Article

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Bryophytes from a residual oak-elm forest: the case study of the "Bosco Siro Negri" reserve in the Ticino River valley (N Italy)

Abstract

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The "Bosco Siro Negri", a State Natural Forest Reserve located within the Ticino river valley (W Lombardy, N Italy), hosts a relict riparian forest dominated by common oak and field elm (Natura 2000 Habitat 91F0). The forest has been left unmanaged since 1950, representing therefore an important case study of a lowland habitat allowed to its natural dynamics. The bryophyte flora of the Reserve was surveyed in Spring 2014. Overall, 5 liverwort and 55 moss taxa are reported. Growth forms, substrate preferences, ecology according to four indices, chorology and distribution have been analyzed, in order to outline the bryophyte flora of the Reserve. About 21% of the bryophyte species of the whole Ticino River valley occur in the Reserve, which can be considered an important area for the conservation of bryophytes in the Po Plain, especially for forest-inhabiting species.

Key words: Riparian forest, liverwort, moss, Natura 2000 Network.

Introduction

Bryophytes, and generally thallophytes, colonizing living trees and dead wood have been consistently ignored in classical forest vegetation studies, but they have been gaining attention as early and sensitive indicators of air pollution, ecosystem changes or naturalness of forests since about the 1960s. Moreover, such thallophytes often represent a large proportion of the flora of forests, in many cases outnumbering vascular plants in terms of species numbers (Leuschner & Ellenberg 2017). For example, it is estimated that central European beech forests are colonized by about 215 vascular plant species classified as 'true' forest species (Schmidt & al. 2003, 2011), equivalent to c. 7.2% of the vascular flora of central Europe. However, c. 190 bryophyte and c. 280 lichen species inhabit beech forests, i.e. about 17% of their respective floras. Thus, about two thirds of the beech forest flora (estimated at c. 685 plant species) are lichens and bryophytes (Leuschner & Ellenberg 2017). In Germany, 63 % (658 species) of the bryophyte flora (1051 species; Koperski & al. 2000), are preferably found in forests (Preußing & al. 2011). Epiphytes also can play an

important role in nutrient cycling within forest ecosystems by influencing the amount and chemical composition of stemflow water and contributing to the fixation of CO_2 and N_2 by the forest vegetation (Leuschner & Ellenberg 2017).

The diversity of bryophytes in temperate and boreal forests is generally known to be affected by logging, deadwood removal, nitrogen pollution, and acidification (Bates & Farmer 1992; Dirkse & Martakis 1992; Laaka 1992). Resampling of the epiphytic and epigeic bryophyte flora in 10 beech-dominated forests of Central Germany after c. 110 years revealed a large species turnover since 1900. Species with low nitrogen demand have largely been replaced by N-demanding species, and acidophilic and termophilic taxa have increased (Dittrich & al. 2016). The weakly acidophilic to weakly basophilic bryophytes of cool, shady habitats have undergone a particularly strong decline (Koperski 1998). While total species richness has declined in the ground-living bryophytes vegetation since 1900, it did not in the epiphytic and deadwood-inhabiting vegetation (Dittrich & al. 2016). The resampling studies suggest that elevated atmospheric N and acid deposition are the main drivers of change in the bryophyte vegetation of central European broad-leaved forests.

The "Bosco Siro Negri" Reserve, located within the Ticino river valley (W Lombardy, N Italy), hosts a relict fragment of riparian forest dominated by common oak (*Quercus robur* L.) and field elm (*Ulmus minor* Mill.). The forest fragment has been left unmanaged since 1950, representing therefore an important case study of lowland forest subjected to natural dynamics. The Ticino river valley, placed in the western Po Plain between the Lake Maggiore and the confluence with the Po river, is a hot-spot for biodiversity (Furlanetto 2002). The Po Plain is one of the most human disturbed and polluted areas of Europe, where most of the last natural habitats have been lost in the Twentieth century (Gheza & al. 2022). For that reason, the Reserve is an interesting case study to better understand the biodiversity of primaeval floodplain forests of the Po Plain.

