Unexpected bryophyte lignicolous assemblages in the Izvoarele Nerei beech-wood (southeastern Carpathians, Romania)

Jérémie Scagni & Vincent Hugonnot

Conservatoire Botanique National du Massif Central, le Bourg, 43 230 Chavaniac-Lafayette, France; e-mail: vincent.hugonnot@cbnmc.fr (corresponding author)

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Abstract. The Izvoarele Nerei Forest (in the southeastern part of Romania) on the southern slopes of the Semenic Mountain has been bryofloristically surveyed. This is one of the largest old beech forests of Europe, covering more than 5000 ha of pure beech stands. Quantitative relevés were set systematically and the Index of Ecological Significance for each taxon was calculated. Seventy-five taxa were identified, including 62 mosses and 13 liverworts. Two Red List species were found: *Dicranum viride* (EN) and *Lophozia ascendens* (VU). The bryoflora of the site is strikingly distinct from that of other old-growth forests. The overall bryophyte cover is scarce, CWD liverworts are mostly absent or very infrequent, and pleurocarpous mosses dominate almost everywhere to the detriment of pioneer specialized liverworts. The beech old-growth forest of Nerei is mentioned as escaping the simplistic interpretations in regard to the indicator value of bryophytic assemblages. The unfavourable bioclimatic context is pointed out as the most likely potential explaining factor.

Key words: bioindicators, Coarse woody debris, Index of Ecological Significance, liverworts, old-growth forests

Introduction

Romania certainly deserves to be qualified as a wooded country, because its share of forests accounts for no less than 26.7 % (6.37 million hectares). Roughly, one-third of this surface is under ancient forests, 400 000 hectares out of which are considered as "virgin or almost virgin forests" (i.e. "naturally sown, long unmanaged old-growth") (Giurgiu & al. 2001; Peterken 1996), which is a unique feature for Europe. The vast majority of these almost virgin forests are confined to mountain ranges. Beech occupies a considerable surface in Romania (almost 2 millions ha) at altitudes ranging from 400 m to 1300 m a.s.l. In the best preserved Romanian forests, the beech may reach extravagant dimensions: up to two meters in diameter and 50 meters in height (Giurgiu & al. 2001).

The Nerei Forest is one of the exceptionally well preserved forests of Southeast Romania. This forest is poorly known, as far as biodiversity is concerned. The scarce studies carried out on this site mainly concern forest structure (Frățilă 1999; Degen 2000; Lemaire 2000; Giurgiu & al. 2001; Turcu 2002, 2012; Tomescu 2009). Only one reference deals partly with bryophytes of Izvoarele Nerei (GEVFP 2006). That study mentions eight species, mostly of the genus *Sphagnum*.

With the aim of partially filling this gap, a bryophyte survey of the Nerei Forest was made. Our main goals were to improve floristic knowledge of one of the largest remnant old-growth forest of Europe and to explore the potential use of bryophytes as ancient forest indicators in this particular case study.

Material and methods

Study site

The Izvoarele Nerei Forest is located in the southeastern part of Romania, between 45°5' and 45°10' N and 22°2'30" and 22°6'40" E (Fig. 1). This forest is part of the Semenic-Cheile Carasului National Park on the southern slopes of the Semenic Mountain. The forest is included in the communal area of Bozovici, Caras-Severin district. The impressive 5253 ha of pure beech forest make Nerei one of the largest old beech forests of Europe. The entire Reserve encompasses a wide altitudinal gradient (of more than 700 m), from 620 m to 1400 m a.s.l. The Reserve is shaped out by two rivers, which form two main valleys. The bedrock of the Reserve is made of mica-schists, sericite-schists and amphiboles. These types of rocks are highly sensitive to weathering and support deep brown soils (with pH mostly below 7; Turcu unknown date). The climate is of the temperate-continental type, with a moderate Mediterranean influence. The mean annual temperature varies from 7.5 °C inside the Reserve to 4.5 °C in the higher part of the Semenic Mountain. The meteorological station of Semenic Mountain recorded precipitations of 1169.7 mm/year at 1432 m a.s.l. Very likely, these figures would drop significantly at lower altitudes. The meteorological station of Bozovici recorded precipitations of 631.9 mm/year at 254 m. The mostly southern aspect of the study site results in a significant local increase of precipitations, which remain very difficult to determine with accuracy without implementation of the meteorological disposal. The forest is dominated by beech, which accounts for 99 % of its cover. In the lower part of the Reserve, some other species can be found too: *Ulmus montana*, *Abies alba*, *Acer platanoides*, *Acer pseudoplatanus*, *Populus tremula*, *Betula pendula*, *Picea abies*.

