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Terricolous lichens of the western Padanian Plain: new records of phytogeographical interest

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Abstract: Very little is known of the earlier lichen flora of the Padanian Plain, the most heavily anthropized and industrialized part of Italy, which is currently extremely poor. Terricolous lichens in particular are the most sensitive to threats, and have almost totally disappeared from the western Padanian Plain. This paper reports new findings of 20 terricolous lichen species, several of which are rare or poorly known in Italy or are of some phytogeographical interest because they are found at lower altitudes than their usual distribution (i.e. *Cladonia coccifera*, *Cladonia uncialis*). In addition, *Cladonia humilis* is new for Lombardy and two other species, *Cladonia portentosa* and *Stereocaulon condensatum*, are reported for the second time in the same region. The significance of these species is discussed with regard to their historical records from the same area and their current altitudinal distribution; they were probably much more widespread in the past, but the decline and disappearance of their habitats in lowland areas have been followed by their own disappearance in many localities. A modification of the rarity status of some of these species in the considered phytoclimatic belts, based on the new records, is proposed.

Keywords: dry grasslands; heathlands; historical records; lichens; inland sand dunes; Ticino Natural Park

Introduction

Very little is known of the earlier lichen flora of the Padanian Plain, which is currently extremely poor, mainly due to air pollution and almost total deforestation (Nimis 1993; Nimis and Martellos 2004). Especially in Lombardy, the most heavily industrialized region of Italy, vast parts of the lowlands are now deprived of their native lichen flora (Nimis 1993); the features of this part of the region are not favourable to lichen diversity (Nimis and Martellos 2004).

Unlike epiphytic lichens, which have essentially no competitors on their elective substrates, terricolous lichens are exposed to strong competition with vascular plants, and are not able to overcome them because of their smaller size and slower growth rate (Scheidegger and Clerc 2002); therefore, they are often more vulnerable and less represented. Furthermore, particularly sensitive or rare species are unable to recover after their disappearance due to disturbance, even when the causes of their disappearance have ceased (e.g. Sparrius 2011; Leppik et al. 2013). On the other hand, their physiological characteristics, which make them more stress-tolerant than phanerogams, and their independence from the substrate for their sustenance, allow them to colonize habitats that are prohibitive for plants, making them important pioneer organisms; these habitats are characterized by, for example, oligotrophic soils, severe edaphic conditions and extreme climates (Scheidegger and Clerc 2002). Habitats with these features are becoming increasingly rare due to anthropization and agricultural exploitation, leading to loss of natural habitats, pollution and

eutrophication; the terricolous lichen diversity in them could be used to infer information about the whole diversity they host, their stability and the anthropogenic influence acting on them (Scheidegger and Clerc 2002).

At present, in the western Padanian Plain, such habitats are even scarcer than in the other, less anthropized, phytoclimatic belts of Italy. Realistically, this lack of suitable habitats is the reason for the absence of studies focused on terricolous lichens in this part of Italy, together with the high level of anthropization; here, they were included in very few studies, only in some areas of conservation concern (Valcuvia Passadore et al. 2002a,b; Gheza, Assini, and Valcuvia Passadore 2015).

The aim of this paper is to describe recent findings of terricolous lichen species that are new or poorly known in the Padanian Plain, or which are interesting because they are recorded outside their previously known distribution in Italy; some implications of their presence at low altitudes are discussed.

Materials and methods

Study area

The study area is located in the western Padanian Plain (northern Italy), mainly along the valley of the Ticino river, which is the natural boundary between the two regions of Piedmont and Lombardy. Thirteen sites selected for this research are located here and included in two regional natural parks; two additional sites are located in the Lomellina, south of the previous sites, and not included within protected areas but occurring in a

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military base and in a private hunting preserve (Table 1). The lichen flora of the latter has been previously described in detail by Gheza, Assini, and Valcuvia Passadore (2015).

According to Rivas-Martinez, Penas, and Diaz (2004), the bioclimate of the study area is temperate continental in the low and medium plain and temperate oceanic in the high plain. Following the phytogeographic subdivision of Italy stated by Nimis and Martellos (2004, 2008), the lower plain falls into the Padanian region and the upper plain into the sub-Mediterranean region; however, this separation is considered artificial, because the Padanian differs from the sub-Mediterranean only in having heavier anthropization (Nimis and Martellos 2004).