Moreover, the Ticino river valley is known to host overall 278 bryophyte taxa (Brusa 2002). In this context, it was highlighted that a better knowledge of the bryophyte flora of the Reserve was important to be achieved, to gain a better comprehension of its real importance and to improve knowledge about its diversity not only at the local scale, but also in relation to the whole river valley. This contribution aims at describing and characterizing the bryophyte flora of the Reserve, including not only the woodland area but also all the other habitats found around it.

Material and methods

Study area

The study site is located in the "Siro Negri" State Natural Forest Reserve, established in 1970 within the Ticino Regional Park, Northern Italy (45°12′N, 9°03′E, 63 m a.s.l.) and covering 11 ha.

The Reserve, historically, has always been forested, but formerly was managed for wood production and used as a hunting reserve; nevertheless, currently represents one of the best conserved relicts of the original riparian forest along the Ticino river, and has

remained unmanaged for about six decades. The last important human activities coincide with the two world wars, when there was an elevated demand for firewood (1910–1920 and 1940–1960). No logging has been carried out since the establishment of the reserve in 1950.

The Reserve, occurring on the right side of the Ticino river, protects a mixed broadleaved forest which is dense, structurally complex, and rich in biomass, as expected for stands unmanaged for decades. The stand is dominated by *Quercus robur* L.; other tree species are *Robinia pseudoacacia* L., *Ulmus minor* Mill., *Carpinus betulus* L., *Populus alba* L., and *Acer campestre* L. (see Motta & al. 2009 for detailed characteristics of the stand, such as other co-occurring species, density and tree age). The forested area was described as a *Polygonato multiflori-Quercetum roboris* association (Sartori 1984) and was attributed to the Natura 2000 Habitat 91F0 "Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)", i.e. a riparian mixed forests of hardwood trees on the banks of large rivers, liable to flooding. In accordance with Directive 92/43/EEC, the Reserve is included in an EU Special Areas of Conservation (IT2080014 "Boschi Siro Negri e Moriano").

Mean annual precipitation is about 717 mm (last 8 years) and 820 mm (last 100 years), while mean annual temperature is 14 °C (last 8 years) and 13°C (last 50 years) (Pavia weather station, 10 km from the study site).

Floods occur in spring or autumn every 5-10 years (Castagneri & al. 2013). Except during such events, groundwater level is around -2.50 m in winter, while it reaches -3.50 m during summer (Bracco & Mazzucchi 2020).

According to Castaldini & al. (2020), the study area is located in the Holocene Floodplain physiographic unit. It specifically occupies the alluvial plain with surface lithology mainly characterized by gravel and sand (Castiglioni & Pellegrini 2001). At local scale, the surface is flat, but several micro-discontinuities occur in local geomorphology topography, with depressions, reaching 2 m of depth, and small mound (Tomaselli & Gentile 1971).

The soil pH (first 10 cm) is acidic (Giordani & al. 2007).

Selection of sampling sites

Within the woodland area, a standardized sampling was performed in 50 randomly selected sites, keeping each site at least 30 m apart from the nearest other site. In the woodland, sampling took place on bark of living shrubs and trees (from the basal part of the trunks up to 180 cm), on dead wood (trunks and branches fallen to the ground) and on soil (understory soil and soil among the roots of trees fallen to the ground).

In addition, further samplings occurred outside the wood, in other habitat types surrounding in the Reserve and on other substrates (i.e. on water-wetted banks along channels and on rocks or concrete blocks along the river), in order to point out the whole bryophyte diversity of the study area. This additional sampling aimed at being exhaustive, but it was not organized with a standard sampling design; therefore, specimens were collected from every suitable substrate in the study area, aiming at fulfilling all the possible substrate/habitat combinations. In conclusion, sampling were taken on bark, dead wood, soil, rock and handworks, the last two substrates lacking in the woodland area.

All the specimens were collected in Spring 2014 and are currently retained in the senior author's personal herbarium.

Data analysis

Bryophytes were classified on the bases of their substrate preference (Dierßen 2001; Heilmann-Clausen & al. 2014), and epiphytic and/or epixylic species were particularly selected.