In the 17th century, grazing and forestry have affected the margins of the forest. A wood evacuation canal system was still active in the 20th century. The pronounced heterogeneity of vertical and horizontal structures, large diameters of a huge number of trees, abundance of CWD (coarse woody debris), and a rich fauna of rare species (wolf, lynx, forest cat) strongly vouch for the naturalness of this forest. For example, the average amount of dead wood is 87 m^3/ha, which drops dramatically to 3 m^3/ha in most European managed forests (Dudley & Vallauri 2004). The Nerei Forest is an old-growth and maybe virgin forest, but pending further studies dealing with naturality of the stands and historical researches, we would prefer to qualify it as an "old-growth forest" (Peterken 1996). The terms "virgin or almost virgin" seem also appropriate.

Fig. 1. Location of the study site.

Data collection

The taxonomy and nomenclature follow Hill & al. (2006) for mosses and Ros & al. (2007) for liverworts. The varieties and species within the *Hypnum cupressiforme* complex have proved very troublesome to determine with accuracy, because of frequent sterility and intergradation, notably between *Hypnum cupressiforme* var. *cupressiforme*, var. *filiforme* and *H. andoi*. A wide species concept has been adopted in this case. As far as flowering plants are concerned, Kerguélen's (1993) nomenclature is followed. Taking into account the recent Romanian Red Data List (Ştefănut & Goia 2012), the list provided in Annex II of the Directive on Habitats and the publications dealing with Romanian bryoflora, a selection of high conservation value taxa was made.

Large parts of the Reserve were not surveyed because of inaccessibility: approximately 1156 ha out of 5253 ha were crossed out. The Reserve's several-hundred-meters-wide external marginal forested strip was not surveyed, because of more evident human influences like forest trails or grazing marks.

Wood-, rock-, and soil-dwelling species have been included in the survey. The ecological relevés were set at random within different ecological compartments (different trunk diameters, wood decomposition phases). Lignicolous taxa grew either on living trees (LT), on standing dead trees (SDT), or on coarse woody debris (CWD). The following standardized method was followed. For standing trunks (LT and SDT), the relevés were always made at breast height (dbh = diameter at breast height), i.e. approximately 1.2 m from the ground; the area of relevés was standardized: 6 dm^2 for LT and SDT and 3 dm^2 for CWD. For lignicolous taxa, the following cover classes have been used : **0.5** < 1 %; 1 ≤ **1**< 5 %; 5≤ **2** < 25 %; 25 ≤ **3** < 50 %; 50 % ≤ **4** < 75 %; 75 % ≤ **5** < 100 %.

Data analysis

The taxa colonizing only one type of substrate are considered as locally "specialized", whereas the ubiquitous taxa are qualified as "unspecialized". The total abundance of the species was estimated by the Index of Ecological Significance (IES) (Lara & Mazimpaka 1998). This index combines the relative abundance and the frequency of a particular species:

$$IES = 100/ n \times (x+\sum c_i),$$

where **n** is the total number of samples collected in the locality, **x** is the number of samples containing the species, and **ci** are the cover classes attributed to the species in each sample.

The following classes are used to describe the IES significance of each taxon: scarce < 7; 7 ≤ common < 30; 30 ≤ abundant < 50; 50 ≤ dominant.

Results

Floristic checklist

A total of 75 taxa were listed in the Nerei Forest (Table 1). Sixty-two taxa are mosses (82.7 %), whereas only 13 taxa (17.3 %) are liverworts. Among the mosses, 36 species are pleurocarps (58 %) and 26 are acrocarps (42 %). The best represented families are *Brachytheciaceae* (12 %; 9 taxa), *Plagiotheciaceae* (9.3 %; 7 taxa), *Orthotrichaceae* (9.3 %; 7 taxa), *Dicranaceae* (6.7 %; 5 taxa), and *Neckeraceae* (5.3 %; 4 taxa). The best represented genera are *Plagiothecium* (6.7 %; 5 taxa), *Orthotrichum* (6.7 %; 5 taxa), *Neckera* (5.3 %; 4 taxa), and *Dicranum* (4 %; 3 taxa).

