alpine regions (MONTACCHINI & PIERVITTORI 1979, CANIGLIA et al. 1998, 2002) and in coastal areas of Sardinia (COGONI et al. 2011) and Sicily (GRILLO & CANIGLIA 2004).

The Po Plain in particular has been rather overlooked in regard to terricolous lichens, because of its heavy human pressure, not favourable to lichen diversity (cf. NIMIS 1993); however, areas hosting these lichens are still present in several localities in its western part, often within protected areas (VALCUVIA PASSADORE et al. 2002a, b, GHEZA 2015, GHEZA et al. 2015). In this region, the study of terricolous lichens is limited to few lichen-rich habitats, represented by dry grasslands and heathlands, which are still present in the western Po Plain, even if restricted to fragments surrounded by an anthropized landscape.

One of the habitats most interesting in regard to the lichen vegetation is the dry acidophilous grassland dominated by *Corynephorus canescens* (L.) P. Beauv., which is attributable to habitat 2330 (inland dunes with open *Corynephorus* and *Agrostis* grasslands) of the Directive 1992/43/EEC (ASSINI 2007). Due to the stressful edaphic and ecological conditions in these grasslands, cryptogams often dominate, and can play a syntaxonomical role as characteristic or differential species. Lichen communities found in the *Corynephorus* grasslands of Central Europe have been well studied by several authors (e.g. KRIEGER 1937, TOBLER & MATTICK 1938, LANGERFELDT 1939, ZIELIŃSKA 1967, MASSELINK 1994, KETNER-OOSTRA 1994, BIERMANN & DANIËLS 1997, PAUS 1997, HAVEMAN & SCHAMINÉE 2003, HASSE 2005, 2007, JUSKIEWICZ-SWACZYNA 2009, DANIËLS et al. 2008a, b, KETNER-OOSTRA & SÝKORA 2008, SPARRIUS 2011, KETNER-OOSTRA et al. 2012).

The Italian *Corynephorus* grasslands, all referred to the *Spergulo vernalis-Corynephoretum canescentis* (R. Tx. 1928) Libbert 1933, are located in the western Po Plain (northern Italy), along the courses of the Sesia and Ticino rivers and in the Lomellina region (ASSINI 2007, 2008, ASSINI et al. 2013). The sites near the Sesia are void of lichens, which are instead well represented in the other localities. The cryptogamic component of these grasslands has been rather overlooked: studies regarding exclusively the lichen flora have been carried out only recently (GHEZA 2015, GHEZA et al. 2015), while the lichen vegetation has never been studied.

The aim of this study is therefore the description, within a European perspective, of the lichen communities found in the Italian range of the *Spergulo-Corynephoretum*. This study aims to contribute to a better knowledge of the terricolous lichen vegetation of Italy and the ecological and syntaxonomical characterization of the Italian *Corynephorus* grasslands.

2. Study area

2.1 Geographic position

The study area lies in the western Po Plain of Northern Italy, along the valley of the Ticino river (provinces of Novara and Varese) and includes the western area of the province of Pavia known as Lomellina. Within this area, eight sites hosting well preserved lichen-rich *Corynephorus* grasslands were found. Dossi di Cergnago (45°11'15"N 8°47'15"E, 102–109 m a.s.l.) and Dossi di Remondò (45°13'55"N 8°48'18"E, 103–109 m a.s.l.) are located in the residual inland sand dunes of Lomellina, while all the other study sites are located in the valley of the Ticino river. They are: Tenuta Bornago (45°33'08"N 8°42'04"E and 45°33'15"N 8°42'10"E, 143–146 m a.s.l), Turbigaccio (45°34'49"N 8°42'01"E, 147 m a.s.l.), Marcetto (45°36'53"N 8°40'49"E and 45°36'56"N 8°40'52"E, 160–162 m a.s.l.), Barbelera (45°37'10"N 8°40'39"E, 161–162 m a.s.l.), Castelnovate (45°37'34"N 8°39'57"E, 163–164 m a.s.l.) and Cascina Casone (45°38'03"N 8°40'48"E, 172–175 m a.s.l.).

2.2 Geology and climate

The study sites in Lomellina are situated on diluvial inland sand dunes made up of siliceous sediments subjected to eolic shaping (BONI 1947) on the fundamental level of the plain. The valley of the Ticino river is instead the result of fluvial shaping of alluvial sediments of various texture (sands, gravels and pebbles) and chemistry, deposited in a more recent period (D'ALESSIO & COMOLLI 1996).

The climate of the study area is continental, with annual temperatures ranging widely between cold winters and warm summers.

The study area is included in the temperate bioclimate (RIVAS-MARTÌNEZ et al. 2004), in the mesaxeric zones of type B (Dossi di Cergnago and Dossi di Remondò) and C (valley of the Ticino river) (TOMASELLI et al. 1973). Both zones have a mean annual temperature of between 0 and 10 °C, but differ in terms of mean annual rainfall (TOMASELLI et al. 1973).

There is no real floristic difference between type B and type C zones, either from a phytoclimatic or from a lichenological point of view (cf. TOMASELLI et al. 1973), with the subdivision between the Padanian (Dossi di Cergnago and Dossi di Remondò) and the Submediterranean (valley of the Ticino river) regions being merely formal and due to the strong anthropogenic disturbance affecting the Padanian area (NIMIS & MARTELLOS 2004).

2.3 Vegetation

The climax vegetation of the Po Plain is mesophilous mixed wood dominated by *Quercus robur* L. and *Carpinus betulus* L. (TOMASELLI et al. 1973). It occurs mainly on the fundamental level of the plain, while in the valley of the Ticino the most mature forest is dominated by *Q. robur* and *Ulmus minor* Mill. In Lomellina, the climax vegetation, found on the inland dunes, is open wood dominated by *Q. robur* (habitat 9190 of the Directive 1992/43/EEC: old acidophilous oak woods with *Quercus robur* on sandy plains). *Corynephorus* grasslands (association *Spergulo-Corynephoretum*) occur in the more or less widespread clearings of these woods, often in patches with other xerophilous grasslands (alliance *Thero-Airion* Tüxen 1951), at least in the valley of the Ticino.

3. Materials and methods

3.1 Sampling design and data collection

A total of 138 phytosociological relevés (method of BRAUN-BLANQUET 1928) were carried out over four years, every May, from 2012 to 2015, within a movable standard plot of 30 cm x 30 cm. This plot size has been used by several authors for the study of terricolous lichen vegetation in Central Europe (e.g. PAUS 1997, GÜNZL 2005, HASSE 2005, 2007). Relevés were carried out in lichen-rich stands.

The cover-abundance scale of BRAUN-BLANQUET (1928) was used, with the following values: cover <1%: +; 1–5%: 1; >5–25%: 2; >25–50%: 3; >50–75%: 4; > 75%: 5. For data analysis, the scale was transformed according to VAN DER MAAREL (1979), as follows: cover <1%: 2; 1–5%: 3; >5–25%: 5; >25–50%: 7; >50–75%: 8; > 75%: 9.

The number of relevés carried out in the different study sites depended on the number of relevés already collected for the present lichen communities (i.e. if a study site showed only already well-recorded lichen communities, no relevés were carried out; this happened for Cascina Casone).

