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Katarzyna ŻÓŁKOŚ[1], Włodzimierz MEISSNER[2]

[1] Department of Plant Taxonomy and Nature Conservation, University of Gdańsk, Al. Legionów 9, 80-441 Gdańsk, Poland, e-mail: biokz@univ.gda.pl
[2] Avian Ecophysiology Unit, Department of Vertebrate Ecology and Zoology, University of Gdańsk, Al. Legionów 9, 80-441 Gdańsk, Poland

THE EFFECT OF GREY HERON (*ARDEA CINEREA* L.) COLONY ON THE SURROUNDING VEGETATION AND THE BIOMETRICAL FEATURES OF THREE UNDERGROWTH SPECIES

ABSTRACT: Bird breeding colonies are known to influence the habitats and phytocoenoses they occupy in different ways. Most papers concern long-lasting colonies, in which floristic composition of phytocoenoses have been already altered largely. This research was aimed to estimate the changes in the floristic composition of the forest phytocoenosis after three years of the existence of the Grey Heron (*Ardea cinerea* L.) breeding colony as well as to examine the influence of nutrient enrichment on the size and shape of leaves and inflorescences of three plant species *Rumex acetosella* L., *Anthoxanthum odoratum* L. and *Moehringia trinervia* (L.) Clairv., which have different habitat requirements. The number of vascular plant species within the colony area (0.4 ha) increased almost double and appearance of new, mostly nitrophilous, taxa like *Sambucus racemosa* L., *Galeopsis pubescens* Besser and *Stellaria media* (L.) Vill. were observed. The vertical structure of phytocoenosis has also changed. The undergrowth appeared and dense moss layer was mostly eliminated. In case of all investigated species, the enlargement of leaf surface was found. The greatest relative increase concerned leaf width of *Moehringia trinervia* and *Rumex acetosella* – 67 and 73%, respectively. The leaf blade of *Anthoxanthum odoratum* increased largely in length (99%). The enlargement of the surface of assimilative apparatus was not only due to the increase of linear dimensions, but also to rounding of the leaf blade. This was not observed in case of *Rumex acetosella* which is characterized by elongated, lanceolate leaf blade. Differences observed among the species are probably due to differentiated leaf blade structure. Only *Moehringia trinervia* can be found in well-established Grey Heron colonies, while *Rumex acetosella* and *Anthoxanthum odoratum* are known to be suppressed by heavy input of nitrogen fertilizer. Thus, it seems that after few years of benefits at least *Rumex acetosella* and *Anthoxanthum odoratum* withdraw from the area altered by Grey Heron colony, because the change in root absorption and capacity in highly fertile habitat leads to toxic accumulation of nutrients.

KEY WORDS: *Ardea cinerea* L., fertilization, nesting site, *Rumex acetosella* L., *Anthoxanthum odoratum* L., *Moehringia trinervia* (L.) Clairv.

1. INTRODUCTION

Bird breeding colonies influence the habitats and phytocoenoses they occupy in different ways (Smith 1978). One of the most important factors changing the phytocoenosis is an increased supply of nutrients into soil. Excreta coming from piscivorous bird colonies lead to an increased content of N-NH_4^+ and N-NO_3, exchangeable potassium and available phosphorus concentration

(Sobey and Kenworthy 1979, Ishida 1996, Ligeza and Smal 2003). Range and rate of undergoing changes depends mainly on the species of nesting bird, abundance, size of its local population, density of nests, age of the colony, floristic composition of colonized phytocoenosis, property of the soil and the spatial pattern of vegetation (Sobey and Kenworthy 1979, Maesako 1991, Ishida 1996, Mun 1997, García *et al.* 2002).

Many studies on the impact of bird colonies on flora and soil concerned mainly marine and oceanic islands and the sea-coasts of different regions of the world (Breslina and Karpovich 1969, Sobey and Kenworthy 1979, Hogg and Morton 1983, Hogg *et al.* 1988, Paradis and Larenzoni 1996, Norton *et al.* 1997, Vidal *et al.* 1998, Abbot *et al.* 2000) and only few of them dealt with forest ecosystems (Maesako 1991, Ishida 1996, Mun 1997). Composition of chemical elements in the leaves of selected plant species growing within the area of bird colonies have been analyzed among others by Smith (1978), García *et al.* (2002) and Hobara *et al.* (2005). However there are only few papers in which the response of particular plant species to excessive soil fertilization due to bird colonies activity is described (Ishida 1996).