Remarkable species

Two species of high conservation value were found during the course of our floristic survey. *Dicranum viride* was observed on CWD. It is quoted as EN in Romania (Ştefănut & Goia 2012). With only four observations, this species is not abundant within the Reserve. Locally, *Dicranum viride* was mostly observed at altitudes ranging from 800 m to 1100 m. *Lophozia ascendens* was equally found only on CWD lying close to small rivulets. It is quoted as VU in Ştefănut & Goia (2012). This liverwort is not very abundant and was found only twice. On one occasion, an abundantly fertile population was found, with hundreds of sporophytes .

Substrate preference

One hundred and seventy-nine relevés were set on LT and 160 on dead wood (45 on SDT and 115 on CWD). CWD was the most important substrate in terms of the number of taxa. No less than 47 taxa were linked with CWD (i.e. 63 % of all species), among which only 17 % were liverworts (8 taxa). LT and SDT showed a medium number of taxa (34 and 30, respectively), while rocks and ground were poorer, with 17 and 20 taxa, respectively. CWD showed the highest number of specialized taxa, with 12 mosses and three liverworts (i.e. 32 % of the specialised taxa). The ground

Table 1. Check-list of the "Izvoarele Nerei" bryoflora by ecological compartment.

	Living tree	Standing dead tree	CWD	Rock	Ground
Mosses					
Amblystegium serpens (Hedw.) Schimp.	X	X	X		
Anomodon attenuatus (Hedw.) Huebener	X	X	X		
Anomodon longifolius (Schleich. ex Brid.) Hartm.	X				
Anomodon viticulosus (Hedw.) Hook. & Taylor	X	X	X		
Atrichum undulatum (Hedw.) P.Beauv.			X		X
*Brachytheciastrum velutinum (*Hedw.) Ignatov & Huttunen *var. velutinum*	X	X	X		
Brachythecium rivulare Schimp.				X	
Brachythecium rutabulum (Hedw.) Schimp.	X	X	X		
Brachythecium salebrosum (Hoffm. ex F.Weber & D.Mohr) Schimp. nom. cons.	X		X		
Bryum moravicum Podp.	X	X	X		
Ceratodon purpureus (Hedw.) Brid.					X
Ctenidium molluscum (Hedw.) Mitt.					X
Dicranella heteromalla (Hedw.) Schimp.				X	X
Dicranum montanum Hedw.	X				X
Dicranum scoparium Hedw.			X	X	
Dicranum viride (Sull. & Lesq.) Lindb.			X		
Eurhynchium angustirete (Broth.) T.J.Kop.				X	X
Fissidens taxifolius Hedw. *subsp. taxifolius*					X
Grimmia hartmanii Schimp.				X	
Herzogiella seligeri (Brid.) Z.Iwats.			X		
Heterocladium heteropterum (Brid.) Schimp.				X	
Homalothecium philippeanum (Spruce) Schimp.		X			
Homalothecium sericeum (Hedw.) Schimp.	X	X			
Hylocomium splendens (Hedw.) Schimp.					X
Hypnum cupressiforme Hedw.	X	X	X	X	X
Isothecium alopecuroides (Lam. ex Dubois) Isov.	X	X	X	X	
Leucodon sciuroides (Hedw.) Schwägr	X	X	X		
Mnium marginatum (Dicks.) P.Beauv.			X		
Mnium thomsonii Schimp.			X		
Neckera besseri (Lobarz.) Jur.	X	X	X		X
Neckera complanata (Hedw.) Huebener	X	X	X		
Neckera crispa Hedw.	X	X	X		
Neckera pumila Hedw.		X			