Geological substrates are composed of sediments of various ages and lithologies. In the high plain, the fundamental level of the plain is constituted by ancient Pleistocene terraces attributed to the ancient and medium Diluvium, mainly gravelly or pebbly (D'Alessio and Comolli 1996). In Lomellina, there are the remains of inland dunes made by siliceous sands attributed to recent Diluvium deposits subjected to aeolic shaping (Boni 1947; Bertossi 1950), which has now ceased. Finally, the fluvial valley of the Ticino River has a more recent origin, being constituted by Holocene pebbly, gravelly and sandy deposits of the recent Alluvium (D'Alessio and Comolli 1996).

The natural vegetation of the western Padanian Plain is now very limited; Sartori and Bracco (1998) provide an exhaustive overview of it. In particular, the vegetation of the study sites considered here is characterized by the presence of dry grasslands and heathlands in the widest openings of the mixed wood of *Quercus robur* L. and *Carpinus betulus* L. which represents the climax of the vegetation in the Ticino river valley and in the low plain (Sartori and Bracco 1998). Grasslands referred to *Corynephorion canescentis* Klika 1931 are found both on diluvial inland sand dunes and on more recent alluvial deposits with various granulometry in the fluvial valley (Assini et al. 2013), whereas several communities attributed to *Thero-Airion* Tüxen 1951 (Assini and Sartori 2004) are found on the second substrate and in the diluvial high plain, but not on the inland dunes. Heathland fragments, often considered as a mere blanket of the wood margin, can be found on recent deposits in the fluvial valley, but proper heathlands referred to *Calluno-Genistion pilosae* Duvigneaud 1944 (Sartori and Bracco 1998) are found only on intermediate and old-age diluvial deposits (Cerabolini, Ceriani, and De Andreis 1998) on the basic level of the plain. All of these three habitats are listed in the "Habitat" Directive 1992/43/CEE (2330: inland dunes with open *Corynephorus* and *Agrostis* grasslands; 4030: European dry heaths; 6220: pseudo-steppes with grasses and annuals of the *Thero-Brachypodietea*) (Biondi and Blasi 2009), and are therefore of some conservation value.

Their importance for the biodiversity of the Padanian Plain rests not only in the abundance of terricolous lichens, but also in the presence of various vascular plants occurring here at the southern limit of their area (Cerabolini, Ceriani, and De Andreis 1998; Assini and Sartori 2004; Assini 2007; Assini et al. 2013).

Lichen sampling

Fifteen sites (Table 1) were selected for a floristic study on terricolous lichens: 13 in open dry grasslands (two with only *Corynephorion*, five with only *Thero-Airion* and six with a mixture of them) and two in heathlands (*Calluno-Genistion*). All the study sites were selected on the basis of their relevance in coverage and richness of the cryptogams in the herbaceous layer of the vegetation and because they represent quite well-preserved fragments of those habitats.

Terricolous lichens were exhaustively collected in each site and identified in the laboratory by means of a stereomicroscope and chemical reagents, following the keys of Nimis (1986), Nimis and Martellos (2004) and Smith et al. (2009). Nomenclature follows Nimis and Martellos (2008).

Records of the considered species from Lombardy and Piedmont were examined from both the available literature and the specimens held in the cryptogamic herbarium of the University of Pavia (hereinafter: PAV), to check their currently known regional and altitudinal distributions. Particular attention was given to historical records from localities sited in the study area (Biroli 1808; Cozzi 1917; Bertossi 1950; Giacomini 1958; Corbetta 1968), which have been examined critically.

A rarity spectrum based on the commonness–rarity categories stated for the phytoclimatic regions of Italy by Nimis and Martellos (2008) was calculated for each site. The nine rarity categories are defined as follows: absent, extremely rare, very rare, rare, rather rare, rather common, common, very common, extremely common. As several species considered "absent" by Nimis and Martellos (2008) in the Padanian and the sub-Mediterranean regions were found in some sites, when calculating the spectra they have been merged in the category "extremely rare", to avoid the nonsense of the presence of "absent" species. Therefore, for these newly found species, the assignment to the "extremely rare" category is proposed on the basis of the criterion stated in ITALIC (Nimis and Martellos 2008) for which a species is to be considered "extremely rare" if it is known from fewer than five sites (in the considered belt).

Results

Commented floristic list

Cetraria aculeata (Schreb.) Fr.

Found in one site. Lombardy: Dossi di Remondò. On open mineral sandy soil. Only in *Corynephorion*.

Table 1. The 15 sites selected for the study of terricolous lichens in the study area, listed from south to north.