Ecological indices, chorological and distributional data were analysed for each bryophyte species.

Ecological indicator values by Ellenberg & al. (1992) were considered according to Hill & al. (2007). The four most important indicator values were supposed to be the following: F (humidity, from 1-arid to 12-submerged), R (substrate pH, from 1-strongly acid to 9-strongly calcareous), L (light, from 1-complete darkness to 9-full light) and N (available nutrients, from 1-anitrophytic to 7-strongly nitrophytic).

Chorological data were considered according the groups suggested by Hill & al. (2007), which fit better with the ecological and geographical context of the study area. Species distribution is based on Hill & Preston (1998), who classified species under a biogeographical view considering separately the occurrence in the main biomes and the eastern distribution limit in Europe.

Life forms, referred to Hill & al. (2007), were simplified in "cushion", "dendroid", "fan", "mat", "tuft" and "turf".

All graphics were drawn only considering the presence/absence value of each species.

Species nomenclature follows Aleffi & al. (2020) and higher taxa of bryophytes are from Hodgetts & al. (2000).

Results

Floristic list

On the bases of what reported previously (Brusa 1999, 2002) and specimens preserved in the personal herbarium of the senior author, it is excluded the occurrence of the two following species formerly reported from the study area, because of their misidentification:

- *Lophocolea bidentata* (L.) Dumort. had been referred to an underdeveloped specimen of *Lophocolea heterophylla*;
- a specimen of *Plagiothecium nemorale* (Mitt.) A. Jaeger instead belongs to *Plagiothecium succulentum*, which is a rather frequent species in the woodlands of the Ticino river valley.

In addition, the occurrence of the two following species, previously reported from the study area, was not confirmed during this study:

- *Alleniella complanata* (Hedw.) S. Olsson, Enroth & D. Quandt had been collected on a trunk of *Acer campestre* in 1998;
- *Leptodictyum riparium* (Hedw.) Warnst. had been collected from the basal, semi-submerged part of a *Salix alba* trunk.

Specimens of *Fissidens limbatus* var. *bambergeri* (Schimp. ex Milde) Düll were reconducted to *Fissidens viridulus* var. *viridulus* on the basis of the synonymy reported by Aleffi & al. (2008).

In conclusion, the total bryophyte flora consists of 5 liverwort and 55 moss species (Tab. 1).

None of the recorded species is reported in the Annex II of the "Habitats Directive" (Directive 1992/43/EEC) nor in the list of the species protected by the Lombardy Regional Law L. R. 10/2008.

Under a conservation standpoint, none of the species is considered endangered according to the Red Data Book of European Bryophytes (ECCB 1995) nor to the recent Red List of European Bryophytes (Hodgetts & al. 2019). At a national scale, none of the recorded species is listed in the national Red List of liverworts (Aleffi & Schumacker 1995), while in the Red List of mosses (Cortini Pedrotti & Aleffi 1992) 4 species are reported: *Neckera pumila* (EN), *Orthotrichum patens* (EX), *Plagiothecium succulentum* (R) and *Trichodon cylindricus* (EN). None of the recorded species is listed in the Italian Red List according to the most recent assessment (Rossi & al. 2013).

Epiphytic and/or epixylic species

Three liverworts and 19 mosses (Tab. 1) were recorded among epiphytic and/or epixylic species. They represented a large amount (40%) of the total bryophyte diversity in the Reserve. Most of them (e.g. *Dicranum montanum*, *Lophocolea heterophylla*, *Platygyrium repens*) are strictly restricted to bark and/or dead wood in the study area, but two species (i.e. *Homalia trichomanoides*, *Leskea polycarpa*) occur additionally on lithic substrates.

Most frequent species include *Homalia trichomanoides*, *Leskea polycarpa* and *Metzgeria furcata* on bark, and *Lophocolea heterophylla*, *Platygyrium repens* and *Homalothecium sericeum*. Several species were recorded few times (e.g. *Neckera pumila*, *Pulvigera lyellii*, *Thamnobryum alopecurum*).