Orthotrichum affine Schrad. ex Brid.	X		X		
Orthotrichum alpestre Bruch & Schimp.	X	X	X		
Orthotrichum obtusifolium Brid.	X				
Orthotrichum pallens Bruch ex Brid.	X	X			
Orthotrichum stramineum Hornsch. ex Brid.	X	X	X		
Paraleucobryum longifolium (Hedw.) Loeske	X	X	X	X	
Philonotis seriata Mitt.			X		
Plagiomnium affine (Blandow ex Funck) T.J.Kop.			X		
Plagiomnium cuspidatum (Hedw.) T.J.Kop.			X		
Plagiothecium cavifolium (Brid.) Z.Iwats.					X
Plagiothecium denticulatum (Hedw.) Schimp. var. denticulatum			X	X	
Plagiothecium nemorale (Mitt.) A.Jaeger	X	X	X		
Plagiothecium platyphyllum Mönk.			X		
Plagiothecium succulentum (Wilson) Lindb.	X			X	X
Platygirium repens (Brid.) BSG		X	X		
Pleurozium schreberi (Willd. ex Brid.) Mitt.			X		
Pogonatum aloides (Hedw.) P.Beauv.					X
Polytrichastrum formosum (Hedw.) G.L.Sm.			X		X
Pseudoleskea saviana (De Not.) Latzel		X			
Pseudoleskeella nervosa (Brid.) Nyholm	X	X	X		
Pseudotaxiphyllum elegans (Brid.) Z.Iwats.					X
Pterigynandrum filiforme Hedw.	X	X	X	X	
Rhizomnium punctatum (Hedw.) T.J.Kop.			X		X
Sanionia uncinata (Hedw.) Loeske			X		
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen			X		
Sciuro-hypnum starkei (Brid.) Ignatov & Huttunen			X		
Sphagnum girgensohnii Russow					X
Ulota bruchii Hornsch. ex Brid.	X				
Ulota crispa (Hedw.) Brid.	X	X			
Liverworts					
Calypogeia neesiana (C.Massal. & Carestia) Müll.Frib.			X		
Frullania dilatata (L.) Dumort.	X	X	X		
Jungermannia leiantha Grolle					X
Lophocolea heterophylla (Schrad.) Dumort.	X		X	X	
Lophozia ascendens (Warnst.) R.M. Schust.			X		
Metzgeria conjugata Lindb.				X	
Metzgeria furcata (L.) Dumort.	X	X	X	X	X
Pellia epiphylla (L.) Corda					X
Plagiochila porelloides (Torrey ex Nees) Lindenb.	X	X	X	X	
Porella platyphylla (L.) Pfeiff.	X	X	X		
Radula complanata (L.) Dumort.	X	X	X		
Riccardia palmata (Hedw.) Carruth.			X		
Scapania nemorea (L.) Grolle				X	
Total	**34**	**30**	**47**	**17**	**20**
% of species compared with the total number of species (75)	45	40	63	23	27
Specialized	3	2	15	5	10
% Specialized	8.8	6.7	31.9	29.4	50.0

had the highest percentage of specialized taxa, approximately 50 %. The rock substrate also possessed a high percentage of specialized taxa (30 %, only five species). LT and SDT were substrates with the highest number of unspecialized taxa, and only with three (i.e. 8.8 % of the specialised taxa) and two (i.e. 6.2 % of the specialised taxa) specialized taxa.

Species frequency and abundance (Table 2)

Pterigynandrum filiforme was dominant on all types of substrate. Several species, as for instance *Herzogiella seligeri*, *Saniona uncinata*, *Brachytheciastrum velutinum, Sciuro-hypnum starkei,* or *Brachythecium salebrosum* had a strong IES only on CWD. IES of the acrocarpous species was lower than of the pleurocarps

Table 2. Ecological significance index (IES) of the "Izvoarele Nerei" bryoflora.