3.2 Identification and nomenclature of species and syntaxa

Most of the species were identified in the field. Whenever necessary, specimens were collected and identified in the laboratory. The keys used include NIMIS (1986), NIMIS & MARTELLOS (2004) and SMITH et al. (2009) for lichens, CORTINI PEDROTTI (2001, 2006) and ATHERTON et al. (2010) for bryophytes and PIGNATTI (1982) for vascular plants.

Nomenclature follows NIMIS & MARTELLOS (2008) for lichens, CORTINI PEDROTTI (2001, 2006) for bryophytes and CONTI et al. (2005) for vascular plants.

Relevés were sorted manually accordingly to species with higher cover-abundance values. Syntaxonomic indicator function was inferred from the following sources: KRIEGER (1937), TOBLER & MATTICK (1938), LANGERFELDT (1939), KLEMENT (1949, 1955), ZIELIŃSKA (1967), DANIËLS et al. (1993), DREHWALD (1993), PAUS (1997), GÜNZL (2005), BÜLTMANN (2005a, b), MÜLLER & OTTE (2007), SCHUBERT & STORDEUR (2011).

Nomenclature of lichen syntaxa follows PAUS (1997) and MUCINA et al. (in press), while vascular plant syntaxa are named as in ASSINI et al. (2013). The name *Cladonietum rei* is accepted here according to the considerations of ROLA et al. (2014).

3.3 Statistical analyses

A matrix of the lichen dataset of all 138 relevés was prepared and multivariate analysis performed on it. Bryophytes and vascular plants were excluded from the dataset because of their occasional presence.

Analysis of similarities (ANOSIM) (CLARKE 1993) and non-parametric MANOVA (NP-MANOVA) (ANDERSON 2001) tests were performed on the groups obtained by manual sorting to evaluate their validity. Statistical significance was established by means of a permutation test with 9,999 permutations.

Indicator species were selected by means of an indicator value (INDVAL) analysis (DUFRENE & LEGENDRE 1997) integrated with a similarity percentage (SIMPER) analysis (CLARKE 1993), with statistical significance being established by means of a permutation test with 9,999 permutations. While INDVAL is based on specificity and fidelity of the species to one group and assigns each species only to one group, SIMPER is based on the mean abundance of the species in each group, thus enabling establishment of the same species as characteristic of more than one group, if its abundance is higher than that of every other species in the same groups.

In order to characterize and differentiate the lichen communities, weighted spectra were calculated for several characteristics, described as follows.

1. Growth forms: foliose-squamulose (L), fruticose with simple podetia (Be), fruticose with ramified podetia (Cl) (BÜLTMANN 2006b).
2. pH of the substrate (pH): 1 (very acid substrates), 2 (rather acid substrates), 3 (subneutral substrates), 4 (rather basic substrates), 5 (basic substrates) (NIMIS & MARTELLOS 2008).
3. Light requirements (L): 1 (very skiophytic, in very shaded positions), 2 (moderately skiophytic, in shaded positions), 3 (moderately photophytic, in diffuse light but with scarce direct irradiation), 4 (rather photophytic, in exposed positions but not under extreme irradiation), 5 (photophytic, in strongly irradiated positions) (NIMIS & MARTELLOS 2008).
4. Humidity requirements (H): 1 (hygrophytic), 2 (rather hygrophytic), 3 (mesophytic), 4 (rather xerophytic), 5 (xerophytic) (NIMIS & MARTELLOS 2008).
5. Tolerance to eutrophication (N): 1 (anitrophytic, not tolerating eutrophication), 2 (moderately nitrophytic, tolerating very weak eutrophication), 3 (rather nitrophytic, tolerating weak eutrophication), 4 (very nitrophytic, tolerating rather high eutrophication), 5 (extremely nitrophytic, tolerating very high eutrophication) (NIMIS & MARTELLOS, 2008).
6. Poleophoby (P): 1 (species also occurring in heavily disturbed areas), 2 (species occurring in moderately disturbed areas), 3 (species occurring in natural or semi-natural habitats) (NIMIS & MARTELLOS 2008).
7. Ecology: pioneer, humicolous, aerohygrophytic (BÜLTMANN 2005b, 2006b; KETNER-OOSTRA & SÝKORA 2008; KETNER-OOSTRA et al. 2012).
8. Chorology: arctic, boreal, south-boreal, temperate, south-temperate, submediterranean, mediterranean (WIRTH et al. 2013). Since species are defined not with a single chorology but with a distribution range (e.g. *Stereocaulon condensatum*: arctic-temperate), when calculating the spectra each species has been considered for every chorological belt in which it occurs.
9. Rarity in the Padanian and Submediterranean phytoclimatic regions of Italy: absent, extremely rare, very rare, rare, rather rare, rather common, common, very common, extremely common (NIMIS & MARTELLOS 2008). Since several species found during the fieldwork were new for the phytoclimatic belt of reference, the category "absent" has been merged in the category "extremely rare", as described by GHEZA (2015).

Other important biological characteristics (i.e. type of photobiont, reproduction strategy) were not considered, because a preliminary evaluation showed they were uniform among the different lichen vegetation types.

A series of Kruskal-Wallis tests was performed in order to evaluate the discriminating value of biological, ecological and chorological characteristics, species richness and cover values in defining the differences between the lichen vegetation types.

A second matrix including only the ecological values of pH, L, H and N for the 138 relevés was also prepared. ANOSIM, NP-MANOVA and Kruskal-Wallis tests were also performed on this matrix.

A principal component analysis (PCA) was performed on the two different matrices: the one with floristic data, to evaluate the effect of floristic diversity on the communities (variance explained by the first and second axes together: 50.53%), and the one with ecological values, to evaluate potential ecological diversity between communities (variance explained by the first and second axes together: 83.94%).

The statistical analyses were performed with the software packages PAST (HAMMER et al. 2001) and R (R CORE TEAM 2014).

4. Results

4.1 Syntaxonomical scheme

Numbers refer to the groups as they are reported in the figures, in the tables and in the synoptic table (Table 2).

Ceratodonto purpurei-Polytrichetea piliferi Mohan 1987 corr. Drehwald 1993
Peltigeretalia Klement 1949
Baeomycetion rufi Klement 1952
1. *Stereocauletum condensati* (Langerfeldt 1939) Klement 1955
Cladonion arbusculae Klement 1949 corr. Bültmann 2016
Cladonietum foliaceae Klement 1953 corr. Drehwald 1993
2. *typicum*
3. *cladonietosum furcatae* Paus 1997
4. *cladonietosum subrangiformis* Paus 1997
5. *Cladonietum mitis* Krieger 1937
6. *Cetraria aculeata* community *sensu* Paus 1997
Cladonion rei Paus 1997
7. *Cladonietum rei* Paus 1997

4.2 Elaboration of the relevés

Manual ordination of relevés discriminated seven groups, corresponding to the lichen communities reported in the syntaxonomical scheme above.

Results of ANOSIM and NP-MANOVA confirmed the validity of the groups from both floristic and ecological points of view, and showed a high level of statistical significance ($p < 0.001$) for almost all comparisons between them. Lower significance levels ($p < 0.05$) were found for ANOSIM for *Cladonietum foliaceae* vs *Cetraria aculeata* community for floristic variables ($p = 0.0221$) and ANOSIM ($p = 0.0014$) and NP-MANOVA ($p = 0.0077$) for *Cladonietum mitis* vs *Cladonietum rei* for ecological variables.