Life forms and relations with substrates

The substrates on which each recorded species was found are reported in Tab. 1. Most of the species were found on bark of living trees and shrubs (n=36) and on soil (n=25). Other substrates – decorticated dead wood (n=16), lithic substrates (n=12) and water-wetted substrates (n=5) – show a lower number of species.

The mat-forming life form prevails on all substrates, except that on soil, where the turf-forming bryophytes are the most represented (Fig. 1). Other life forms are poorly represented in the study area.

Ecology

The distribution of the four ecological indices considered across the substrates is reported in Fig. 2.

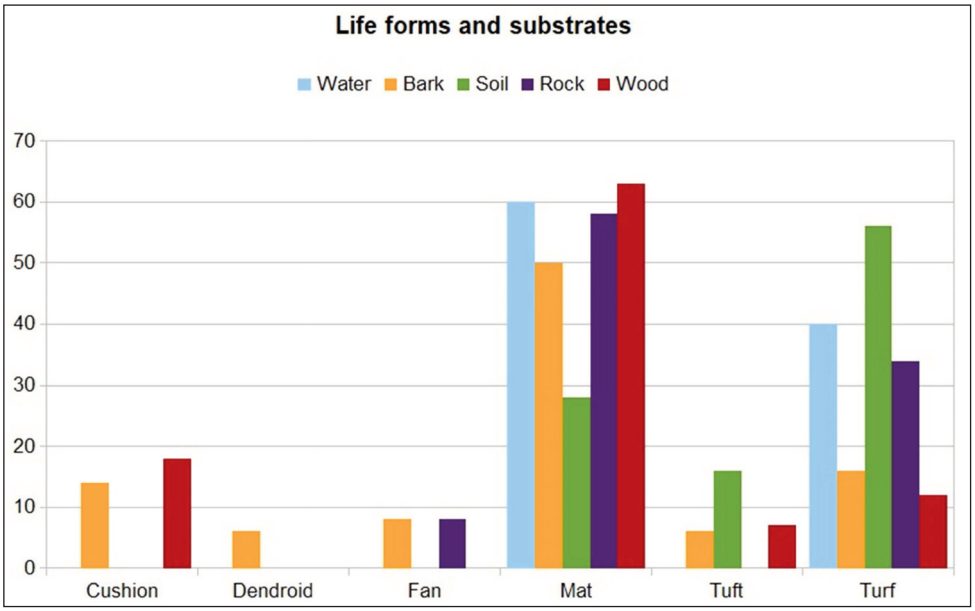

Fig. 1. Distribution of the life forms across the substrates; data are reported in percent values computed in relation to each single substrate.