	Living tree		Standind dead tree		CWD		Wood (LT + SDT + CWD)	
	Frequency in the samples	IES	Frequency in the samples	IES	Frequency in the samples	IES	Frequency in the samples	IES
***Pterigynandrum filiforme* Hedw.**	58.7	**169.0**	48.9	**155.6**	35.7	**103.9**	23.0	**118.6**
***Hypnum cupressiforme* Hedw.**	23.5	**77.1**	15.6	26.7	37.4	**117.0**	27.1	**83.9**
***Metzgeria furcata* (L.) Dumort.**	48.6	**110.9**	46.7	**104.4**	8.7	17.0	32.2	**75.5**
***Leucodon sciuroides* (Hedw.) Schwägr**	36.3	**77.7**	48.9	**121.1**	4.3	12.2	27.1	**61.2**
***Neckera besseri* (Lobarz.) Jur.**	25.7	**66.8**	48.9	**158.9**	4.3	6.5	21.5	**58.6**
Porella platyphylla (L.) Pfeiff.	24.6	**69.0**	28.9	**88.9**	0.9	4.3	17.1	48.5
Lophocolea heterophylla (Schrad.) Dumort.	12.8	40.5			28.7	**77.0**	16.5	47.5
Pseudoleskeella nervosa (Brid.) Nyholm	22.3	**57.5**	35.6	**104.4**	12.2	40.4	10.0	47.3
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen var. velutinum	0.6	2.2	2.2	4.4	39.1	**129.6**	13.9	44.5
Frullania dilatata (L.) Dumort.	30.7	**72.1**	11.1	18.9	2.6	3.9	18.6	41.9
Radula complanata (L.) Dumort.	29.6	**51.7**	42.2	**73.3**	8.7	15.2	21.5	39.5
Isothecium alopecuroides (Lam. ex Dubois) Isov.	12.3	48.9	20.0	**51.1**	2.6	15.7	10.0	37.9
Anomodon attenuatus (Hedw.) Huebener	11,7	32.4	26.7	**82.2**	3.5	15.7	10.9	33.3
Herzogiella seligeri (Brid.) Z.Iwats.					22.6	**90.0**	7.7	30.5
Paraleucobryum longifolium (Hedw.) Loeske	15.6	37.2	6.7	10.0	8.7	26.5	9.4	27.3
Brachythecium rutabulum (Hedw.) Schimp.	1.7	4.2	2.2	4.4	23.5	**65.7**	9.1	24.8
Anomodon viticulosus (Hedw.) Hook. & Taylor	6.1	22.9	28.9	**76.7**	1.7	6.5	7.7	24.5
Brachythecium salebrosum (Hoffm. ex F.Weber & D.Mohr) Schimp. nom. cons.	2.2	7.8			34.8	**89.1**	2.4	23.7
Orthotrichum stramineum Hornsch. ex Brid.	15.6	28.5	15.6	28.9	6.1	14.3	12.4	23.7
Bryum moravicum Podp.	6.1	15.6	6.7	17.8	1.7	4.3	4.7	12.1
Platygirium repens (Brid.) BSG			4.4	6.7	10.4	33.0	4.1	12.1
Neckera complanata (Hedw.) Huebener	6.1	16.5	8.9	18.9	0.9	3.5	4.7	11.5
Amblystegium serpens (Hedw.) Schimp.	3.9	16.8	4.4	11.1	0.9	1.7	2.9	10.6
Rhizomnium punctatum (Hedw.) T.J.Kop.					7.8	24.3	2.7	8.3
Orthotrichum alpestre Bruch & Schimp.	3.9	7.0	4.4	7.8	1.7	8.7	3.2	7.7
Sanionia uncinata (Hedw.) Loeske					17.4	37.0	0.6	7.2
Sciuro-hypnum starkei (Brid.) Ignatov & Huttunen					6.1	20.9	2.1	7.1
Plagiothecium nemorale (Mitt.) A.Jaeger	0.6	0.8	2.2	8.9	6.1	22.6	0.6	6.2
Neckera crispa Hedw.	2.8	6.1	4.4	10.0	0.9	1.3	2.4	4.9
Plagiochila porelloides (Torrey ex Nees) Lindenb.	2.2	6.4	2.2	3.3	0.9	2.6	1.8	4.0
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen					4.3	9.1	1.5	3.1
Dicranum viride (Sull. & Lesq.) Lindb.					1.7	8.7	0.6	2.9
Plagiomnium cuspidatum (Hedw.) T.J.Kop.					4.3	8.3	1.5	2.8
Atrichum undulatum (Hedw.) P.Beauv.					1.7	7.8	0.6	2.7
Dicranum montanum Hedw.	1.7	4.5					0.9	2.4
Orthotrichum affine Schrad. ex Brid.	2.8	3.9			0.9	1.3	1.8	2.4
Mnium thomsonii Schimp.					3.5	5.7	1.2	1.9
Riccardia palmata (Hedw.) Carruth.					1.7	4.8	0.6	1.6
Ulota crispa (Hedw.) Brid.	1.7	2.5	2.2	3.3			1.2	1,6
Lophozia ascendens (Warnst.) R.M. Schust.					0.9	4.3	0.3	1.5
Homalothecium sericeum (Hedw.) Schimp.	1.1	2.0	2.2	6.7			0.9	1.3
Mnium marginatum (Dicks.) P.Beauv.					1.7	3.9	0.6	1.3
Orthotrichum pallens Bruch ex Brid.	0.6	0.8	2.2	4.4			0.6	1.0
Homalothecium philippeanum (Spruce) Schimp.			2.2	6.7			0.3	0.9
Neckera pumila Hedw.			4.4	6.7			0.6	0.9
Plagiomnium affine (Blandow ex Funck) T.J.Kop.					0.9	2.6	0.3	0,9
Anomodon longifolius (Schleich. ex Brid.) Hartm.	0.6	0.8					0.3	0.4
Calypogeia neesiana (C.Massal. & Carestia) Müll.Frib.					0.9	1.3	0.3	0.4
Dicranum scoparium Hedw.					0.9	1.3	0.3	0.4
Orthotrichum obtusifolium Brid.	0.6	0.8					0.3	0.4
Philonotis seriata Mitt.					0.9	1.3	0.3	0.4
Plagiothecium denticulatum (Hedw.) Schimp. var. denticulatum					0.9	1.3	0.3	0.4
Plagiothecium platyphyllum Mönk.					0.9	1.3	0.3	0.4
Plagiothecium succulentum (Wilson) Lindb.	0.6	0.8					0.3	0.4
Pleurozium schreberi (Willd. ex Brid.) Mitt.					0.9	1.3	0.3	0.4
Polytrichastrum formosum (Hedw.) G.L.Sm.					0.9	1.3	0.3	0.4
Pseudoleskea saviana (De Not.) Latzel			2.2	3.3			0.3	0.4
Ulota bruchii Hornsch. ex Brid.	0.6	0.8					0.3	0.4