At least one indicator species was found for each lichen community according to INDVAL (Table 1). Results given by INDVAL and SIMPER generally agreed in defining the most characteristic species of each group.

4.3 Lichen vegetation

4.3.1. *Stereocauletum condensati* (Langerfeldt 1939) Klement 1955

Pioneer community typical of mineral sands, characterized by a low number of cryptogam species (mean 3.8 per relevé, 10 in total) and low cover values (mean 42%), dominated by *Stereocaulon condensatum* and often also by *Racomitrium canescens* or *Polytrichum piliferum*. Rather acidophytic (pH: 2.5), very photophytic (L: 4.0), mesophytic (H: 3.0), anitrophytic (N: 1.3), occurring in natural or semi-natural habitats (P: 2.5). This community was found only on inland sand dunes in the *Spergulo-Corynephoretum typicum*, where it is the only pioneer community referred to the *Baeomycetion rufi*.

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Table 1. Statistically significant indicator species according to INDVAL and the two most abundant species for each group according to SIMPER. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6: *Cetraria aculeata* community; 7: *Cladonietum rei*.

Tabelle 1. Statistisch signifikante Indikatorarten nach INDVAL und die zwei häufigsten Arten für jede Gruppe nach SIMPER (Syntaxonomische Einheiten s. o.).

Group	Indicator species (INDVAL)	Most abundant species (SIMPER)
1	*Stereocaulon condensatum* (indval: 87.06, $p < 0.001$)	*Stereocaulon condensatum* *Cladonia foliacea*
2	*Cladonia foliacea* (indval: 24.78, $p = 0.004$) *Cladonia humilis* (indval: 21.21, $p = 0.020$)	*Cladonia foliacea* *Polytrichum piliferum*
3	*Cladonia furcata* (indval: 48.60, $p < 0.001$)	*Cladonia furcata* *Cladonia foliacea*
4	*Cladonia rangiformis* (indval: 61.52, $p < 0.001$)	*Cladonia rangiformis* *Cladonia portentosa*
5	*Cladonia portentosa* (indval: 52.70, $p < 0.001$) *Hypnum cupressiforme* (indval: 25.21, $p = 0.008$)	*Cladonia portentosa* *Hypnum cupressiforme*
6	*Cetraria aculeata* (indval: 93.59, $p < 0.001$) *Polytrichum piliferum* (indval: 40.38, $p < 0.001$)	*Polytrichum piliferum* *Cetraria aculeata*
7	*Cladonia rei* (indval: 88.14, $p < 0.001$)	*Cladonia rei* *Cladonia foliacea*

4.3.2. *Cladonietum foliaceae* Klement 1953 emend. Drehwald 1993 *typicum*

Pioneer to intermediate community characterized by a rather high number of cryptogam species (mean 4.2 per relevé, 18 in total) and a high cover (mean 76%), distinctly dominated by *Cladonia foliacea*. Rather subneutrophytic (pH: 2.7), very photophytic (L: 4.2), mesophytic (H: 2.8), rather anitrophytic (N: 1.6), occurring in natural or semi-natural habitats (P: 2.5). This community is widespread both on inland sand dunes and in the valley of the Ticino, and is the most frequent terricolous lichen community in the study area. In some situations it becomes reduced to monospecific stands of *C. foliacea*, but more often it includes several species.

4.3.3. *Cladonietum foliaceae cladonietosum furcatae* Paus 1997

Pioneer to intermediate community characterized by a medium-high number of cryptogam species (mean 3.4 per relevé, 15 in total) and a medium cover (mean 75%), dominated by *Cladonia furcata*, which sometimes forms monospecific stands. Rather subneutrophytic (pH: 2.7), rather photophytic (L: 3.8), mesophytic (H: 2.9), rather anitrophytic (N: 1.5), occurring in natural or semi-natural habitats (P: 2.5). This community was found only on inland sand dunes, where *C. furcata* is widespread and strongly characterizes the physiognomy of the terricolous lichen vegetation; it was found in the *Spergulo-Corynephoretum typicum* and *cladonietosum*.

Table 2. Synoptic table with percentual presence of the species. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6: *Cetraria aculeata* community; 7: *Cladonietum rei*.

Tabelle 2. Übersichtstabelle mit der prozentualen Stetigkeit der Arten. (Syntaxonomische Einheiten s. o.).

Lichen community	1	2	3	4	5	6	7
Number of relevés	20	33	33	21	11	5	15
Mean % cover value	42	76	75	89	80	86	81
Number of cryptogams	10	18	15	14	10	4	15
Number of vascular plants	4	13	6	10	7	5	12
Total number of species	14	31	21	24	17	9	27
Mean pH index	2.5	2.7	2.7	3.2	2.4	2.3	2.5
Mean L index (light)	4.0	4.2	3.8	4.2	3.8	4.4	3.6
Mean H index (humidity)	3.0	2.8	2.9	2.8	2.6	3.5	3.0
Mean N index (eutrophication)	1.3	1.6	1.5	1.8	1.5	1.3	1.3
Mean P index (poleophoby)	2.5	2.5	2.5	2.5	2.7	2.7	2.5
C Stereocauletum condensati							
Stereocaulon condensatum Hoffm.	100	11	6	.	.	.	7
C Cladonietum foliaceae							
Cladonia foliacea (Huds.) Willd.	85	91	85	57	55	100	73
D cladonietosum furcatae							
Cladonia furcata (Huds.) Schrad.	75	14	100	10	55	60	47
D cladonietosum subrangiformis							
Cladonia rangiformis Hoffm.	5	49	3	100	64	.	13
C Cladonietum mitis							
Cladonia portentosa (Dufour) Coem.	5	37	55	67	100	.	13
C Cetraria aculeata community							
Cetraria aculeata (Schreb.) Fr.	.	3	3	.	.	100	7
C Cladonietum rei							
Cladonia rei Schaer.	10	6	3	19	.	.	100
C Peltigeretalia, Ceratodonto-Polytrichetea							
Polytrichum piliferum Hedw.	45	57	36	29	18	100	33
Ceratodon purpureus (Hedw.) Brid.	25	14	6	5	.	.	27
Cladonia uncialis (L.) F.H.Wigg ssp. *uncialis*	.	.	.	14	.	.	.
Cladonia pyxidata (L.) Hoffm.	.	43	.	48	9	.	27
Cladonia coccifera (L.) Willd.	.	20	.	24	.	.	27
Other species							
Cladonia squamosa Hoffm.	.	6	3	10	9	.	7
Racomitrium canescens (Hedw.) Brid.	20	11	9	.	27	.	.
Campylopus introflexus (Hedw.) Brid.	.	6	.	29	9	.	13
Cladonia coniocraea (Flörke) Spreng.	10	6	.	.	.	.	.
Hypnum cupressiforme Hedw.	.	.	24	5	36	.	.
Cladonia symphycarpa (Flörke) Fr.	.	6	.	.	.	.	7
Algae	.	6	3	.	.	.	.
Cladonia humilis (With.) J.R.Laundon	.	20	.	.	.	.	.
Dicranum scoparium Hedw.	.	.	3	5	.	.	.
Pseudoscleropodium purum (Hedw.) M. Fleisch. in Broth.	.	.	.	.	.	.	13
Cladonia cervicornis (Ach.) Flot. ssp. *cervicornis*	.	.	3	.	.	.	.

