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Contents

Satura rādītājs

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The effect of urban environment on the mineral nutrition status of street trees in Riga, the problems and possible solution

Pilsētvides ietekme uz Rīgas ielu apstādījumu koku minerālās barošanās stāvokli, problēmas un to iespējamie risinājumi

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Investigation has been done to find out the actual mineral nutrition status of street trees. Soil and plant (lime and chestnut leaves) samples were collected from 11 sites in the central part of Riga during the months of July, August and September 2003. The concentrations of 15 elements were determined in soil and plant samples as well the soil and electrical conductivity (EC).

The investigation showed a severe imbalance in the system of mineral nutrition necessary for healthy tree growth: high concentration of Na in tree leaves and the soil rooting zone primarily from de-icing salt (NaCl), absolute deficit of N in all sampling sites and times, decreased plants supply with K (harmful in combination with Na abundance), an unfavourable soil pH as well as an insufficient level of S and B in the substrate and plant leaves.

The main measures to improve the conditions of Riga city plant growth are fertilizer application (soil and foliar), soil pH reduction etc.

Keywords: street trees, urban soil, biogenous elements, sodium chloride.

Introduction

Street trees, parks and greeneries are one of the city's visiting cards and very important and valuable part of city environment. Unfortunately there are serious problems with the physiological status of the street trees in the central part of Riga – ever increasing visible foliar damages of plants. The damage of most of the deciduous trees appeared as chlorosis, burning of the leaf margins. In severe cases the leaves were completely brown and necrotic.

Tree status in the city can be influenced by many factors, such as application of de-icing materials during winter months, soil structure and chemical properties, microclimate, supply with biogenous elements, soil and air pollution, insect damages etc. (Ripa, 1967; Ripa, Pētersons, 1968; Schwedtfeger, 1970; Bergmann, Neubert, 1976; Blauermel, 1978; Meyer, 1978; Zvirgzds, 1986; Rupais, 1989).

For optimal tree and bush growth, the essential mineral nutrients must be present in adequate levels and correct proportions. There are also some specific demands for mineral nutrients by different plant species. The essential elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) all have specific roles in plant structure, and metabolism. Any disbalance could lead to the stunted growth of plants (Meyer, 1978; Bergmann, 1988; Riņķis, 1989; Leh, 1993; Kafkafi and Bernstein, 1996).

Soil pH also effects the availability of nutrients in the soil and the ability for plants to take up those nutrients. Neutral and alkaline pH of the soil can have adverse effects on the microenvironment of the rhizosphere by reducing mycorrhizae (Meyer, 1978; Zvirgzds, 1986).

The most common de-icing material applied in Riga is sodium chloride (NaCl). Na can affect the fertility status of the soil by exchange with the available nutrients on the soil complex (Holmes 1961; Brod, Brod, 1975; Bergmann, Čumakov, 1977; Meyer, 1978; Glenn et al., 1997; Blomqvist, Johansson, 1999; Schlup, Ruess, 2001; Bryson, Barker, 2002).

An excess of sodium in the soil also reduces soil structure and can alter the physical properties of the soil by dispersing soil aggregates, which would lead to puddling of finer textured soils (Davison, 1971; Meyer, 1978; Bryson, Barker, 2002). This produces decreased soil porosity, reduced oxygen at the roots, increased denitrification, desultification process and CO_2 content in the soil (to 12%), which suppress the biological processes in the soil. At the same time high levels of Na and Cl in a plant can decrease the activity of several enzymes and chlorophyll concentrations, causes damage to different processes of a plant's metabolisms, such as photosynthesis, gas exchange, and others (Ripa, Pētersons, 1968; Rich, 1972; Buschbom, 1973; Ruge, 1978; Dobson, 1991; Sparks, 1995; Bryson, Barker, 2002).

Several investigations were conducted by Ripa and Pētersons in 1966 and 1967 to determine the impact of sodium chloride on the trees in Riga. As the result they found out that excess sodium and chlorine suppressed nutrient uptake ability of plants and reduced the biomass of physiologically active roots. It was also stated that increased concentrations of sodium, chlorine and sulphate ions in the plant leaves stimulated degradation of chloroplasts and expansion of protoplasm colloids (Ripa, Pētersons, 1968).