and this trend was particularly evident on dead wood. Several scarce liverworts have been found only once or twice in the study site (*Calypogeia neesiana, Lophozia ascendens, Riccardia palmata, Plagiochila porelloides*).

Three main groups can be distinguished (Table 2):

– The first group was composed by dominant (IES from 51.7 to 158.9) unspecialized species, mainly concentrated on LT and SDT. *Metzgeria furcata, Leucodon sciuroides, Neckera besseri, Porella platyphylla, Pseudoleskeella nervosa and Radula complanata* were dominant species on LT and SDT, but were scarce on CWD. Only *Hypnum cupressiforme* and *Lophocolea heterophylla* were dominant species on CWD and LT, but scarce or absent on SDT.

– The second group was of common (IES from 7.1 to 27.3) unspecialized species, with *Paraleucobryum longifolium, Neckera complanata,* and *Orthotrichum alpestre*.

– The last group was of scarce (IES from 0.4 to 6.2) specialized species, strictly LT species, such as *Anomodon longifolius*, or SDT species like *Neckera pumila* and CWD species like *Polytrichastrum formosum*.

On CWD, several species were accidental (*Plagiothecium platyphyllum*), while others were characteristic (*Plagiomnium cuspidatum*, *Homalothecium sericeum*). The pioneer liverworts of CWD (*Lophozia ascendens, Calypogeia neisiana*, *Riccardia palmata*) were all scarce (IES < 4.8).

Discussion

Bryophyte originality of the Nerei Forest

A set of unexpected features characterized the bryoflora of the Nerei Forest. First, scarcity of the overall bryophyte cover was striking across the entire forest. Our data do not allow an illustration of this general trend, because the relevés tended to be set in habitats housing bryophyte communities. Nonetheless, from rough estimates it was clearly apparent that a vast majority of potential niches (young LT with smooth bark, all types of SDT and CWD) were unoccupied. Contrary to this, the studies performed in a natural forest generally showed luxuriant bryophyte cover (Vellak & Paal 1999; Andersson & Hytteborn 1991), which was confirmed by examination of the bryoflora of other old-growth Romanian forests (unpublished results).