Locality	Municipality	Coordinates	Altitude	Substrate	Vegetation
Dossi di Cernago PP	San Giorgio di Lomellina (PV), Lombardy	45°11'37.05"N 8°47'5.10"E	101 m a.s.l.	Diluvial sands shaped by aeolic erosion.	<i>Corynephorion</i> on inland sand dunes in glades of a <i>Quercus robur</i> wood.
Dossi di Remondò PP	Gambolò (PV), Lombardy	45°13'54.21"N 8°48'19.08"E	105 m a.s.l.	Diluvial sands shaped by aeolic erosion.	<i>Corynephorion</i> on open inland sand dunes with exotic <i>Ailanthus altissima</i> and <i>Robinia pseudacacia</i> .
Molino d'Isella PP	Gambolò (PV), Lombardy	45°16'04.08"N 8°57'01.11"E	73 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Bosco Ronchi PP	Vigevano (PV), Lombardy	45°16'39.79"N 8°56'08.72"E	76 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
La Chiocciola SM	Cerano (NO), Piedmont	45°26'15.39"N 8°48'21.90"E	109 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Tenuta La Fagiana SM	Pontevecchio di Magenta (MI), Lombardy	45°25'47.11"N 8°49'33.46"E	108 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Tenuta Bomago SM	Cameri (NO), Piedmont	45°33'15.76"N 8°42'10.86"E	144 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
La Promessa SM	Lonate Pozzolo (VA), Lombardy	45°34'07.60"N 8°44'08.11"E	189 m a.s.l.	Diluvial sediments in the upper plain.	Large <i>Thero-Airion</i> grassland with small patches of <i>Calluno-Genistion</i> surrounded by a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Turbigaccio SM	Lonate Pozzolo (VA), Lombardy	45°34'51.88"N 8°41'51.88"E	145 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Quercus robur</i> and <i>Carpinus betulus</i> . <i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Brughiera di Tomavento SM	Lonate Pozzolo (VA), Lombardy	45°35'49.33"N 8°43'21.34"E	202 m a.s.l.	Diluvial sediments in the upper plain.	Well-developed <i>Calluno-Genistion</i> heathland surrounded by a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Marpetto SM	Oleggio (NO), Piedmont	45°36'53.31"N 8°40'49.55"E	161 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Carpinus betulus</i> . <i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Barbelera SM	Oleggio (NO), Piedmont	45°37'10.54"N 8°40'40.10"E	162 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Ansa di Castelnuove SM	Vizzola Ticino (VA), Lombardy	45°37'34.17"N 8°39'57.52"E	164 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Quercus robur</i> and <i>Carpinus betulus</i> . <i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Cascina Casone SM	Pombia (NO), Piedmont	45°38'02.75"N 8°40'49.64"E	173 m a.s.l.	Alluvial sediments in the valley of Ticino.	<i>Quercus robur</i> and <i>Carpinus betulus</i> . <i>Corynephorion</i> and <i>Thero-Airion</i> in large glades of a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .
Baraggia di Pombia SM	Pombia (NO), Piedmont	45°38'56.99"N 8°39'51.62"E	182 m a.s.l.	Diluvial sediments in the upper plain.	Fragmented <i>Calluno-Genistion</i> surrounded by a mixed wood with <i>Quercus robur</i> and <i>Carpinus betulus</i> .

Name of locality, municipality, province, geographic coordinates, altitude above sea level (a.s.l.), substrate and vegetation types in which lichens were collected are reported. The phytoclimatic region is added after the locality, abbreviated as follows: PP, Padanian region; SM, sub-Mediterranean region.

Previously reported in Lombardy only from subalpine and alpine environments (Anzi 1860; Giacomini 1940; Giacomini and Pignatti 1955, 1956; Pignatti and Pignatti 1958; Giacomini, Pirola, and Wikus 1962; Credaro and Pirola 1975; Kärnefelt 1986). It has never been accurately reported before in the lowland area, but was listed in relevés by Assini (2007) from generic “inland sand dunes of Lomellina”. New for the Padanian phytoclimatic belt (cf. Nimis and Martellos 2008), where it should be considered “extremely rare”.

Even if it has not been found in the Piedmont sites, it is worth mentioning that Biroli (1808) reported the species from the heathlands of the valley of Ticino River in Piedmont.

Cladonia cervicornis (Ach.) Flot. ssp. *cervicornis*

Found in four sites. Lombardy: Dossi di Cergnago, Ansa di Castelnovate; Piedmont: Tenuta Bornago, Barbelera. On pebbly, slightly humified soil. In *Corynephorion* and *Thero-Airion*.