Another problem is toxic impact of heavy metals on plants due to transport emissions. It is well known that a variety of motor vehicles produce trace metals. Some of these metals are lead, cadmium and zinc (Rodriguez-Flores, Rodrigues-Castellon, 1982; Nyangababo, Hamya, 1986; Бериня, Калвиня, 1989; Шарковскис, Никодемус, 1989; Park, 1997; Goudie, 2000; Iqbal, Shafig, 2000).

The visual symptoms of salt and heavy metal damage on trees as well as the imbalance in the system of plant mineral nutrition does not always appear in the leaves (Riņķis, Ramane, 1989). At the same time tree growth and development could be seriously inhibited. Plant analysis can detect toxicities or hidden deficiencies before the visual symptoms appear. Therefore it is very important to control the growing environment as well as plant material – tree leaves. The plant leaf test represents not only the effects of soil nutrient status and the degree of pollution, but also all the factors controlling plant growth, whilst the soil test is very important in determining the pH electrical conductivity and nutrient levels. Soil and plant tissue analysis used together is the best reliable method to determine actual tree status in specific urban environment (Riņķis, Ramane, 1989; Riņķis, 1995).

The aim of this study was to investigate the actual mineral nutrition status of the street trees in Riga by plant and soil analysis and developing measures for its improvement.

Material and Methods

Sites

Riga, the capital of Latvia, with a population of 747.2 thousand, is located along the Baltic Sea at the southern coast of the Gulf of Riga. The historical and central part of Riga is situated on the right bank of the Daugava river, about 10 km from where the Daugava flows into the Gulf of Riga (http://www.riga.lv/LV/Channels/About_Riga).

Riga is famous for its green areas constituting 11,252 ha or 36.6% of the total area of the city. In the center parks, gardens, squares and other greenery form 8% of the territory (http://www.ceroi.net/reports/riga/issues/green_areas/). The main species of the street trees are *Tilia x vulgaris* and *Aesculus hippocastanum*.

The climate of Riga is moderately warm and humid. Riga, as every other big city, has its own special microclimate which can be characterized by a decrease in the average level of rain precipitation and increased mean temperature (~2 °C) (Kleinberga, 1988) in comparison with surrounding areas.

The mean annual air temperature is +5.6 °C, the average temperature in July is +16.9 °C, the average temperature in January is –4.7 °C, the average precipitation is 700–720 mm a year. Snow cover forms in the middle of December and remain through in the middle of March.

There is an ever rising traffic intensity in Riga. In 2001, there was 270 cars registered per every 1000 people, currently, the total number of registered vehicles in Riga are more than 200 000 (http://www.riga.lv/LV/Channels/About_Riga).

The most common de-icing material applied in Riga during winter months is sodium chloride (NaCl). The average rate of NaCl application is about 10,000 t per year.

Soils in central part of Riga could be characterized as artificial, highly heterogeneous and compacted.

Sampling

During July, August and September, 2003 tree leaves and soil samples were collected from 11 study sites in the central part of Riga (Table 1, Fig. 1). Soil and leaf samples were taken from each site.

For each soil sample, from 8 to 10 sub-samples were obtained (at the perimeter of the crown of a tree) and thoroughly mixed to form one sample. The soil samples were taken with a soil probe to a depth to 20 cm in July and to 35 cm in August, September (with out mulch material).

Leaf samples were taken with special telescopic scissors. Lime and chestnut leaves were sampled at the proper stage of maturity – leaves which had just reach maturity and the proper size. For each plant sample 60 leaves were taken from different branches of three trees (3×20 leaves).