In the Nerei Forest, the global liverworts/mosses ratio strongly tended toward mosses and the same was observed for CWD. In most European forest systems, the liverworts/mosses ratio on dead wood was largely in favour of liverworts (Ódor & Van Dort 2003; Goia & Schumacker 2002; Philippi 1965). Vellak & Paal (1999) showed that liverworts may account for almost 30 % in unmanaged forests, as compared to only 16.9 % in the managed stands. Natural forests with complex structure are known to favour a liverworts cover (Ohlson & al. 1997; Söderström 1988; Ódor & al. 2005). The authors attributed this to the more shady and humid microclimate in the old natural forests, as compared with younger and drier open stands. Managed forests are subjected to more frequent droughts than natural ancient ones, which have a higher and more constant humidity (Hilitzer 1925; Vellak & Paal 1999). Clausen (1964), Ódor & Van Hees (2004), Ódor & al. (2005, 2006) and Proctor (2009) repeatedly pointed out that drought in the stand was an effective limiting factor for most sensitive epixylic liverworts. Thus scarcity of the liverworts is almost certainly linked to humidity-related parameters, but it is difficult to specify on what scale this limiting factor operates. It cannot be ruled out that regional or local climatic characteristics are unfavourable to bryophytes. Furthermore, beech forests, especially the oldest stands, may have peculiar structural characteristics, such as open canopy, well spaced individual trees which could lead to an aggravated penetration of light at ground level and to increased evaporation. This is indirectly confirmed by scarcity of the specialized liverworts on *Fagus* dead wood in the relevés of Plămadă (1992), and by their overall impressive richness on Norway Spruce of Goia & Schumacker (2003a). Furthermore, the physical properties of beech dead wood may also explain the scarcity of pioneer liverworts. CWD is a very specialized habitat (Heilmann-Clausen & al. 2005; Ódor & al. 2006), with high water retention capacity and a huge number of microhabitats, while beech dead wood is less spongy than conifer wood (Barkman 1958; Raschendorfer 1949) and offers fewer microhabitats.

The pleurocarps/acrocarps ratio was largely biased towards pleurocarps. On a species basis, our results are in accordance with literature data (Ódor & al. 2005; Vellak & Paal 1999) that report similar bias.

Ódor & Van Hees (2004) showed further that pleurocarpous mosses and lichens tend to dominate, when the overall specific richness is low. On an IES basis, the scantiness of acrocarpous as compared to the pleurocarpous cover is even more apparent. The first phases of wood decomposition are favourable for a high number of otherwise typical bark-inhabiting species (*Anomodon attenuatus, Pteryginandrum filiforme, Isothecium alopecuroides*), which are also frequent on SDT. Observations carried out in a natural beech forest of Hungary (Ódor & Van Hees, 2004) and a natural spruce forest of Sweden (Andersson & Hytteborn 1991) showed that emergence of genuine rotten wood communities seems to be delayed until the wood has been profoundly transformed. In Nerei, on the contrary, the transformation of wood corresponds to a shift towards climacic bryophyte communities (*Herzogiella seligeri, Brachythecium rutabulum, Plagiomnium cuspidatum*), with almost total absence of the pioneer liverwort stage. In dry forests, pleurocarpous mosses tend to dominate cryptogamic vegetation (Raschendorfer 1949; Barkman 1958; Muhle & Leblanc 1975; Ódor & Van Hees 2004) and again this could explain their particular abundance even on CWD.