Previously reported for the mountain regions both in Lombardy (Anzi 1860; Sandstede 1931; Rivellini and Valcuvia Passadore 1996; Rossi, Pirola, and Zurli 1998) and in Piedmont (Baglietto 1863; Baglietto and Carestia 1867, 1880), but actually already recorded “in ericetis Ticini” by Biroli (1808). New for the Padanian phytoclimatic belt (cf. Nimis and Martellos 2008), where it should be considered “extremely rare”.

Cladonia chlorophaea s. lat.

Found in eight sites. Lombardy: Molino d’Isella, La Promessa, Turbigaccio, Brughiera di Tornavento, Ansa di Castelnovate. Piedmont: Tenuta Bornago, Marcetto, Barbelera. On pebbly, slightly humified soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Cladonia coccifera (L.) Willd.

Found in eight sites. Lombardy: La Fagiana, La Promessa, Brughiera di Tornavento, Ansa di Castelnovate; Piedmont: Tenuta Bornago, Marcetto, Barbelera, Baraggia di Pombia. On pebbly, slightly humified soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Previously reported for mountain regions both in Lombardy (Anzi 1860; Baroni 1893; Rivellini and Valcuvia Passadore 1996; specimens in PAV) and in Piedmont (Baglietto and Carestia 1876, 1880; Martel 1911; Cengia-Sambo 1931, 1933; Montacchini and Piervittori 1979; Montacchini et al. 1982; Piervittori, Tarchetti and Montacchini 1988; Piervittori, Isocrono, and Maffei 2001; Isocrono et al. 2003a,b), but actually already recorded from Lombardy and Piedmont Ticino areas by several authors (Biroli 1808; Cozzi 1917; Giacomini 1958). New for the sub-Mediterranean phytoclimatic

region (cf. Nimis and Martellos 2008), where it should be considered “extremely rare” or “very rare”.

Cladonia coniocraea (Flörke) Spreng.

Found as terricolous in four sites. Lombardy: Dossi di Cergnago, Dossi di Remondò, Ansa di Castelnovate; Piedmont: Tenuta Bornago. On slightly humified soil. Only in *Corynephorion*.

Cladonia fimbriata (L.) Fr.

Found as terricolous in four sites. Lombardy: Molino d’Isella, Brughiera di Tornavento; Piedmont: Marcetto, Barbelera. On slightly humified soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Cladonia foliacea (Huds.) Willd.

Found in 12 sites. Lombardy: Dossi di Cergnago, Dossi di Remondò, Molino d’Isella, Bosco Ronchi, La Fagiana, Turbigaccio, Ansa di Castelnovate; Piedmont: La Chiocciola, Tenuta Bornago, Marcetto, Barbelera, Cascina Casone. On sandy, pebbly and slightly humified soil. In *Corynephorion* and *Thero-Airion*.

The most widespread species in the study area. Already reported by Gheza, Assini, and Valcuvia Passadore (2015) for the Padanian belt, where it should be considered “extremely rare” (cf. Nimis and Martellos 2008), whereas it could be considered “very rare” in the sub-Mediterranean belt.

Cladonia furcata (Huds.) Schrad.

Found in five sites. Lombardy: Dossi di Cergnago, Dossi di Remondò, Molino d’Isella, Bosco Ronchi, La Fagiana. On sandy and slightly humified soil. In *Corynephorion* and *Thero-Airion*.

Cladonia humilis (With.) J.R.Laundon.

Found in two sites. Lombardy: Ansa di Castelnovate; Piedmont: Tenuta Bornago. On sandy and pebbly soil. In *Corynephorion* and *Thero-Airion*.

Previously reported for Piedmont only by Coassini Lokar, Nimis, and Ciconi (1986). New for Lombardy (cf. Nimis and Martellos 2008).

Cladonia parasitica (Hoffm.) Hoffm.

Found as terricolous in one site. Piedmont: Baraggia di Pombia. On organic soil above a rotten stump. Only in *Calluno-Genistion*.

Widespread in Piedmont (cf. Nimis 1993; Nimis and Martellos 2008), but recorded mainly as epiphytic.

It is worth mentioning here that it was also found on *Quercus robur* in Bosco Ronchi, which represents the first record for the Padanian phytoclimatic belt (cf.

Nimis and Martellos 2008), where the species should be considered “extremely rare”.