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Lichen community	1	2	3	4	5	6	7
Vascular plants							
Corynephorus canescens (L.) P.Beauv.	85	89	97	90	91	100	93
Filago minima (Sm.) Pers.	.	23	15	5	18	60	.
Rumex acetosella L.	.	14	3	48	27	20	53
Teesdalia nudicaulis (L.) R.Br.	40	29	48	14	18	.	20
Hypericum perforatum L.	10	.	6	5	27	40	53
Aira caryophyllea L.	.	57	.	57	36	.	13
Micropyrum tenellum (L.) Link	.	17	.	24	18	.	7
Hieracium pilosella L.	.	6	.	.	.	.	7
Hieracium piloselloides Vill.	.	6	.	5	.	.	7
Teucrium chamaedrys L.	.	3	.	14	.	.	.
Erigeron annuus (L.) Desf.	5	.	3	.	.	.	20
Veronica peregrina L.	.	.	.	.	.	20	.
Verbascum sp.	.	.	.	.	.	.	7
Armeria arenaria (Pers.) Schult. in Roem. & Schult.	.	3	.	.	.	.	.
Helianthemum nummularium (L.) Mill.	.	6	.	.	.	.	.
Potentilla tabernaemontani Asch.	.	6	.	.	.	.	.
Thymus pulegioides L.	.	3	.	.	.	.	.
Euphorbia cyparissias L.	.	.	.	.	.	.	20
Sonchus sp.	.	.	.	.	.	.	7
Fraxinus ornus L. (seedling)	.	.	.	5	.	.	.

4.3.4. *Cladonietum foliaceae cladonietosum subrangiformis* Paus 1997

Intermediate to evolved community characterized by a rather high number of cryptogam species (mean 4.2 per relevé, 14 in total) and a high cover (mean 89%), dominated by *Cladonia rangiformis*. Neutrophytic (pH: 3.2), very photophytic (L: 4.2), mesophytic (H: 2.8), rather anitrophytic (N: 1.8), occurring in natural or semi-natural habitats (P: 2.5). This community was found rarely on inland sand dunes while it is widespread in the valley of the Ticino, where *C. rangiformis* seems to replace *Cladonia furcata* in the intermediate stage of the lichen succession on the less acidic soils; it was found in the *Spergulo-Corynephoretum cladonietosum*.

4.3.5. *Cladonietum mitis* Krieger 1937

Evolved community, characterized by a rather low number of cryptogam species (mean 3.8 per relevé, 10 in total) and a high cover (mean 80%), dominated by *Cladonia portentosa* and differentiated by *Cladonia furcata* and *Hypnum cupressiforme* on inland sand dunes and by *C. rangiformis* in the valley of the Ticino. Rather acidophytic (pH: 2.4), rather photophytic (L: 3.8), mesophytic (H: 2.6), anitrophytic (N: 1.5), occurring in natural or semi-natural habitats (P: 2.7). This community was found in both inland sand dunes and the valley of the Ticino in the *Spergulo-Corynephoretum cladonietosum*. The association described here is impoverished, without other species of reindeer lichens, probably due to the climate of the study area.

4.3.6. *Cetraria aculeata* community *sensu* Paus 1997

Pioneer community typical of mineral sands, characterized by a very low number of cryptogam species (mean 3.6 per relevé, 4 in total) and a high cover (mean 86%), dominated by *Cetraria aculeata* and *Polytrichum piliferum*. Rather acidophytic (pH: 2.3), very photophytic (L: 4.4), slightly xerophytic (H: 3.5), anitrophytic (N: 1.3), occurring in natural or semi-natural habitats (P: 2.7). This community was found only on inland sand dunes in the *Spergulo-Corynephoretum typicum*.

4.3.7. *Cladonietum rei* Paus 1997

Ruderal or rather pioneer community typical of mineral soils, characterized by a rather high number of cryptogam species (mean 4.1 per relevé, 15 in total) and a high cover (mean 81%), dominated by *Cladonia rei*, which often forms monospecific stands. Rather acidophytic (pH: 2.5), slightly photophytic (L: 3.6), mesophytic (H: 3.0), anitrophytic (N: 1.3), occurring in natural or semi-natural habitats (P: 2.5). This community was found both on inland sand dunes and in the valley of the Ticino. In the latter situation it has a higher cover of the cup lichens *Cladonia coccifera* and *Cladonia pyxidata*. The *Cladonietum rei* has been rarely recorded within the *Spergulo-Corynephoretum* (cf. PAUS 1997).

4.4 Ecological comparison

Biological spectra reveal some variability between the lichen communities in regard to the growth forms (Fig. 1). In general, the pioneer communities such as the *Stereocauletum condensati*, *Cladonietum foliaceae typicum* and *Cladonietum rei* have a higher cover of foliose-squamulose and fruticose lichens with simple podetia, except in the case of *Cetraria aculeata* community, while the intermediate and more evolved communities *Cladonietum foliaceae cladonietosum furcatae*, *C. f. cladonietosum subrangiformis* and *Cladonietum mitis* have more fruticose lichens with ramified podetia.

Mean ecological values (reported in Table 2: pH, L, H and N indexes) disclose a rather homogeneous situation, characterized by rather acidophytic to neutrophytic, moderately to very photophytic, moderately hygrophytic to rather xerophytic and scarcely nitrophytic to anitrophytic communities. The only exception is the *Cladonietum foliaceae cladonietosum subrangiformis*, with a distinctly higher pH index.

Mean poleophoby values (reported in Table 2: P index) are also rather similar, disclosing a moderate to strong preference of the lichen communities for good quality habitats with high naturality and rare or no occurrences of human disturbance.

The ecology spectra (Fig. 2) show that the *Stereocauletum condensati* and the *Cetraria aculeata* community are pioneer communities, the *Cladonietum foliaceae typicum* and *C. f. cladonietosum furcatae* and the *Cladonietum rei* have pioneer to intermediate character, while the *Cladonietum foliaceae cladonietosum subrangiformis* and the *Cladonietum mitis* are evolved communities with a high cover of aerohygrophytic species.

The chorological spectra (Fig. 3) show that temperate (temperate and south-temperate) and southern (submediterranean and mediterranean) elements play the main role in almost all the communities, with species which also occur in the North (arctic, boreal and south-boreal elements) being less well represented: > 30% in the *Stereocauletum condensati*, the *Cladonietum rei* and the *Cladonietum foliaceae cladonietosum furcatae* and > 20% in the *C. f. cladonietosum subrangiformis* and *Cladonietum mitis*. Most of the species have a broad distribution from the temperate to the (sub)mediterranean zone, while fewer species range from the arctic/boreal zone to the temperate or (sub)mediterranean zones.