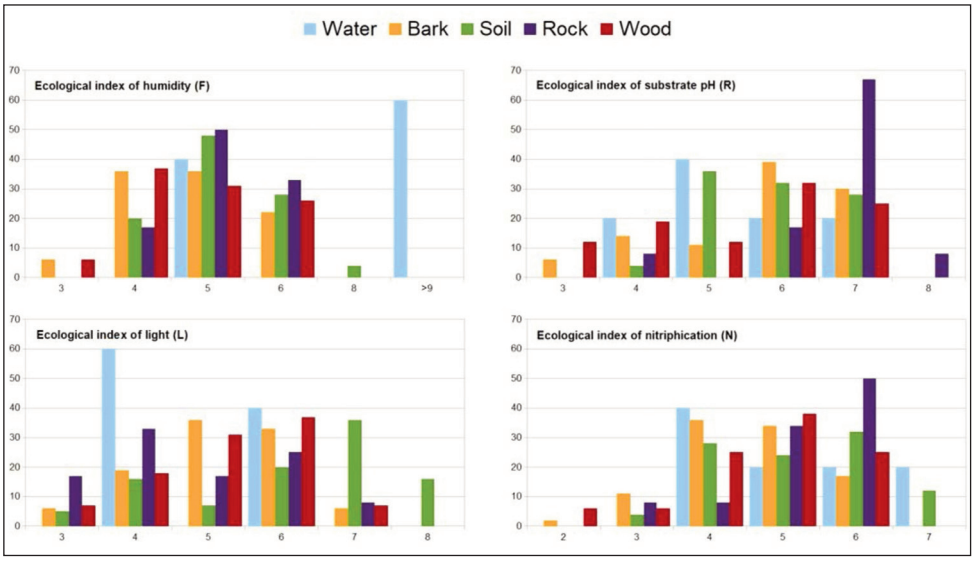

Fig. 2. Distribution of the ecological indices values across the substrates; data are reported in percent values computed in relation to each single substrate.

The index F reveals the presence of several strictly hydrophytic species (i.e. *Chiloscyphus polyanthos*, *Leptodictyum riparium*, *Rhynchostegium riparioides*) occurring only on inundated substrates. The other species found on this substrate type indicate a medium humidity, which likely indicates a seasonal variability of the water level. Species occurring on the other substrates indicate medium moisture (indicator value 5), even if on bark and dead wood species revealing aridity (indicator values 4 and 3) also occur.

The distribution of the index R is more difficult to interpret. In water, species of intermediate conditions prevail (indicator value 5). Furthermore an intermediate situation is recorded on soil, although there are several species with higher values, indicating a moderate basicity (e.g. *Bryum dichotomum*, *Fissidens taxifolius, Streblotrichum convolutum*). Corticolous and lignicolous species show a similar pattern, highlighting the same origin of the two substrates. Epilithic species show higher values, due to the limy nature of the artificial lithic substrates occurring in the study area (concrete and calcareous blocks), such as the calciphilous *Rhynchostegiella tenella* (indicator value 8) and several species generally absent from acidic substrates (indicator value 7: e.g. *Cirriphyllum crassinervium*, *Fissidens viridulus*, *Leskea polycarpa*).

Epilithic species generally show lower values for the index L. In the study area, this substrate type is always found in shaded situations, due to the placement in the understory and to the shape of lithic blocks, on which there are micro-habitats where light is excluded. Water bryophytes are also conditioned by woodland shading. Bark and dead wood species indicate partially shaded conditions, typical of the understory habitats in which these substrates are frequently found. Soil bryophytes show instead the highest values, indicating the presence of situations of almost total exposure to sunlight, which are found in the open uncultivated around the core woodland area.

The distribution of value for the index N is rather similar among the substrates, since most of the species indicates moderately fertile substrates (indicator value 5). Conditions of slightly higher eutrophication (indicator value 7) are revealed by some species in water (*Leptodictyum riparium*) and on soil (*Bryum argenteum*, *Bryum dichotomum*, *Funaria hygrometrica*).

Chorological and distributional spectra

The distribution of the biogeographical groups referred to the biome is shown in Fig. 3. A generic temperate origin prevails, whilst the boreal origins are clearly lower. Among the former, a temperate s. str. origin (e.g. *Brachythecium rutabulum*, *Oxyrrhynchium hians*, *Ptychostomum moravicum*) is the prevailing over the other temperate origins. Among species with a more southern temperate distribution, the most frequent are *Fissidens taxifolius*, *Orthotrichum diaphanum*, *Syntrhichia laevipila*, *Weissia brachycarpa* and *Zygodon rupestris*. Among boreal species, the most frequent are *Amblystegium serpens*, *Ceratodon purpureus*, *Homalia trichomanoides*, *Metzgeria furcata* and *Plagiothecium succulentum*.