Cladonia portentosa (Dufour) Coem.

Found in four sites. Lombardy: Dossi di Cernago, Dossi di Remondò; Piedmont: Tenuta Bornago, Marcetto. On sandy or pebbly, mineral or humified soil. Only in *Corynephorion*.

Previously reported in Lombardy only for residual inland sand dunes in the Padanian phytoclimatic belt (Gheza, Assini, and Valcuvia Passadore 2015) and in Piedmont for the mountain regions (Martel 1911; Cengia-Sambo 1931, 1933; Montacchini et al. 1982; Isocrono et al. 2006). It should be considered “extremely rare” in the Padanian belt (cf. Nimis and Martellos 2008).

Cladonia pyxidata (L.) Hoffm.

Found in nine sites. Lombardy: Dossi di Cernago, La Fagiana, La Promessa, Brughiera di Tornavento, Ansa di Castelnuovate; Piedmont: Tenuta Bornago, Marcetto, Barbelera, Cascina Casone. On sandy or pebbly, mineral or humified soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Cladonia rangiformis Hoffm.

Found in 11 sites. Lombardy: Dossi di Cernago, Molino d’Isella, Bosco Ronchi, La Fagiana, Turbigaccio, Ansa di Castelnuovate; Piedmont: La Chiocciola, Tenuta Bornago, Marcetto, Barbelera, Cascina Casone. On rather evolved, humified soil. In *Corynephorion* and *Thero-Airion*.

The most widespread species in the valley of Ticino River.

Cladonia rei Schaer.

Found in eight sites. Lombardy: Dossi di Remondò, Bosco Ronchi, Turbigaccio, Brughiera di Tornavento, Ansa di Castelnuovate; Piedmont: Marcetto, Barbelera, Cascina Casone. On sandy and gravelly-pebbly, not or scarcely humified soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Previously reported for the montane belt both in Lombardy (Rivellini and Valcuvia Passadore 1996) and Piedmont (Cengia-Sambo 1934; Isocrono et al. 2003b). New for the Padanian phytoclimatic region (cf. Nimis and Martellos 2008), where it should be considered “extremely rare”.

Cladonia squamosa Hoffm.

Found as terricolous in seven sites. Lombardy: Dossi di Cernago, Molino d’Isella, La Fagiana, La Promessa, Ansa di Castelnuovate; Piedmont: La Chiocciola, Tenuta

Bornago. On slightly humified soil. In *Corynephorion* and *Thero-Airion*.

Cladonia symphyrcarpa (Flörke) Fr.

Found in seven sites. Lombardy: Bosco Ronchi, La Fagiana, Ansa di Castelnuovate; Piedmont: Tenuta Bornago, Barbelera, Cascina Casone, Baraggia di Pombia. On rather mineral soil. In *Corynephorion*, *Thero-Airion* and *Calluno-Genistion*.

Previously reported in Lombardy only in montane and alpine localities (Nimis and Tretiach 1993; Rivellini and Valcuvia Passadore 1996; Nascimbene, Thor, and Nimis 2012; specimens in PAV) and in the sub-Mediterranean belt in Piedmont (Re 1825). New for the Padanian phytoclimatic region (cf. Nimis and Martellos 2008), where it should be considered “extremely rare”.

Cladonia uncialis (L.) F.H.Wigg. ssp. *uncialis*

Found in two sites. Piedmont: Tenuta Bornago, Marcetto. On humified gravelly soil. In *Corynephorion* and *Thero-Airion*.

Previously reported in Piedmont only for the alpine belt (Allioni 1785; Biroli 1808; Pollini 1824; Baglietto 1863; Baglietto and Carestia 1867, 1880; Martel 1911; Cengia-Sambo 1931, 1933; Isocrono et al. 2003b; Isocrono et al. 2006) and considered restricted to the Alps in Italy (Nimis and Martellos 2008). New for the sub-Mediterranean phytoclimatic region (cf. Nimis and Martellos 2008), where it should be considered “extremely rare”.

Cladonia sp.

Found in one site. Lombardy: Molino d’Isella.

Lepraria sp.

Found in one site. Lombardy: Brughiera di Tornavento.

Stereocaulon condensatum Hoffm.

Found in two sites. Lombardy: Dossi di Cernago, Dossi di Remondò. On open mineral sandy soil. Only in *Corynephorion*.