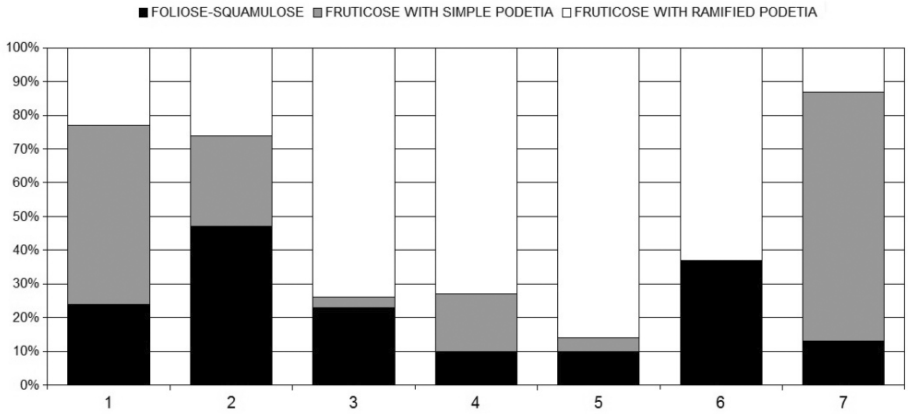

Fig. 1. Growth forms spectra. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6: *Cetraria aculeata community*; 7: *Cladonietum rei*.

Abb. 1. Spektren der Wuchsformen (Syntaxonomische Einheiten s. o.).

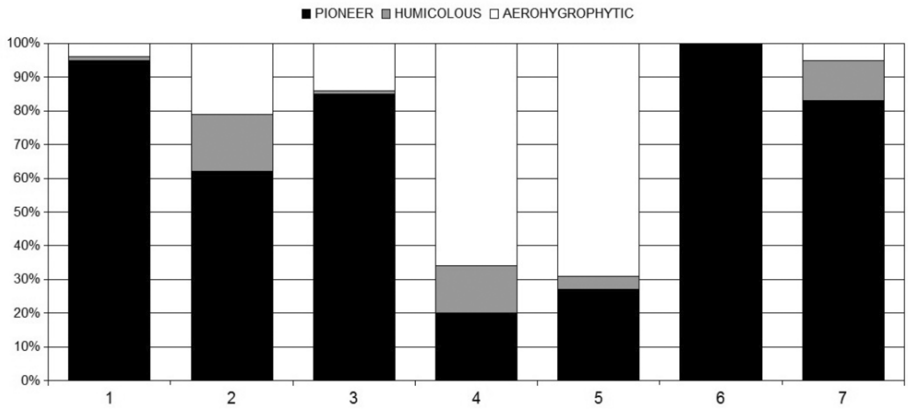

Fig. 2. Spectra of substrate ecology. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6*: Cetraria aculeata community*; 7: *Cladonietum rei*.

Abb. 2. Spektren der Substrat-Ökologie (Syntaxonomische Einheiten s. o.).

The rarity spectra (Fig. 4) provide useful information for conservation priorities of lichen communities. The percentage of extremely rare species is high especially in the communities in the Padanian phytoclimatic region. Higher rarity values were observed for all communities in the Padanian region, while in the Submediterranean region the same communities can have a considerable cover of extremely common species, the latter not recorded in relevés from the Padanian region.

All the biological, ecological and chorological features considered, as well as species richness and cover values, play a role in the differentiation of the detected communities. This is shown by the results of the Kruskall-Wallis test ($p < 0.001$ for every variable).

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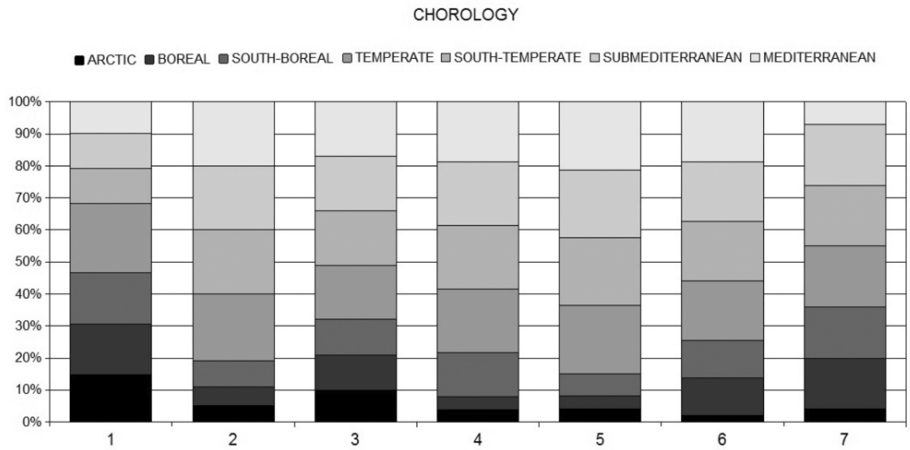

Fig. 3. Chorological spectra. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6: *Cetraria aculeata community*; 7: *Cladonietum rei*.

Abb. 3. Chorologische Spektren (Syntaxonomische Einheiten s. o.).

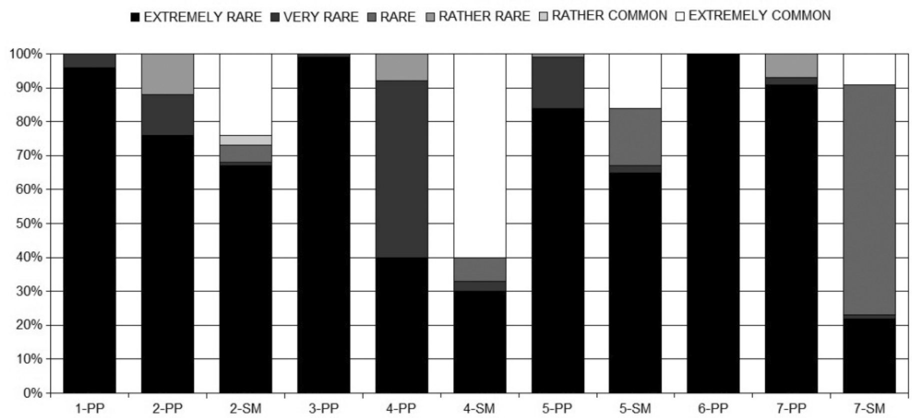

Fig. 4. Rarity spectra for Padanian (PP) and Submediterranean (SM) regions. Lichen communities are considered only in the phytoclimatic regions in which they have been found. 1: *Stereocauletum condensati*; 2: *Cladonietum foliaceae typicum*; 3: *Cladonietum foliaceae cladonietosum furcatae*; 4: *Cladonietum foliaceae cladonietosum subrangiformis*; 5: *Cladonietum mitis*; 6: *Cetraria aculeata* community; 7: *Cladonietum rei*.

Abb. 4. Spektren der Seltenheit für sowohl padanische (PP) als auch submediterrane (SM) Gebiete. Flechtengesellschaften werden nur in den phytoklimatischen Regionen betrachtet in denen sie gefunden wurden (Syntaxonomische Einheiten s. o.).

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The scatterplots of the two PCA (Fig. 5) well represent the situation of the detected lichen communities. Although these communities are impoverished, they are rather different from a floristic point of view (Fig. 5A). This results in a rather good physiognomic characterization of each community even in the field. However, several species have a wide distribution and frequency, appearing in many communities, and other species are very rare, thus playing a minor role in the differentiation of the lichen vegetation types. Overlaps are typical in intermediate situations, and are useful to understand successional dynamics. Contrariwise, the communities seem very similar ecologically (Fig. 5B).