The mentioned above studies were carried out within the area of long-lasting colonies, in which floristic composition of phytocoenoses have already been altered to a great extent. Research conducted in the initial stage of the breeding colony existence could provide information not only on the rate of species replacement but also would give the possibility to observe the response of particular taxa to a rapid change of habitat conditions.

The aim of this work was to estimate the changes in the floristic composition that took place in the forest phytocoenosis three years after the colony of Grey Heron (*Ardea cinerea* L.) had settled and to examine the influence of nutrient enrichment on the change of the size and shape of leaves and inflorescences of the three plant species: *Rumex acetosella* L., *Anthoxanthum odoratum* L. and *Moehringia trinervia* (L.) Clairv. These species were selected, because they have different habitat requirements. First two are typical species of the clearings, fields and meadows, whereas *Moehringia trinervia* is a characteristic plant of forests (Grime *et al.* 1988). Bioindicative method according to Ellenberg's scale (Ellenberg 1992) was used to assess the effect of nitrogen enrichment on the vegetation.

2. STUDY AREA

Investigation was carried out in the summer of 2004 year in northern Poland (Pomeranian region) in locality Osiek (53°43'N, 18°25'E), in forestry "Kałębnica".

The area of study made a small forest complex (1.56 ha), in which western part (about 0.4 ha) a colony of Grey Heron had settled. It was covered by a young, circa about 40-year old stand with Scots pine as a dominant and Silver birch as an admixture. Canopy closure within the tree stand didn't exceed 60%. The undergrowth was present only in the part occupied by bird colony. The tree stand, introduced into formerly arable land, created good conditions for development of heterogeneous forest floor. The floor was covered by spontaneous species as, among others, species of the clearings, fields and meadows (*Anthoxanthum odoratum*, *Rumex acetosella*, *Achillea millefolium* L., *Viola arvensis* Murray) as well as typical of forests (*Moehringia trinervia*, *Mycelis muralis* (L.) Dumort., *Deschampsia flexuosa* (L.) Trin.). In the forest part outside of the colony presence of some Bryophyta in the forest floor has been noted. Within the colony 20 nests of Grey Heron were built exclusively on Scots pines. Nests were uniformly distributed in this area.

3. MATERIAL AND METHODS

Since the colony settlement, no form of land cultivation (e.g. ploughing, fertilization) has been performed in the study area as well as no hay or timber harvesting took place. Thus, an assumption was made that all the observed differences concerning both studies areas were the result of the bird colony activity.

In order to examine the floristic composition as well as individual dimensions of the three selected species, two study plots of size of 20 × 20 m each have been set and a list of vascular plant species composing tree stand, undergrowth and forest floor has been made. The first plot was located within the bird colony nesting site, another (the control one) outside of the colony in a distance of about 50 m. On the basis of plants' habitat requirements (Ellenberg 1992) each species has been classified into an appropriate ecological group. Soil pH was checked in the area of colony and outside at depth of 5 cm; pH was 4.0 in both sites.

For biometrical examination three species of different habitat requirements have been chosen. These are: *Rumex acetosella* (Polygonacae), *Anthoxanthum odoratum* (Poacae) and *Moehringia trinervia* (Caryophyllacae). The species were relatively numerous, both in the area of the colony and outside of it. *Rumex acetosella* is most often found in logged areas, fields, dry meadows, roadsides and embankments (Grime *et al.* 1988, Tacik 1992). *Anthoxanthum odoratum* occurs in meadows, fallows, roadsides, clearings, along forest edges (Falkowski 1982, Grime *et al.* 1988). *Moehringia trinervia* is a component of decidous forests, rarely of mixed forests and brushwoods and sometimes of ruderal communities (Grime *et al.* 1988, Sychowa 1992).

To collect the material for biometrical measurements in both plots, two parallel transects were traced. They were divided into squares of 1 m^2. From each square, every second metre, the biggest, undamaged individual of each species was collected. For each of the species two samples were taken – one from within the colony, another one from the control area, outside of the colony. Plants growing at the border of the plot were not taken into account.

Leaves measurements for all species were carried at maximally straighten leaf blade. The length was measured along the main or middle nerve. Inflorescences were measured at maximally straighten axis (Fig. 1).