Previously reported by Gheza, Assini, and Valcuvia Passadore (2015) for the Padanian phytoclimatic belt; the only other citation for Lombardy has been resumed by Rivellini and Valcuvia Passadore (1996) from Anzi (1860), and refers to the alpine region. According to Nimis and Martellos (2008) it would be restricted to the Alps in Italy, since all the other Italian findings refer to mountainous regions. It should be considered “extremely rare” in the Padanian belt (cf. Nimis and Martellos 2008).

Table 2. Number of total, extremely rare and exclusive species per site.

	No. of species	No. of extremely rare species	No. of exclusive species
Dossi di Cernago	9	6	0
Dossi di Remondò	7	6	1
Molino d'Isella	8	4	1
Bosco Ronchi	5	4	0
La Chiocciola	4	1	0
La Fagiana	7	2	0
Tenuta Bornago	13	6	0
La Promessa	5	1	0
Turbigaccio	4	1	0
Brughiera di Tornavento	6	1	1
Marcetto	10	4	0
Barbelera	9	3	0
Ansa di Castelnovate	11	4	0
Cascina Casone	5	1	0
Baraggia di Pombia	3	1	1

Composition and distribution of the whole terricolous lichen flora

The whole floristic list includes 20 species, among which four (*Cetraria aculeata*, *C. coniocraea*, *C. portentosa*, *S. condensatum*) were exclusive to *Corynephorion* grasslands, while one (*Cladonia* sp.) was exclusively found in a *Thero-Airion* grassland and two others (*C. parasitica*, *Lepraria* sp.) were found only in one heathland each. Two species (*C. parasitica*, *Lepraria* sp.) have been collected only on ancient diluvial sediments of the fundamental plain level, two (*Cetraria aculeata*, *S. condensatum*) only on recent diluvial inland

dunes, and three (*C. humilis*, *C. uncialis*, *Cladonia* sp.) only in the alluvial valley of the Ticino river.

Only fruticose and squamulose species were found; no crustose or foliose terricolous species were observed in the study sites. Furthermore, all the recorded species have green algae as photobionts; no cyanolichens were found.

Considering the different habitats, *Corynephorion* grasslands are the richest in species (7.88 ± 2.64 species per site, 17 species overall), *Thero-Airion* grasslands show a slightly lower lichen diversity (6.09 ± 2.43 species per site, 14 species overall) and the heathland is