The distribution of the biogeographical groups referred to their eastern European limit (see Hill & Preston 1998) is reported in Fig. 4. Most of the species have a circumboreal distribution, showing the bryological affinity between the Reserve and similar habitats occurring in the boreal hemisphere. Among them, the most frequent are *Amblystegium serpens*, *Fissidens bryoides*, *Hypnum cupressiforme*, *Oxyrrhynchium hians* and *Pleuridium*

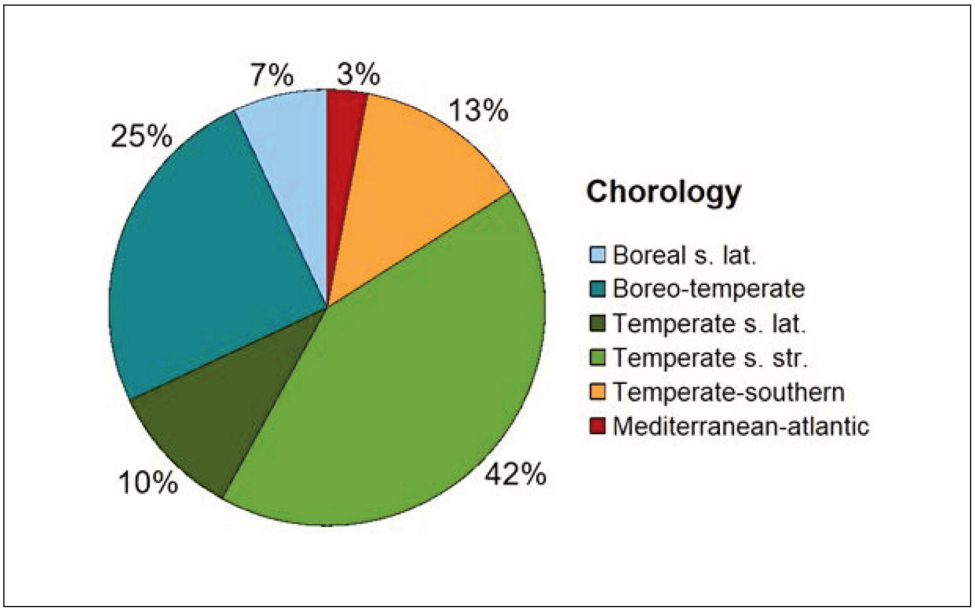

Fig. 3. Chorological distribution.

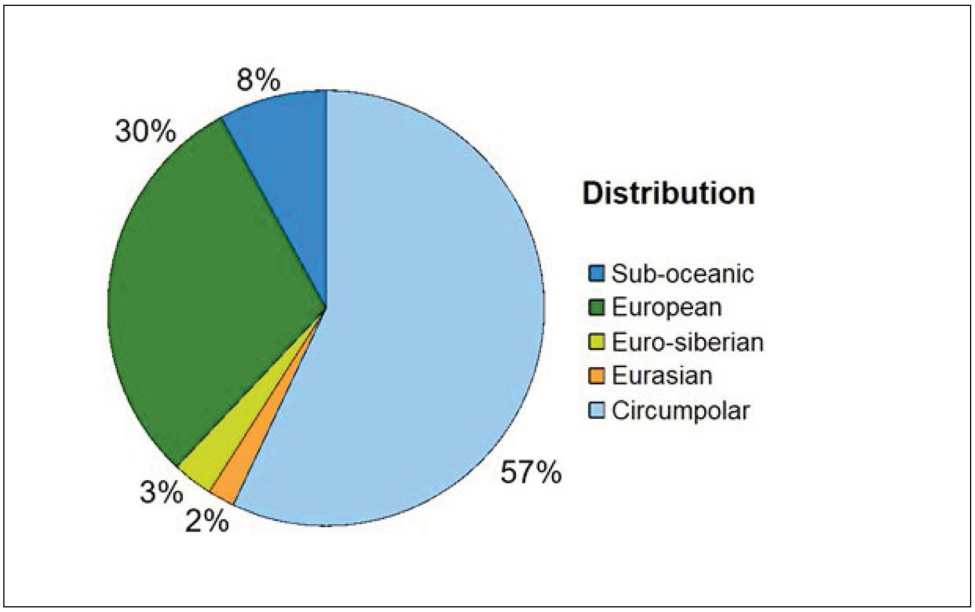

Fig. 4. Distribution in relation to the eastern European boundary.

subulatum. European species (i.e. extending to more continental parts of Europe but not to Siberia) are also well represented in the local flora (e.g. *Brachythecium rutabulum*, *Metzgeria furcata* and *Rhynchostegium confertum*).