Most floristic assemblages are marked with scarcity of taxa of pioneer character and abundance of climacic taxa. The Nerei Reserve hosts a non-negligible number of bark-inhabiting *Orthotrichaceae* species, but their ecological significant index (IES) is very low ("scarce" for all taxa, except for *Orthotrichum stramineum* and *Ulota crispa* which are "common"). A similar trend was evident from the relevés of Goia & Schumacker (2003b). Scantiness of *Orthotrichaceae* was not related to a lack of pioneer trunk habitats, which were extremely abundant in the Nerei young phases of "thicket stage" (i.e. young trees with small diameter, smooth and not decomposed bark). A quick examination of the young and managed forests located in the vicinity of the study site showed a total absence of *Orthotrichaceae,* which largely favour a climatic limiting factor hypothesis. The relevés set at breast height do not permit reaching the communities which grow higher on the trunk and the branches. Nevertheless, a close examination of most beeches growing in the Nerei Forest demonstrated unambiguously total absence of *Orthotrichaceae* higher up on the trunks. Hilitzer (1925) considers the *Orthotrichum* species as "aerophilous", which means that they require a vapor saturated atmosphere. The *Ortotrichaceae* are generally growing on medium or high-level branches, due to atmospheric humidity (Hilitzer 1925).

Bryophytes as potential indicators

The best ancient forest bryophyte indicators are highly specialized species with dioicous mating system, large spores and other features impeding competitivity and easy dispersal (Frego 2007; Gignac 2001; Gustafsson & al. 2004; Nicholson & Gignac 1995; Vitt & al. 2003). They are not well adapted to tracking efficiently out their specific habitats. To the contrary, CWD species in the Nera Forest are mostly non-specialized taxa, which possess a monoicous mating system, along with a profusion of sporophytes – small spores that are easily wind-dispersed. They are mostly very frequent and abundant European species. The pioneer and late CWD liverworts are generally considered the best indicators of forest ancientness (Klama 2007; Gustafsson & Hallingbäck 1988; Söderström 1988, 1981). This strongly suggests that the indicator value of pioneer liverworts is questionable under certain circumstances. Their absence, combined with the occurrence of huge amounts of CWD, should not be automatically interpreted as indicative of young age of the forest stand. In a part of a large-scale study, it was shown that bryophyte diversity was positively affected by an absence of sylviculture (Paillet & al. 2010), and thus the Nerei Forest stands out as an original example of ancient but bryophyte-poor system. The bioclimatic context (low annual rainfall, geographic position, moderate altitude, etc.) is considered here as having a prime importance in explaining the overall poverty, a fact which could be aggravated by unfavourable structural characteristics of pure beech woods (cf. supra). The usefulness of very large-scale bryophytic indicators is also questioned. Pleurocarpic mats may have an indicator value which could be limited to the Nera Forest and to forest stands with similar biogeographical characteristics. Comparative studies are needed to better understand these issues.

Conservation and management

Two taxa are of conservation concern. *Dicranum viride* is mentioned in the Red Data Book of European Bryophytes (ECCB 1995) as Vulnerable (IUCN). It is also listed in Annex II of the Directive on Habitats. In Romania it is considered "sporadic" (Dihoru 1994). This is a species with circumboreal affinities and subcontinental character. On European scale, rarefaction of the species could be partially related to its low fertility and non-appropriated forest management. *Dicranum viride* could be considered as an old-growth forest indicator because of its affinity for veteran trees (Hugonnot 2002). *Lophozia ascendens* is considered as a rare species in Europe (ECCB 1995). It is a boreal-mountain liverwort. Plants with gemmae and male individuals are frequent, while females and plants with sporophytes are rare (Holá & al. 2011). They have been observed on one occasion and this is a favourable factor since it demonstrates that male and female plants coexist locally. *Lophozia ascendens* is a species strictly linked to rotten wood in advanced stages of decomposition. In Europe, this species is considered as indicator of ancient forests by Nitare (2000).

Forest management is crucial for the conservation of *Dicranum viride*. Clear cutting of mature stages should be prohibited, as it is the most serious regression factor. The main threat for *Lophozia ascendens* is the removal of dead wood (Goia & Schumacker 2003a). *Dicranum viride* is dependent on important trunk diameter, whereas *Lophozia ascendens* is dependent on the dead wood occurrence at advanced stage of decomposition. In the Nerei Natural Reserve, long-term conservation of these two remarkable taxa is ensured by complete absence of forestry. In managed forests, conservation of these two species requires keeping the mature stands with old trees and a great amount of dead wood on significant surfaces.

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