5. Discussion

5.1 Overview in a European perspective

The identified lichen communities are quite diversified from a floristic point of view, but rather similar ecologically. This is in accordance with the sampling procedure of recording only relevés from one vascular plant community ecologically well characterized as acidophilous, xerophilous and oligotrophic (ASSINI et al. 2013).

From a chorological point of view, lichen communities have several analogies with the *Spergulo-Corynephoretum* in the study area: they host fewer species which are frequent in relevés from more northern and atlantic areas, and which are partly replaced by a higher presence of more southern species (cf. ASSINI 2007; ASSINI et al. 2013).

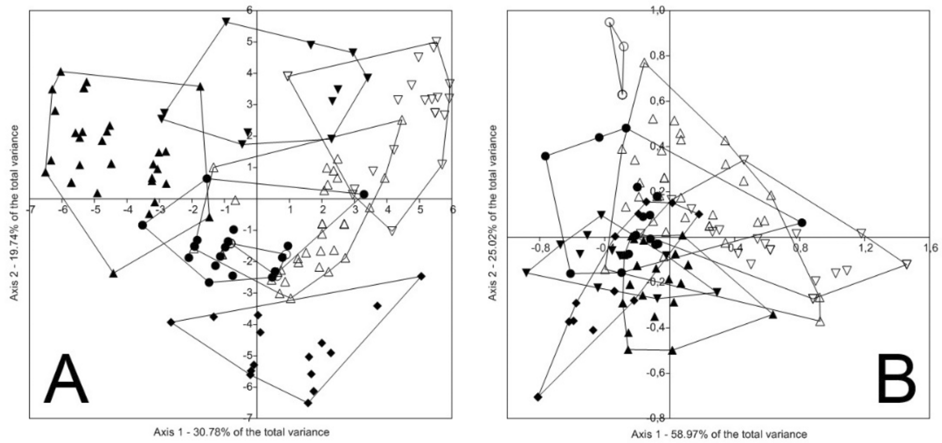

Fig. 5. PCA scatterplot of floristic (A) and ecological (B) variables. Full dots: *Stereocauletum condensati*; empty triangles: *Cladonietum foliaceae typicum*; full triangles: *Cladonietum foliaceae cladonietosum furcatae*; empty inverted triangles: *Cladonietum foliaceae cladonietosum subrangiformis*; full inverted triangles: *Cladonietum mitis*; empty dots: *Cetraria aculeata* community; full diamonds: *Cladonietum rei*.

Abb. 5. PCA Streudiagramm von floristischen (A) und ökologischen (B) Variablen. Gefüllte Punkte: *Stereocauletum condensati*; leere Dreiecke: *Cladonietum foliaceae typicum*; gefüllte Dreiecke: *Cladonietum foliaceae cladonietosum furcatae*; leere umgekehrte Dreiecke: *Cladonietum foliaceae cladonietosum subrangiformis*; gefüllte umgekehrte Dreiecke: *Cladonietum mitis*; leere Punkte: *Cetraria aculeata* community; gefüllte Rauten: *Cladonietum rei*.

Comparing the lichen communities of Northern Italy with those found in the *Corynephorus* grasslands of Central Europe, the most evident difference is the floristic impoverishment of the former. This could be due to the localization of our study area in a highly anthropized region and also to its southern latitude, since many species found in the lowlands of Central Europe are confined to montane and upper altitudinal belts in Northern Italy.

Central European relevés of the *Stereocauletum condensati* show a higher number of species, including diagnostic species of the *Baeomycetion rufi*, which are lacking from our relevés; and they show that bryophytes play a more prominent role, particularly *Polytrichum piliferum* (LANGERFELDT 1939, KLEMENT 1955, ZIELIŃSKA 1967, PAUS 1997, SCHUBERT & STORDEUR 2011). The *Stereocauletum condensati* is always found on more or less extended drift sands (PAUS 1997, KETNER-OOSTRA & SÝKORA 2008), preferably undisturbed by human activities, as in Dossi di Cergnago in our study area. It is an oligohemerobic community which does not tolerate eutrophication (BÜLTMANN 2005b). The character species, *Stereocaulon condensatum*, is particularly vulnerable (cf. SPARRIUS 2011).

The *Cladonietum foliaceae typicum* includes most of the character species cited by PAUS (1997) and GÜNZL (2005), but a lower number of lichen species in total. It develops in rather pioneer conditions on mineral or slightly humified sand and gravel and it is considered from oligohemerobic to mesohemerobic (PAUS 1997, BÜLTMANN 2005b). As recorded by PAUS (1997), initial stages host less fruticose species, which are more common in evolved stages of the two subassociations, differentiated by *Cladonia furcata* and *C. rangiformis*.

The former subassociation also seems to correspond well with the *Cladonia furcata*-Assoziation described by KRIEGER (1937): it occurs mainly on inland sand dunes, on mineral or slightly humified soil and, in several situations, it is a stage of the typical subassociation of *Cladonietum foliaceae* with a more pioneer character. The latter subassociation resembles the community described as *Corynephoretum canescentis cladonietosum* var. *Cladonia rangiformis* by ZIELIŃSKA (1967), and is more evolved than the former subassociation. In the study area, it probably even replaces the *Cladonietum mitis* as the final stage of succession in less acidophytic communities than the *Spergulo-Corynephoretum* (e.g. in *Thero-Airion* plant communities).

The aspect of the *Cladonietum mitis* found in the study area is a heavily depleted variant in which the only characteristic species is *Cladonia portentosa* and the total number of species is much lower than that observed in Central Europe (cf. KRIEGER 1937, LANGERFELDT 1939, KLEMENT 1949, 1955, PAUS 1997, GÜNZL 2005, SCHUBERT & STORDEUR 2011). A similar aspect, also dominated by *C. portentosa*, was described for inland sand dunes of Central Europe by PAUS (1997). It is an evolved community, found on humified soil, often at the margins of the grasslands, in positions at least partly sheltered by oak canopies. It is considered from oligohemerobic to mesohemerobic (BÜLTMANN 2005b).Though impoverished, the *Cladonietum mitis* is important because *C. portentosa* is rare in Italy and especially in the study area.

The *Cetraria aculeata* community is also relevant in the study area, because of the rarity of *C. aculeata*. This photophytic and xerophytic community, found in extreme pioneer sites on drift sand surfaces, fits very well with the homonymous community described by PAUS (1997), even though it hosts a lower number of species. It is restricted to one of the study sites, Dossi di Remondò, showing environmental conditions virtually identical to Dossi di Cergnago, where the species is lacking. This could be due to the different degrees of disturbance that have occurred in the two sites: the inland dunes of Remondò were subjected to disturbance by military activities until a few years ago, while those in Cergnago have been left practically undisturbed for decades. Mechanical disturbance, from which it usually benefits, could thus have played a role in maintaining and dispersing *C. aculeata* (cf. GALLEGO FERNÀNDEZ & DÌAZ BARRADAS 1997; PAUS 1997).