Figure 1

Sampling site locations in the central part of Riga

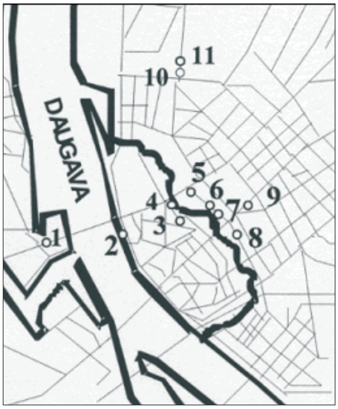


Table 1

Plant and soil sampling sites in Riga

Nr.	Sampling site	Species sampled	Status of trees
1	Near «Preses nams» (Vanšu bridge)	Lime (*Tilia x vulgaris*)	Damaged
2	Greenery along the river Daugava	Lime (*Tilia x vulgaris*)	Healthy
3	Basteja boulevard (near underground parking place «Jēkaba kazarmas»)	Lime (*Tilia x vulgaris*)	Healthy
4	Basteja boulevard (city canal side)	Lime (*Tilia x vulgaris*)	Damaged
5	Valdemāra street (near Rīgas Dome)	Lime (*Tilia x vulgaris*)	Medium damaged
6	Raiņa boulevard*	Lime (*Tilia x vulgaris*)	Medium damaged
7	Raiņa boulevard**	Lime (*Tilia x vulgaris*)	Medium damaged
8	Raiņa boulevard***	Lime (*Tilia x vulgaris*)	Medium damaged
9	Brīvības street (alley in the middle of street, near Orthodox cathedral)	Lime (*Tilia x vulgaris*)	Medium damaged
10	Pulkveža Brieža street (along the street)	Chestnut (*Aesculus hippocastanum*)	Damaged
11	Pulkveža Brieža street(in the middle of the street)	Chestnut (*Aesculus hippocastanum*)	Damaged

* Young limes, tree peeling mulch

** Young limes, road chipping mulch

*** Old limes

Soil and plant analysis

The soil samples were cooled below +4 °C to stop nitrification, dried at +35 °C in two days and bolted. The leaves were washed with distilled water, dried at +60 °C and ground.

Soil extraction and plant tissue ashing

To determine N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B, Na, and Pb the soil samples were extracted with 1 M HCl solution (soil – extractant mixture 1:5). Soil electrical conductivity (EC) and chloride content were determined in distilled water extract (soil – distilled water mixture 1:5), soil pH – in 1 M KCl (soil – extractant mixture 1:2,5) (Риньких и. др., 1987).

The plant samples were dry-ashed in HNO_3 vapors and re-dissolved in HCl solution (HCl – distilled water mixture 3:100) (Риньких и. др., 1987).

Chemical analysis

Concentrations of 15 elements (biogenous elements – N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B, Na, Cl and Pb) were determed in all the soil and leaf samples. The levels of Ca, Mg, Fe, Cu, Zn and Mn were estimated by atomic absorption spectrophotometry (Perkin Elmer 403, acetylene-air flame) (Page et al. (ed.), 1982), those of N, P, Mo, B by colorimetry, S by nephelometry (*ФЭК – 56 М*) (Риньких и. др., 1987), K and Na by flame photometer *JENWAY PFPJ*, EC by conductometr *N 5711*, and soil pH by pHmetr *Sartorius* (Риньких и. др., 1987). Chlorides were determined by $AgNO_3$ titration (Риньких и. др., 1987) in the soil samples and by 0,02n $Hg(NO_3)_2$ (Поповцева (ед.), 1974) in the leaf samples.

The results are the means of at least three independent replications.

Results

The use of the most common de-icing material NaCl in Riga caused an increased sodium accumulation in the soil (Fig. 2) and leaves (Fig. 3).

Figure 2

Sodium concentrations (mg l^{-1}) in different soil layers taken from sampling sites in Riga (summer, 2003)