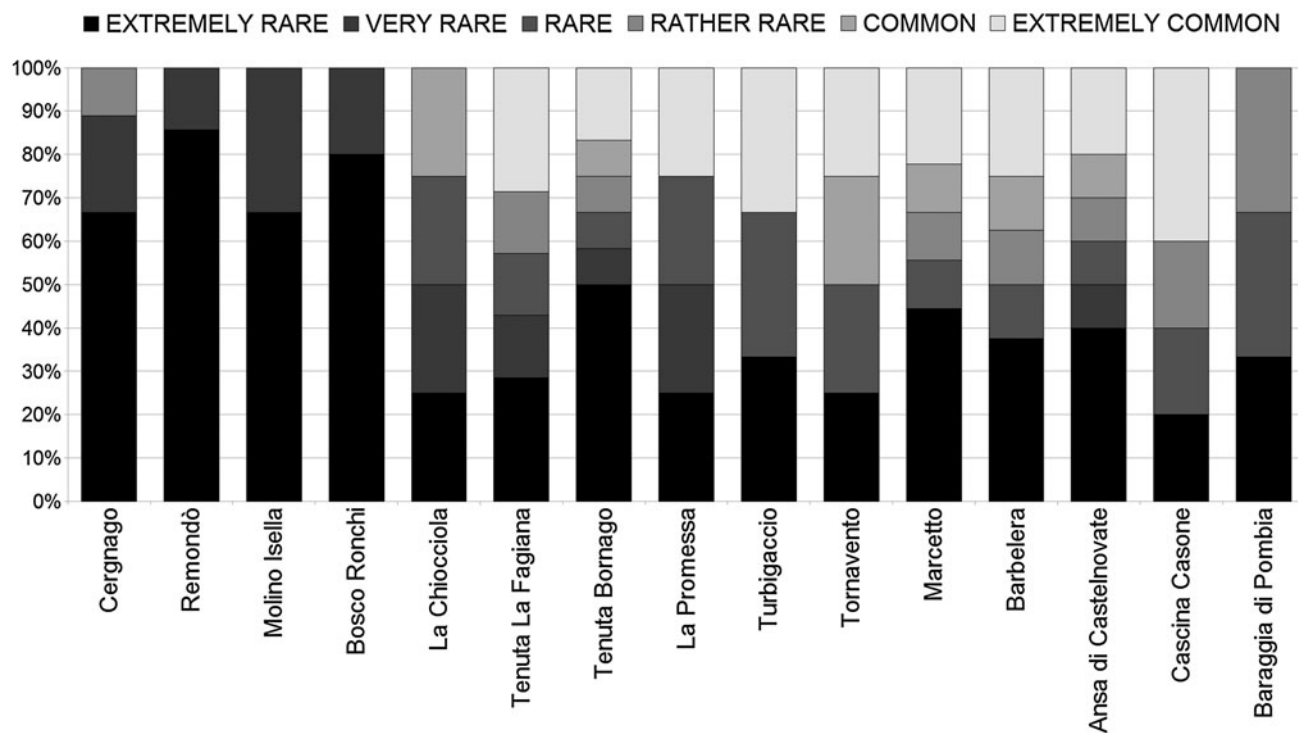


Fig. 1. Rarity spectra. Rarity refers to the phytoclimatic region where the site belongs, as stated by Nimis and Martellos (2008), modified accordingly with the new records (i.e. “absent” species have been merged in the category “extremely rare”).

the habitat that is poorest in lichens (4.5 ± 2.12 species per site, eight species overall). Considering the different substrates, alluvial (6.81 ± 2.76 species per site, 15 species overall) and recent diluvial (8 ± 1.41 species per site, 11 species overall) substrates host a similar number of species per site but a different number of total species, whereas the ancient diluvial plain is poorer (4.67 ± 1.53 species per site, nine species overall). The number of species per site is reported in Table 2.

According to Nimis and Martellos (2008), three species (*Cetraria aculeata*, *C. rei*, *C. symphycarpa*) are new for the Padanian phytoclimatic region, and three other species (*C. foliacea*, *C. portentosa*, *S. condensatum*) are recorded there for the second time after the records by Gheza, Assini, and Valcuvia Passadore (2015); two species (*C. coccifera*, *C. uncialis*) are new for the sub-Mediterranean region. One species (*C. humilis*) is new for Lombardy, and the record of *C. portentosa* reported here for Remondò is the second in the same region. The two records of *S. condensatum* from the inland sand dunes of Lomellina represent the second and third findings for the whole of Lombardy more than 150 years after the first report (Anzi 1860).

The rarity spectra (Figure 1) show a very high percentage of extremely rare species, mainly in the sites located in the lower plain, which is mostly the result of the heavily depleted condition of the Padanian region, in which they are placed, resulting in high rarity values for species that are less rare in the sub-Mediterranean region. However, also, several sites in the sub-Mediterranean belt have quite high percentages of extremely and very rare species.

Discussion

Although the lichen flora of the Ticino Natural Park has been well studied recently (Valcuvia Passadore et al. 2002a, b), the research presented here highlights the presence of several species previously not found or overlooked. These results could be a basis for reconstructing at least a fragment of the original composition of the terricolous lichen flora of the Padanian Plain.

The most interesting question is whether at least part of all those terricolous species that are restricted to mountainous regions today are truly limited by climate, or if they remain at high altitudes only because less pollution and anthropogenic disturbance are found there. Some historical and recent records suggest that the distribution of some species was wider in the past, extending to lowland areas. In fact, according to the altitudinal distribution stated by Nimis and Martellos (2008), only three species (*C. coccifera*, *C. uncialis*, *S. condensatum*) found in this research are formally typical of higher altitudinal belts, but the number increases when considering the historical records of six other species in several sites of the same study area near the Ticino river (*Cetraria islandica* (L.) Ach., *Cladonia*

amaurocraea (Flörke) Schaer., *Cladonia arbuscula* (Wallr.) Flot., *Cladonia gracilis* (L.) Willd., *Cladonia pleurota* (Flörke) Schaer., *Cladonia rangiferina* (L.) F.H.Wigg) (cf. Biroli 1808; Cozzi 1917; Giacomini 1958). Historical records from grasslands of the inland dunes of Lomellina are instead useless, because Bertossi (1950) and Corbetta (1968) overlooked lichens almost completely, reporting only the two most widespread species; several species unnoticed by them but reported in the present day (i.e. *Cetraria aculeata*, *C. cervicornis*, *C. portentosa*, *S. condensatum*) were certainly present, so it cannot be excluded that other species, that have since disappeared, could have been present but unseen by those authors in the past.