Another community that seems to grow well on mineral soils in disturbed conditions is the *Cladonietum rei*, which is considered ruderal and euhemerobic (BÜLTMANN 2005b). However, it shows a ruderal character mainly in the oceanic climate and develops in more natural habitats in the continental climate (BÜLTMANN 2005b). This is more in accordance with the anitrophytism deduced from the spectrum for relevés obtained in the continental climate of the study area. Here this community is often reduced to monospecific stands of the character species *Cladonia rei*, while it occurs in more structured aspects in other areas of Europe (cf. PAUS 1997, GÜNZL 2005, ROLA et al. 2014). Stands richer in species, with several cup lichens (mainly *Cladonia coccifera* and *C. pyxidata*), were found in the valley of the Ticino. In some sites, several stands attributable to the *Cladonion rei* but not necessarily to the *Cladonietum rei* were dominated by these species.

5.2 Dynamics

Dynamic relationships are summarized in Figure 6.

The communities with the most distinctly pioneer character are the *Stereocauletum condensati* and the *Cetraria aculeata* community in inland sand dunes and the typical variant of the *Cladonietum foliaceae* in the valley of the Ticino. These pioneer communities are found on mineral sandy to pebbly soils.

The *Cladonietum foliaceae typicum* can develop into the two other subassociations *cladonietosum furcatae* (in inland sand dunes) and *cladonietosum subrangiformis* (mainly in the valley of the Ticino). The former is found on mineral sandy soil and, like the typical

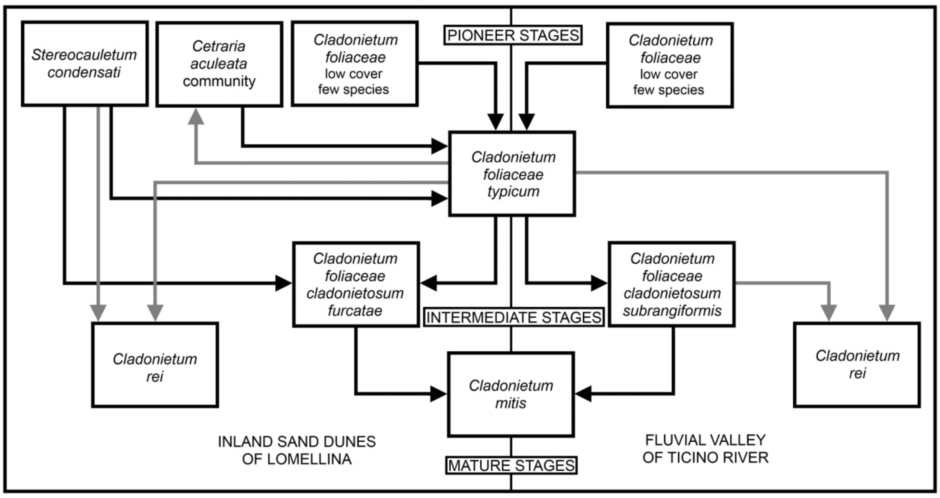

Fig. 6. Succession of lichen communities in *Corynephorus* grasslands of Northern Italy. Black arrows indicate regular succession dynamics, while grey arrows indicate disturbance-driven dynamics.

Abb. 6. Vegetationsentwicklung der Flechtengesellschaften in *Corynephorus* Trockenrasen Norditaliens. Schwarze Pfeile zeigen die normale Sukzessionsdynamik, während grauen Pfeile die von Störung gesteuerte Dynamik zeigen.

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variant, can have a rather pioneer role, while the latter is typical of more mature and less acidic soils. Both subassociations are considered intermediate stages of the succession and are reported also for central European *Corynephorus* grasslands (PAUS 1997).

The most evolved community in the study area is the *Cladonietum mitis* in the variant dominated by *Cladonia portentosa*, found on humified soils, often near the border between grassland and wood.

The *Cladonietum rei* and the *Cetraria aculeata* community appear in disturbed sites.

5.3 Threats and suggestions for conservation

The importance of the detected lichen communities for conservation issues is evident for several reasons. They represent microhabitats for locally (i.e. *Cetraria aculeata*, *Cladonia coccifera*, *C. uncialis*) and nationally (i.e. *C. portentosa*, *S. condensatum*) rare species with phytogeographical elements at the southern margin of their distribution range (e.g. *S. condensatum*). They include diagnostic elements for the vascular plant communities in which they occur (e.g. *Stereocauletum condensati* is diagnostic for *Spergulo-Corynephoretum typicum*, cf. PAUS 1997), as well as for the assessment of the dry grasslands quality (cf. ROSENTRETER & ELDRIDGE 2002, BÜLTMANN 2005b). Finally, they provide microhabitats for invertebrates (cf. MERKENS 2002, VOGELS et al. 2005, RIKSEN et al. 2006) and several ecosystem services (MAESTRE et al. 2011, ZEDDA & RAMBOLD 2015).

Habitat loss, the most pressing threat for both the *Spergulo-Corynephoretum* and its lichen communities in the study area (ASSINI 2008), has already taken place in the past, especially in inland dunes, mainly due to anthropogenic disturbance and land reclamation for agricultural purposes. Nowadays, loss in the residual habitat is mainly due to the encroachment of invasive exotic woody species (*Robinia pseudoacacia*, *Ailanthus altissima*, *Prunus serotina*) and/or to the natural succession of vegetation causing the development of *Corynephorus* grassland in shrublands and then in oak woods. The situation is aggravated by the small extent of *Corynephorus* grasslands, which, in the study area, are confined to more or less wide clearings in the oak wood.

Therefore, both the vascular plant and lichen communities need a proper management. Some actions have been planned on the basis of the observed situations and the available literature.

The most effective management action to prevent habitat loss is the recreation of drift sands through mechanical disturbance (KETNER-OOSTRA & SÝKORA 2008, KETNER-OOSTRA et al. 2012, LEPPIK et al. 2013). The availability of new sand surfaces reverses the succession to its pioneer stages and is therefore recommended to preserve pioneer communities like the *Stereocauletum condensati* or the *Cetraria aculeata* community. A small-scale mechanical disturbance consisting in the removal of the cryptogamic crust to favour *Corynephorus canescens* was tested in Dossi di Cergnago as a management action for the *Spergulo-Corynephoretum* (ASSINI 2008). Contrariwise, evolved communities like the *Cladonietum mitis* are not likely to benefit from this treatment. Therefore, because of the rarity of this community and of *C. portentosa* in the study area, attention is recommended where management actions are performed, to avoid damaging reindeer lichens.

The removal of seedlings and young woody plants should accompany mechanical disturbance (ASSINI 2008, KETNER-OOSTRA et al. 2012).

Low-intensity grazing (preferably by rabbits, in this case) would be a useful form of mechanical disturbance to maintain rather pioneer conditions (KOOIJMAN & DE HAAN 1995, SCHWABE et al. 2002, 2013, LEPPIK et al. 2013).

Eutrophication also threatens lichen communities, especially the most pioneer ones (SCHEIDEGGER & CLERC 2002, RIKSEN et al. 2006, BRITTON & FISHER 2010, SPARRIUS 2011, STEVENS et al. 2012). In the study area the *Spergulo-Corynephoretum* patches are almost all situated in clearings in oak woods, which could serve at least in part as barriers to nutrients and pollution.

Finally, the ability of terricolous lichens to propagate through thallus fragments (BAYFIELD et al. 1981, CHRISTENSEN 1988, HEINKEN 1999, CRITTENDEN 2000, BÜLTMANN 2005b, HASSE 2005, JESCHKE 2012) makes them suitable for (re)introductions.