Conclusions

The "Bosco Siro Negri" Reserve hosts 5 liverwort and 55 moss taxa. Among them, 40% species are epiphytic and/or epixylic. However, no species with absolute conservation concern were found, even if several species are rare in the Po Plain due to its present condition of heavy anthropization, in which natural habitats are becoming more and more rare and fragmented. Considering the overall distribution (Aleffi & al. 2008; Cortini Pedrotti & Aleffi 1992), the strictly epiphytic *Neckera pumila* is the most interesting species occurring in the study area, where it was found only on a single elm trunk in the woodland area. In general, the typically woodland species, such *Neckera pumila*, are the most important for conservation. The uncultivated area surrounding the woodland in the Reserve hosts no species of conservation concern, even if there are two mosses (*Trichodon cylindricus*, *Ephemerum serratum*) regarded as uncommon at national level. These two mosses, as well as some other bryophytes found in the uncultivated area, are usually hard to find because of their ephemeral life cycle and small size. Their presence is likely underestimated in the Ticino river valley, considering that this type of habitat is rather frequent in the area.

Considering that the bryophyte flora of the Ticino river valley includes 278 taxa (41 liverworts and 237 mosses; Brusa 2002), the Reserve hosts about 21% of the bryophyte diversity of the river valley on a surface corresponding to the 0.035% of the whole protected area including the Piedmont and the Lombardy Parks. The Reserve has a great relevance under a bryological standpoint, mostly for its location within a human-altered landscape.

If we consider the vascular flora of the Reserve, estimated at c. 133 species (Tomaselli & Gentile 1971; Rozzarin 2017-2018; expert-based surveys), bryophytes have a very important role in its overall biodiversity, representing c. 31 % of the total diversity of higher plants (bryophytes + tracheophytes equal to 193).

The Reserve, with its dense, complex and biomass rich structure, typical of an unmanaged forest, associated with the presence of different tree old age classes (Motta & al. 2009), seems therefore suitable to host a rich bryophyte diversity. The remarkable occurrence of weakly acidophitic species, basiphilitic species and moderately N-demanding species seems to indicate a low influence or a low level of atmospheric N and acid deposition affected the "Siro Negri" Reserve. In addition, boreal or sub-oceanic species may be the most sensitive to climate changes.

In a future perspective, the present floristic analysis represents the first step towards a more complex study of bryophytes communities as indicators of air pollution, climate changes and naturalness in forest habitats of the Po plain.

Acknowledgements

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Tab. 1. List of liverwort and moss taxa recorded in the "Bosco Siro Negri" Reserve. Species mainly regard as epiphytic and/or epixylic are reported in bold. Abbreviations: D: dead wood; B: bark; R: lithic substrates; S: soil; W: water-submerged substrates.

		D	B	R	S	W
MARCHANTIOPHYTA						
JUNGERMANNIOPSIDA						
Jungermanniales						
Lophocoleaceae	*Chiloscyphus polyanthos* (L.) Corda					+
	***Lophocolea heterophylla* (Schrad.) Dumort.**	+	+			
Porellales						
Radulaceae	***Radula complanata* (L.) Dumort.**		+			
Metzgeriales						
Metzgeriaceae	***Metzgeria furcata* (L.) Dumort.**		+			
MARCHANTIOPSIDA						
Marchantiales						
Ricciaceae	*Riccia glauca* L. var. *glauca*				+	
POLYTRICHOPSIDA						
Polytrichales						
Polytrichaceae	*Atrichum undulatum* (Hedw.) P.Beauv.				+	
BRYOPSIDA						
Funariales						
Funariaceae	*Entosthodon fascicularis* (Hedw.) Müll.Hal.				+	
	Funaria hygrometrica Hedw.				+	
	Physcomitrium pyriforme (Hedw.) Bruch & Schimp.				+	
Dicranales						
Dicranaceae	***Dicranum montanum* Hedw.**	+	+			
	Dicranum scoparium Hedw.	+	+			
Ditrichaceae	*Ceratodon purpureus* (Hedw.) Brid. subsp. *purpureus*				+	
	Pleuridium subulatum (Hedw.) Rabenh.				+	
	Trichodon cylindricus (Hedw.) Schimp.				+	
Fissidentaceae	*Fissidens bryoides* Hedw.				+	+
	Fissidens taxifolius Hedw.		+	+	+	
	Fissidens viridulus (Sw.) Wahlenb.			+		
Pottiaceae	*Didymodon fallax* (Hedw.) R.H.Zander			+		
	Ephemerum serratum (Hedw.) Hampe				+	
	Streblotrichum convolutum (Hedw.) P.Beauv. var. *convolutum*				+	
	***Syntrichia laevipila* Brid.**	+	+			
	***Syntrichia papillosa* (Wilson) Jur.**		+			
	Tortula truncata (Hedw.) Mitt.				+	
	Weissia brachycarpa (Nees & Hornsch.) Jur.				+	
Rhabdoweisiaceae	***Dicranoweisia cirrata* (Hedw.) Lindb.**	+	+			
Bryales						
Bryaceae	*Bryum argenteum* Hedw.				+	
	Bryum dichotomum Hedw.				+	