Rumex acetosella: for measurements the largest leaf from the inflorescence axis was chosen (rosette leaves were omitted). Its length was checked from the petiole basis to the leaf tip. The width of the leaf was measured in two places: between tips of the leaf lamina and in the widest part of a distal

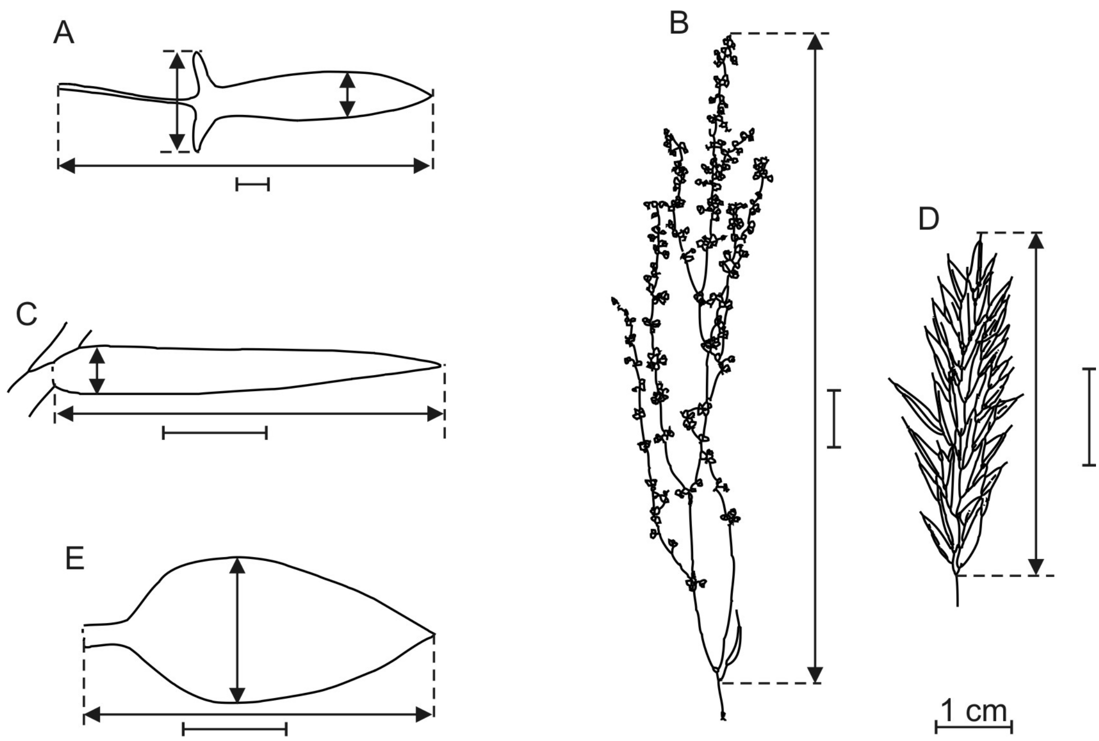

Fig. 1. Measurement of the leaves (A, C, E) and inflorescence (B, D) of examined species. Arrows indicate places in which measurements were made; *Rumex acetosella* – A, B; *Anthoxanthum odoratum* – C, D; *Moehringia trinervia* – E.

fragment of the leaf. The length of the inflorescence was measured starting from its lowest branching to the inflorescence apex (Fig. 1A, 1B).

Anthoxantum odoratum: the first leaf from under inflorescence was measured. The measurement was made in the bottom side of the leaf from its basis to the tip. The leaf width was measured in its widest part. The length of the inflorescence was measured from the axis lowest spikelet to the tip of the most distal glume (Fig. 1C, 1D).

Moehringia trinervia: for the measurements the largest leaf from the inflorescence axis was taken. Its length was measured from the petiole basis to the leaf's tip. The width of the leaf blade was checked in its widest part (Fig. 1E).

Distributions of all measurements were normal. However, due to unequal variances in samples, Cochran-Cox test instead of t-Student test was used in testing differences between mean values (Zar 1996). Plant names was used according to Mirek *et al.* (2002) and Ochyra *et al.* (2003).

4. RESULTS

4.1. Floristic composition and structure of phytocoenosis

Study areas located within and outside of the colony differed with regard to the number of species, floristic composition and the structure of phytocoenosis.