Erweiterte deutsche Zusammenfassung

Einleitung – Erdflechten-Vegetation wurde bisher in Italien kaum untersucht, und nur wenige Publikationen zu diesem Thema liegen vor. Habitate, die reich sind an Erdflechten, kommen insbesondere in den Alpen und an den Küsten vor, sie können jedoch auch in der Po-Ebene nachgewiesen werden. Reiche Vorkommen von Erdflechten finden sich in *Corynephorus* Rasen, die sehr gut (unter Einschluss der Flechten)in Zentraleuropa studiert wurden; in Italien beschränkten sich die Untersuchungenbisher auf die Gefäßpflanzen-Vegetation (ASSINI et al. 2013).

Das Ziel dieser Arbeit ist, die Kenntnis zum Habitattyp 2330 der Directive 1992/43/EEC („Offene Grasflächen mit *Corynephorus* und *Agrostis* auf Binnendünen“) mit der Beschreibung der Flechten-Gesellschaften, die im italienischen Vorkommensgebiet des *Spergulo vernalis-Corynephoretum canescentis* auftreten, zu erweitern.

Material und Methoden – Das Untersuchungsgebiet befindet sich in der westlichen Po-Ebene (Nord-Italien) und setzt sich aus 8 Gebieten mit Flechten-reichen Beständen des *Spergulo-Corynephoretum* zusammen: 2 in den Binnendünen von Lomellina (Provinz Pavia) und 6 im Flusstal des Ticino (Provinzen: Varese, Novara).

138 pflanzensoziologische Aufnahmen wurden in 7 der 8 Gebiete nach der Methode von BRAUN-BLANQUET (1928) erhoben (unter Verwendung von Standard-Plots von 30 cm x 30 cm). Verschiedene Ausbildungsformen der *Corynephorus* Rasen wurden analysiert: von der Pionierphase zu den am weitesten entwickelten Stadien.

Die Aufnahmen wurden manuell sortiert und dann mit multivariaten Methoden bearbeitet („Analysis of Similarities and Non Parametric MANOVA“ und PCA: Principal Component Analysis). Weitere Analysen wurden durchgeführt, um Indikatorarten für die Gruppen zu bestimmen („Indicator Value Analysis“ und SIMPER); hierzu erfolgte auch eine Einbeziehung der Literatur (KLEMENT 1955, DREHWALD 1993, PAUS 1997, GÜNZL 2005, BÜLTMANN 2005a, b).

Die Gruppen mit ihren Indikatorarten sind unter Verwendung der relevanten Literatur den jeweiligen Gesellschaften zugeordnet worden. Folgende gewichtete Indikator-Spektren wurden für jede Gesellschaft kalkuliert: Wuchsformen, Boden pH, Lichtbedarf, Feuchtigkeitsansprüche, Toleranz gegenüber Eutrophierung, Poleophobie, Ökologie, Chorologie und Seltenheit in den für diese Studie relevanten phytoklimatischen Regionen (padanisch und submediterran). Die Berechnung der Spektren wurde mit dem Kruskal-Wallis-Test geprüft.

Ergebnisse – Die manuelle Sortierung ergab 7 Gruppen, deren Signifikanz durch statistische Verfahren bestätigt wurde (ANOSIM und NP-MANOVA)und deren Charakterarten mit

INDVAL und SIMPER Analysen sowie Literaturvergleich festgelegt wurden (Tab. 1). Die 7 Gruppen spiegeln7 Flechten-Vegetationstypenwider (Tab. 2). Die Mehrzahl der Pionier-Gesellschaften konnte dem *Stereocauletum condensati* und der *Cetraria aculeata*-Gesellschaft zugeordnet werden, beide wurden nur an offenen Stellen in Binnendünen gefunden und sind durch niedrige Deckungswerte der Vegetation gekennzeichnet. Die am häufigsten vorkommende Gesellschaft war (zumeist in einer intermediären Phase der Sukzessionsreihe wachsend) das *Cladonietum foliaceae*; von dieser Gesellschaft konnten 3 Subassoziationen festgestellt werden.Wo das *Stereocauletum* und die *Cetraria*-Gesellschaft fehlen, kann das „typicum“ des *Cladonietum foliaceae* das Pionierstadium aufbauen, aber es kann auch eine mehr intermediäre Phase prägen. Die anderen 2 Subassoziationen sind bessere Indikatoren, sowohl floristisch als auch ökologisch betrachtet. Das „*cladonietosum furcatae"* kommt nur in Binnendünen vor und hat einen ausgeprägten Pioniercharakter, wohingegen das „*cladonietosum subrangiformis"* im Tal des Ticino weiter verbreitet ist. Das Endstadium der Sukzession in den untersuchten Pflanzengesellschaften war das *Cladonietum mitis* (das hier in einer sehr verarmten Ausbildung gefunden wurde), dominiert von *Cladonia portentosa*. Das *Cladonietum rei* wächst an gestörten Stellen (ruderal geprägt oder sekundäre Pionier-Standorte).

Die Ordination der floristischen Struktur (Abb. 5A) zeigte einige Überlappungen zwischen den Gesellschaften; sie belegt die zum Teil verarmte Ausbildung der Erdflechten-Flora im Untersuchungsgebiet, wo verschiedene Arten weite Verbreitung und hohe Stetigkeit haben und in vielen Gesellschaften vorkommen. Andere Arten hingegen sind selten und spielen eine geringere Rolle in der Differenzierung der Flechten-Vegetationstypen. Diese Überlappungen zeigen auch die intermediäre Situation zwischen mehreren Gesellschaften im dynamischen Kontext. Nach der Ordination der ökologischen Faktoren scheinen die Gesellschaften ökologisch sehr ähnlich zu sein (Abb. 5B).

Die Flechten-Gesellschaften zeigten folgende ökologische Charakteristika: azidophytisch bis zu subneutrophytisch, ziemlich bis stark photophytisch, meso- bis ziemlich xerophytisch und anitrophytisch bis schwach nitrophytisch. Der Kruskall-Wallis Test belegt, dass alle biologisch-ökologischen und chorologischen Charakteristika sowie Diversität und Deckungswerte eine Rolle für die Differenzierung der Erdflechten-Gesellschaften im Untersuchungsgebiet.

Diskussion – Insgesamt erscheinen diese Gesellschaften, wenn man ihre Ausprägung mit der in Zentraleuropa vergleicht, verarmt. Dies dürfte mit den abweichenden klimatischen Bedingungen und der starken anthropogenen Überprägung im Untersuchungsgebiet zusammenhängen.

Die Hauptgefährdungen für diese Gesellschaften im Untersuchungsgebiet sind Habitatverlust durch anthropogenen Einfluss und spontane Sukzession (oft durch die Etablierung von holzigen exotischen Gehölzen gefördert) sowie Eutrophierung. Durch Management versucht man, die Sukzession, insbesondere die Gebüschetablierung, zu stoppen; davon profitieren sowohl die Flechten-Gesellschaften als auch das *Spergulo-Corynephoretum.* Zu den Maßnahmen gehören*:* kleinräumige mechanische Störungen des Substrates, Entnahme von Sämlingen der Gehölze, extensive Beweidung.

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