	Ptychostomum capillare (Hedw.) Holyoak & N.Pedersen				+	
	Ptychostomum moravicum (Podp.) Ros & Mazimpaka			+		+
	Ptychostomum rubens (Mitt.) Holyoak & N.Pedersen				+	
Mniaceae	*Mnium hornum* Hedw.			+	+	+
	Plagiomnium affine (Blandow ex Funck) T.I.Kop.			+		
Orthotrichales						
Orthotrichaceae	***Lewinskya affinis* (Schrad. ex Brid.) F.Lara, Garilleti & Goffinet**			+		
	***Orthotrichum diaphanum* Schrad. ex Brid.**			+		
	***Orthotrichum patens* Bruch ex Brid.**			+		
	***Pulvigera lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra**			+		
	***Zygodon rupestris* Schimp. ex Lorentz**			+		
Hypnales						
Amblystegiaceae	*Amblystegium serpens* (Hedw.) Schimp.	+	+	+	+	
	Leptodictyum riparium (Hedw.) Warnst.					+
Anomodontaceae	***Anomodon viticulosus* (Hedw.) Hook. & Taylor**			+		
Brachytheciaceae	*Brachytheciastrum velutinum* (Hedw.) Ignatov & Huttunen			+		
	Brachythecium rutabulum (Hedw.) Schimp.	+	+	+	+	
	Brachythecium salebrosum (Hoffm. ex F.Weber & D.Mohr) Schimp.	+	+			
	Cirriphyllum crassinervium (Taylor) Loeske & M.Fleisch			+		
	***Homalothecium sericeum* (Hedw.) Schimp.**	+	+			
	Oxyrrhynchium hians (Hedw.) Loeske		+	+	+	
	Rhynchostegiella tenella (Dicks.) Limpr.			+		
	Rhynchostegium confertum (Dicks.) Schimp.	+	+	+	+	
	Rhynchostegium riparioides (Hedw.) Cardot					+
	Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen		+			
Hypnaceae	*Hypnum cupressiforme* Hedw. var. *cupressiforme*	+	+		+	
Lembophyllaceae	***Isothecium myosuroides* Brid.**		+			
Leskeaceae	***Leskea polycarpa* Hedw.**	+	+	+		
Neckeraceae	***Alleniella complanata* (Hedw.) S.Olsson, Enroth & D.Quandt**		+			
	***Homalia trichomanoides* (Hedw.) Brid.**		+	+		
	***Neckera pumila* Hedw.**		+			
	***Pseudanomodon attenuatus* (Hedw.) Ignatov & Fedosov**		+			
	***Thamnobryum alopecurum* (Hedw.) Gangulee**		+			
Plagiotheciaceae	*Plagiothecium succulentum* (Wilson) Lindb.	+	+		+	
Pylaisiadelphaceae	***Platygyrium repens* (Brid.) Schimp.**	+	+			

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