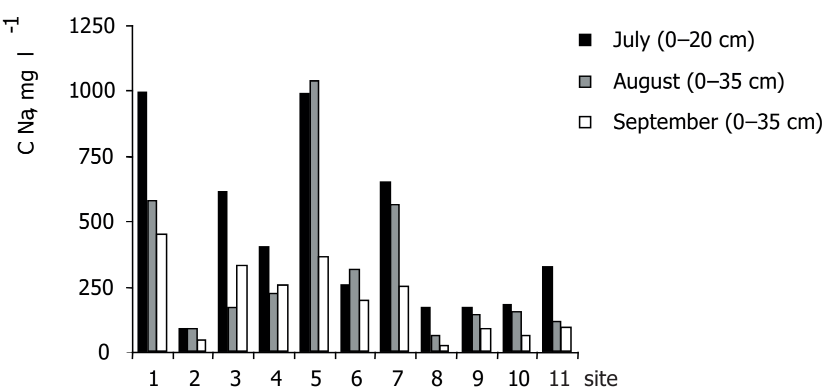
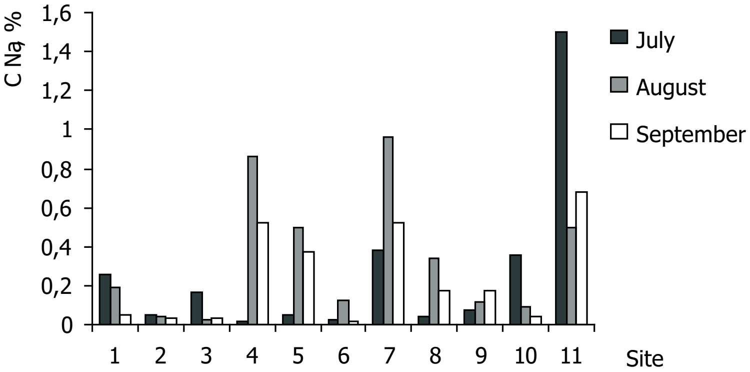


Figure 3

Sodium concentrations (%) in lime and chestnut leaves taken from sampling sites in Riga (summer, 2003)



Visual symptoms of Na toxicity, such as browning of the leaves and poor development of young leaves were observed in the most of study sites. The highest Na concentrations in the soil samples were found close to the main streets (site 1, 3, 5, 7). There were high rates of NaCl application during winter months, and inevitably much of this material was splashed on the verges. A marked decrease in the concentration of Na in the soil was observed as the distance from the road increased, for example, in the green zone near the river Daugava (site 2).

The highest concentrations of Na in the soil samples were observed in July (decreased sampling depth). A decrease in the concentrations of Na was stated in September in almost 9 of the sampling sites. It could be explained by the sodium ions uptake by the plants during the vegetation period and increased sodium ions leaching during autumn season.

The concentration of Na in the leaves of the damaged trees (site 4, 5, 7, 11) was about 10 to 20 times higher than in healthy leaf samples (site 2, 3). A marked decrease in the concentration of Na in the plant leaves (site 1, 4, 5, 6, 7, 8, 10) was stated in September shortly before the trees shed their leaves, when sodium transmigration from leaves to branches occurred.

The concentrations of Cl in the soil samples were relatively low (from 6 mg l^{-1} to 160 mg l^{-1}), and only at site Nr.1 we observed an increased Cl level – 418 mg l^{-1}. A marked decrease in the concentrations of Cl occurred during summer – autumn season after abundant rainfall.

The concentrations of Cl in tree leaves were low and do not exceed the acceptable level – 0.4% in all sampling sites and times.

Slightly increased concentrations of Pb were stated in 7 of the sampling sites examined in Riga (max concentration – 107 mg l^{-1}). Concentrations of Pb in the tree leaves did not exceed the toxic level (20 mg kg^{-1}) and ranged from 4 to 16 mg kg^{-1} due to high concentrations of Pb antagonist Ca and Mg (Table 2) in the soils as well as neutral and a slightly alkaline reaction of the soil.

To characterize the mineral nutrition status of street trees, the levels of 12 other biogenous elements were estimated in the soil and tree leaves. Information obtained showed serious N deficits in all of the soil samples (12 to 66 mg l^{-1}) as well as in the lime and chestnut leaves. Plant supply with such macro elements as P, Ca, Mg could be characterized as optimal to more than optimal (Table 2). Accordingly, optimal till abundant levels of the elements were stated in leaves (Table 3).