In the area outside of the colony 23 plant species were found, while within the area almost twice as many – 43 species (see Appendix). The flora of the area outside the colony was composed mainly by forest species. However within the colony they made only the third part of plant species (Fig. 2). Meadow plants were noted in both study areas, although they were more numerous within the colony area. Nitrophilous and ruderal species (12), were found within the territory of the colony, while in the control area only one nitrophilous species was stated. It was a young, of 30-cm height individual of *Sambucus racemosa*. The abundance of species of broad ecological spectrum was relatively small in both areas (Fig. 2)

Three-year period of Great Heron colony influence had a visible impact on the structure of phytocoenosis. The coverage of undergrowth about 40% and an average height of 1.5 m was found exclusively in the area of bird colony. It was mainly composed of *Sambucus racemosa* with small admixture of *Sorbus aucuparia* L. and *Frangula alnus* Mill. Moss layer was eliminated from the forest floor; only some individuals survived in the vicinity of pine trunks. On the contrary, moss layer of the control area was well developed, covered about 40% of the area surface and consisted of 5 species.

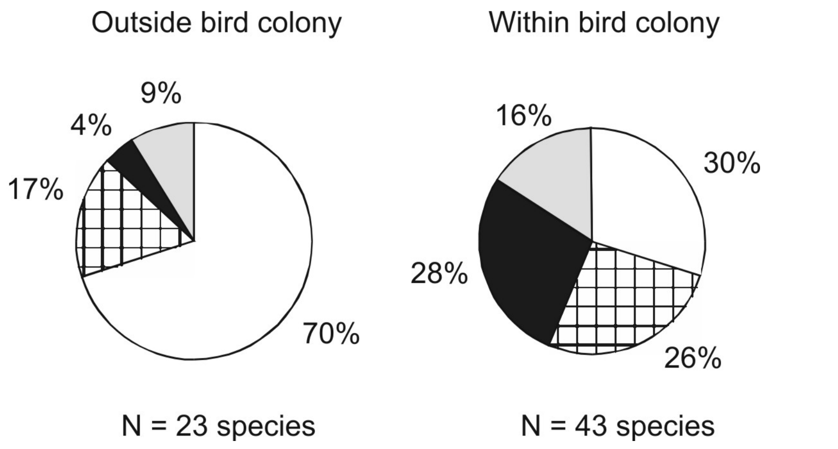

Fig. 2. Participation of ecological groups of species composing flora of the area within and outside of the colony. White – forest species, crosshatched – meadow species, black – nitrophilous and ruderal species, grey – species of broad phytosociological scale.

4.2. Biometrical analysis

Plants of *R. acetosella* growing within the colony displayed significantly greater average values of all measurements in comparison with the individuals coming from the outside of the colony (Table 1). The biggest relative difference referred to the width of leaf blade in its widest part and in the part between the lamina. Ratio of the leaf length to width for the plants collected from both plots didn't differ significantly. It points at the proportional increase of both parameters.

Significant differences of mean values of the dimensions of *A. odoratum* were found in case of the individuals collected from both within and outside of the colony (Table 2). Individuals of *A. odoratum* growing within the colony were bigger. The greatest relative difference concerned the leaf length, the least difference was connected with the mean length of the inflorescence. Individuals growing within the colony had significantly longer leaf blades compared to their width (Table 2).

Both the length and the width of the leaf of *M. trinervia* were significantly greater in case of plants growing within the colony (Table 3). Relatively greater difference concerned the leaf width. Ratio of the leaf length to width equals 2.2 for the species from within the colony and 2.4 for the plants growing outside of it. The difference was statistically significant. This means that individuals coming from the area of bird colony have proportionally wider and more rounded leaves in comparison with the plants from the outside of the colony area.

5. DISCUSSION

Species composition of the forest floor distinctly indicated changes that have taken place as a result of soil fertilization after

Table 1. Mean values of leaf and inflorescence dimensions of *Rumex acetosella* collected outside and within the Grey Heron colony.