The occurrence of terricolous lichens seems related to the presence of residuals of dry grasslands and heathlands, which are the only habitats currently hosting them in the planitial regions of northern Italy. The integration between historical records and new findings from those habitats may help to better understand their importance. In fact, these habitats seem to have once hosted a higher lichen diversity than in the present day, including several species thought to be typical of mountainous regions in Italy (cf. Biroli 1808; Cozzi 1917; Giacomini 1958). The richest and best-known site was the Gallarate heathland (of which the site referred to as ‘Tornavento’ here represents the residual part), which extended far further until the first half of the twentieth century, before the noticeable enlargement of the Malpensa Airport occurred since the 1960s.

Considering those ancient records critically, some considerations can be made. The records of *C. arbuscula* and *C. rangiferina*, not currently found, could even be misidentifications of *C. portentosa*, which is found today at least in the valley of Ticino; but misidentifications of *C. amaurocraea* and *C. gracilis* are more unlikely. The disappearance of such species, now restricted to the mountains in Italy, could be due not only to the habitat loss, but also to global warming, which is known to affect terricolous lichens (Aptroot and Van Herk 2007); this topic requires further research in the Padanian Plain.

The peculiarity of the lichen flora of the inland sand dunes of Lomellina represents a relict of the previous conditions (for a comparison with central European inland sand dunes see Gheza, Assini, and Valcuvia Passadore 2015). Through previous centuries, those species closely linked to these geomorphological formations have certainly paralleled the disappearance of these formations caused by the spread of agriculture (cf. Boni 1947; Bertossi 1950; Corbetta 1968), but, just like the dunes themselves, they were surely much more widespread, at least in Lomellina and in the surrounding regions that hosted dunes of the same age (for a discussion about the origin and age of these dunes see Boni 1947).

Leppik et al. (2013) found that terricolous lichen communities in Estonian calcareous grasslands were mainly soil-type specific, but were also affected by

historic disturbances and land use change. Effects of these events are detectable at several study sites, because the reduction of occurrence and the disappearance of terricolous lichens are linked to the progressive diminution and loss of their habitats. For example, today the area occupied by the “Gallarate” heathland is vastly decreased, and most of the historically recorded species are no longer present.

The occurrence of anthropogenic disturbance is suggested in several sites also by the presence of the ruderal *C. rei*, which is particularly abundant in formerly disturbed sites, such as Tornavento, La Promessa and Dossi di Remondò. In the last of these sites, the grassland has been the site of military exercises for several decades, which have probably made a fundamental contribution to maintaining open bare sand areas, which are important for the maintenance of *Cetraria aculeata* too. In Dossi di Cernago, where the environmental conditions are almost identical to Remondò but no heavy disturbance occurred, *Cetraria aculeata* and *C. rei* are absent.

Finally, a practical observation underlines the persistence of interesting lichen florae in these habitats in well-preserved areas with forbidden access: a private hunting preserve and a military base in inland dunes (Dossi di Cernago and Dossi di Remondò, 11 species overall) and a private estate (Tenuta Bornago, 13 species) in the Ticino fluvial valley. Conversely, the exploited, disturbed and reduced areas in the high plain (La Promessa and Tornavento) show a lower terricolous lichen diversity.

Conclusions

This research has shown the presence of terricolous lichen species not found previously in the Padanian Plain and, in some cases, generally considered montane–alpine species at these latitudes. Together with several historical records, these findings highlight the possibility of a broader distribution for these species, at least in the past.

The fate of terricolous lichens in this part of Italy is strictly connected to the fate of the habitats where they can develop (cf. Scheidegger and Clerc 2002). Here, these habitats are represented by dry grasslands and heathlands, which have become very rare and fragmented due to anthropogenic disturbance (Sartori and Bracco 1998), and which are therefore considered nature fragments of conservation concern, both for the biodiversity that they host as habitats for relict populations and, in some cases, for their location at the southern limit of their areal (Cerabolini, Ceriani, and De Andreis 1998; Assini and Sartori 2004; Assini 2007; Assini et al. 2013). A lichen flora showing elements of phytogeographical and conservation interest could be added to the motivations supporting the conservation claims of such habitats.

This research focused on an area that is relatively rich in residual grassland and heathland habitats, but restricted to part of the western Padanian Plain; other residual habitats suitable for terricolous lichens may be present in more or less distant areas of the plain, and so further work is advisable to better clarify whether in these fragments of lichen-rich habitats we can find a realistic representation of the primitive lichen flora of the ancient Padanian Plain.

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