Table 2

Mean element concentrations (mg l^{-1}) in different soil layers taken from sampling sites in Riga (summer, 2003)

Element	Average concentrations (mg l^{-1})		
	July (0–20 cm)	August (0–35 cm)	September (0–35 cm)
Ca	9931,82	9170,46	7875,00
Mg	3213,09	2417,09	2273,86
P	445,27	576,18	391,36
Mn	121,64	121,91	101,00
Fe	1920,00	1603,64	1299,55
Zn	90,73	62,36	49,67
Cu	57,67	32,45	24,26
Mo	0,08	0,08	0,11
S	25,36	37,64	16,51
B	0,41	0,36	0,35

Table 3

Mean element concentrations in lime and chestnut leaves taken from sampling sites in Riga (summer, 2003)

Element	Average concentrations		
	July	August	September
mg kg^{-1}			
Mn	78,46	65,35	245,46
Fe	520,00	501,82	552,73
Zn	33,82	27,91	34,18
Cu	21,09	15,09	21,66
Mo	0,56	1,05	1,26
B	13,09	45,55	46,36
%			
Ca	1,33	1,67	1,86
Mg	0,44	0,46	0,38
P	0,34	0,24	0,25
S	0,17	0,17	0,12

Figure 4

Potassium concentrations (mg l^{-1}) in different soil layers taken from sampling sites in Riga (summer, 2003)

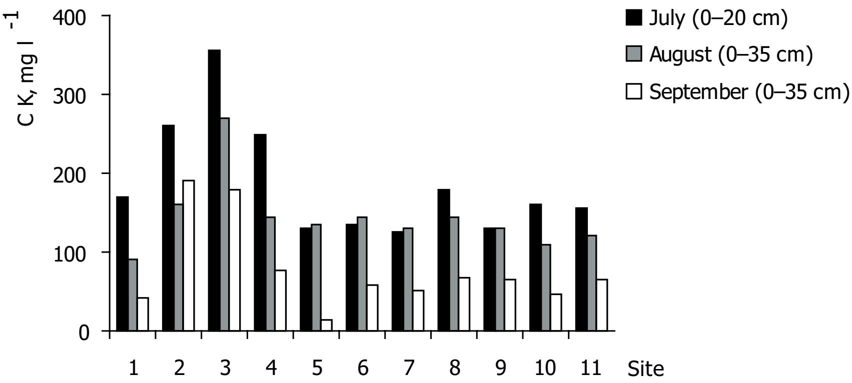
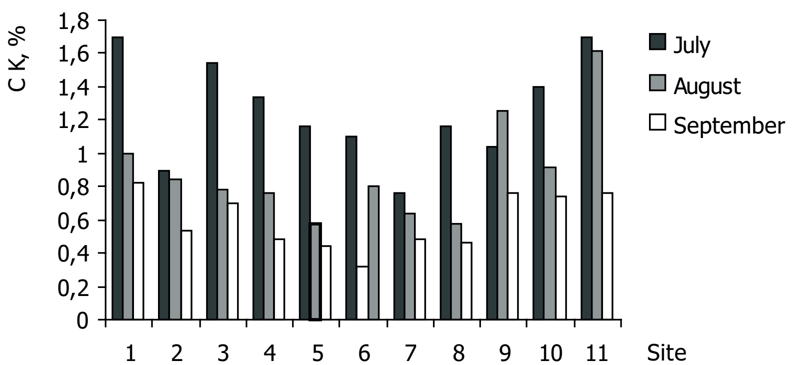


Figure 5

Potassium concentrations (%) in lime and chestnut leaves taken from sampling sites in Riga (summer, 2003)



The results obtained on K levels in the soils and plants are of particular interest (Fig. 4, 5). The potassium concentrations decreased during the vegetation period and almost in all sampling sites did not correspond to the optimal levels in the soils and leaves. Only in two of the lime growing sites (Nr. 2, 3) where K status could be characterized as optimal, limes were without visual damage symptoms in the leaves. The decrease in the concentration of K during vegetation period could hardly be explained by the difference in the soil sampling depth. Plant supply with potassium (essential macroelement) in most cases is insufficient, but the decrease of K concentration in such conditions could mainly be explained by potassium uptake of plants during the vegetation season.