Measurement (mm)	Outside colony			Within colony			Cochran-Cox test		Relative difference (%)
	Mean	SD	N	Mean	SD	N	t'	*P*	
Leaf length	73.8	11.96	28	111.1	23.21	23	7.0	<0.001	51
Leaf width	9.6	2.11	30	16.6	3.45	24	8.7	<0.001	73
Leaf lamina	24.4	5.69	25	43.5	10.05	23	8.0	<0.001	78
Inflorescence length	137.3	29.89	33	208.0	70.9	24	4.6	<0.001	52
Length/width ratio	8.02	1.99	28	7.13	2.28	23	1.5	>0.05	13

Table 2. Mean values of leaf and inflorescence dimensions of *Antoxantum odoratum* collected outside and within the Grey Heron colony.

Measurement (mm)	Outside colony			Within colony			Cochran-Cox test		Relative difference (%)
	Mean	SD	N	Mean	SD	N	t'	*P*	
Leaf length	41.7	13.1	38	83.1	20.35	30	9.7	<0.001	99
Leaf width	3.6	0.55	38	5.6	1.03	31	9.7	<0.001	56
Inflorescence length	64.3	9.85	40	75.6	11.65	31	4.3	<0.001	18
Length/width ratio	11.7	3.33	38	15.1	3.28	30	4.2	<0.001	29

Table 3. Mean values of leaf dimensions of *Moehringia trinervia* collected outside and within the Grey Heron colony.

Measurement (mm)	Outside colony			Within colony			Cochran-Cox test		Relative difference (%)
	Mean	SD	N	Mean	SD	N	t'	*P*	
Leaf length	22.4	4.06	39	34.3	5.50	30	10.0	<0.001	53
Leaf width	9.3	1.70	39	15.5	2.39	30	12.1	<0.001	67
Length/width ratio	2.4	0.35	39	2.2	0.26	30	2.9	<0.01	9

settlement of the Grey Heron colony. Although in this work the amount of nitrogen compounds produced by the colony was not examined, it is well known that in the colonies of Grey Heron the content of total nitrogen in the litter and soil can be 1.5 to 5 times higher in comparison with the area outside of the colony (Mun 1997, Ligeza and Smal 2003). Despite the fact that the colony had existed for only three years, it had significant influence on composition of the forest floor. One of the observed phenomena was almost double increase of the number of vascular plant species within the colony area. In spite of the short time of the colony existence entirely new taxa appeared, which were also characterized by presence of quite great number of individuals e.g. *Galeopsis pubescens*, *Stellaria media*, *Urtica dioica* L. (see Appendix). These species are commonly regarded as nitrophilous plants (Ellenberg 1992) and they indicate an increased content of nitrogen in soil.

As a consequence of soil fertilization the vertical structure of phytocoenosis has also changed. Within the colony the undergrowth appeared. Changes were also observed in case of the forest floor. Dense moss layer was eliminated and only few individuals were found around the tree trunks. Disappearing of typical Scots pine forest mosses is, most probably, connected with their high sensitivity to the fluctuations of soil fertility. It was observed in a dozen of Grey Heron colonies in northern Poland that Bryophytes withdraw quickly from the patches of vegetation staying under influence of bird colony (K. Żółkoś and W. Meissner, unpublished data).

Increased supply of nitrogen leads to the enlargement of plants size, in particular of their assimilative organs. The enlargement of leaf surface results in the increase of photosynthesis intensity and plan biomass (Mohr and Schopfer 1995). It was found in case of all three investigated plant species growing within the Grey Heron colony. The observed inter-species differences are the most probably the effect of differentiated structure of a leaf blade. *M. trinervia* and *R. acetosella* are dicotyledons, in case of which two meristems take part in the process of the blade length (intercalary meristem) and width (plate meristem) growth. *A. odoratum* is a monocotyledon belonging to grasses and its blade's width increase is limited due to morphological reasons and the intercalary meristem plays the main role (Bell 1993). With reference to *M. trinervia* and *R. acetosella* the greatest relative increase concerned leaf width. In case of *A. odoratum* leaf blade increased to a greater extent in length. The length/width ratio of the leaves of *M. trinervia* growing within the colony has changed significantly. It points at the enlargement of the surface of assimilative apparatus not only due to the growth of linear dimensions, but also to the tendency to roundening, ovate in shape, leaf blade. One can suppose it may be a kind of a strategy of this species used in order to achieve maximum size of the leaf surface. This phenomenon was not observed with *R. acetosella*, which is characterized by elongated, lanceolate leaf blade.

At the very first stages of the colony existence permanent supply of nutrients is advantageous for most of the plant species and results in the increase of the number of individuals and biomass. These changes refer even to non-forest species, which, after the tree stand has been introduced, should steadily disappear because of an increased shading, however the enhanced income of nutrients compensate lack of insolation (Odum 1982, Krebs 2001).

From three investigated species only *M. trinervia* can be found in well established Grey Heron colonies (K. Żółkoś and W. Meissner, unpublished data). As the species exploits disturbed soil, e.g. rabbit scrapes or sites of tree falls (Grime *et al.* 1988). As to *R. acetosella* and *A. odoratum* it is a well-known phenomenon that both these plant species are suppressed by heavy applications of nitrogenous fertilizer (Grime *et al.* 1988). Thus, it seems that after few years of benefits at least *R. acetosella* and *A. odoratum* will withdraw from the area of Grey Heron colony, because limited change in root absorption capacity in fertile habitat leads to toxic accumulation of nutrients and reduced growth and vigour (Haynes and Goh 1978, Mohr and Schopfer 1995, Crawford *et al.* 2000, Paul and Clark 2000).

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APPENDIX

List of species and their occurrence in the area affected by Grey Heron colony and outside
Explanations: Layer: a – tree stand, b – shrubs, c – herbs, d – mosses and lichens. Species quantity due to Braun-Blanquet scale: 4 – 50–75%, 2 – 5–25%, 1 – 1–5 %, + – few individuals. In B-B scale density (%) of a, b layers and cover (%) of c, d layers.

Species name	Quantity of species		
	Layer	Within colony	Outside colony
Trees and shrubs			
Pinus sylvestris L.	a	4	4
Betuala pendula Roth	a	1	1
" "	b	+	.
" "	c	+	.
Sambucus racemosa L.	b	2	.
" "	c	1	+
Sorbus aucuparia L.	b	1	.
" "	c	1	1
Frangula alnus Mill.	b	+	.
" "	c	.	+
Quercus robur L.	c	+	+
Acer platanoides L.	c	+	.
Acer pseudoplatanus L.	c	+	.
Fagus sylvatica L. (planted)	c	+	.
Tilia cordata Mill. (planted)	c	+	.
Carpinus betulus L. (planted)	c	.	1
Padus sreotina (Ehrh.) Borkh.	c	.	+
Herbs and mosses			
Deschampsia flexuosa (L.) Trin.	c	1	2
Anthoxantum odoratum L.	c	1	+
Rumex acetosella L.	c	1	+
Cerastium vulgatum L.	c	+	+
Moehringia trinervia (L.) Clairv.	c	1	+
Holcus lanatus L.	c	1	+
Rumex acetosa L.	c	+	+
Galeopsis pubescens Besser	c	2	.
Stellaria media (L.) Vill.	c	1	.
Agrostis capillaris L.	c	1	.
Viola arvensis Murray	c	+	.
Convolvulus arvensis L.	c	+	.
Achillea millefolium L.	c	+	.
Poa trivialis L.	c	+	.
Ranunculus repens L.	c	+	.
Artemisia vulgaris L.	c	+	.
Rosa rugosa Thunb.	c	+	.
Elymus repens (L.) Guld	c	+	.
Senecio sylvaticus L.	c	+	.
Urtica dioica L.	c	+	.
Potentilla argentea L.	c	+	.
Mycelis muralis (L.) Dumort.	c	+	.
Rubus idaeus L.	c	+	.

Species name	Quantity of species		
	Layer	Within colony	Outside colony
Galium aparine L.	c	+	.
Melampyrum pratense L.	c	+	.
Trifolium repens L.	c	+	.
Poa annua L.	c	+	.
Taraxacum officinale Weber	c	+	.
Deschampsia caespitosa (L.) P. Beuv.	c	+	.
Lapsana communis L.	c	+	.
Fallopia convolvulus (L.) Á.Löve	c	+	.
Epilobium montanum	c	+	.
Dryopteris carthusiana (Vill.) H. P. Fuchs	c	+	.
Veronica officinalis L.	c	.	+
Trientalis europaea L.	c	.	+
Vaccinium myrtillus L.	c	.	+
Plagothecium sp.	d	.	1
Pleurozium schreberi (Willd. *ex* Bridt.) Mitt.	d	.	+
Dicranum polysetum Sw. *ex* anon.	d	.	+
Brachythecium sp.	d	.	+
Atrichum undulatum (Hedw.) P. Beauv.	d	.	+