It was stated that contents of the microelements Mn and Mo where relatively stable during the vegetation period (Table 2), but not always optimal for plant growth and development. The abundant concentrations of Fe, Zn and Cu in the soil samples decrease during the summer months. The mean concentrations of Fe, Zn and Cu in the tree leaves were high and relatively stable, levels of Mn and Mo increased during vegetation period (Table 3).

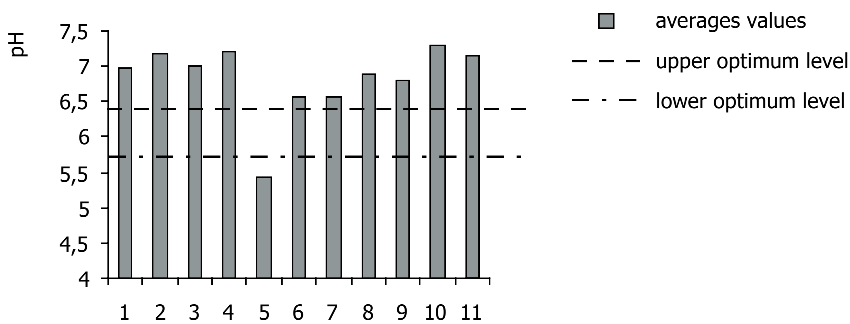
The low levels of S and B in the soils did not correspond to the optimal supply of plants, accordingly decreased levels of these elements were also stated in the leaves (Table 3).

EC and pH

Urban soils were highly heterogeneous in most of sampling sites and can not be characterized as the natural soils. They consist of building remains, brick pieces and other artificial materials with an alkaline reaction. Therefore results obtained on the mean (July, August, September) soil pH values (Fig. 6) in most of the cases were from neutral to slightly alkaline (pH 6.5 to 7.5). These soil pH values did not correspond to optimal lime and chestnut growth. The exception was Kr. Valdemāra street and Raiņa boulevard (site 5, 6) where tree peeling mulch was used and soil reaction could be characterized as acid. It was stated that road chipping mulch application (site 7) on the same Raiņa boulevard increased soil reaction to pH 6.65.

Figure 6

Mean pH values in the upper soil layers taken from sampling sites in Riga (summer, 2003)



The EC values (0.61 to 2.69 mS/cm), a measurement of the soluble salts, correlated closely with increased concentrations of sodium in the soils. The electrical conductivity values decreased at the end of the vegetation period due to increased rainfall.

Discussion

The results of the investigation on street trees in Riga during the summer of 2003 revealed the main problems and unfavourable factors which affected the condition of lime and chestnut in the city.

Our study suggests that one of the main problems is sodium damage to the plants along the streets. Sodium chloride applied during winter month in the de-icing procedures caused an increased sodium accumulation in the soil and plants. Thus, massive accumulation of Na (1.50%) in chestnut leaves (site 11) and widespread damage on plants (necrosis degree 80%) was stated in Pulkveža Brieža street (site 11).

High concentrations of Na in the soil can also affect plant species in other ways than direct toxicity by Na. The sodium ions can replace K^+, NH_4^+, Ca^{++}, Mg^{++} and other cations on the soil exchange complex, on the plant root cation uptake places and could eventually lead to nutrient deficiencies. The concentrations of Cl in the soil and plants were relatively low because chlorides as anions are more leaching and therefore less toxic to plants (Meyer, 1978). But higher concentrations of chloride ions in plants in spring could have a negative effect the uptake of sulphate and phosphate ions during the vegetation period.

The results obtained on the nutrition status of street trees showed decreased levels of potassium in most of the sampling sites. This is extremely harmful in combination with an abundance of Na. For optimal tree growth the proportion of potassium/sodium must be from 2.0 to 2.5 in the soils and the K levels in plant leaves can not be under 1.2% (optimally it should be from 1.5 to 2.5%). An optimal supply of potassium was stated only in the limes along the river Daugava which grow in some distance from the street.

High levels of sodium ions can affect the physical properties of the soil. From our results it appears that the Na in the soil complex results in a slightly alkaline soil. Similar phenomena has been reported for Na accumulation in soils and plants along roadsides in Massachusetts (Bryson, Barker, 2002). Such tendencies can be stimulated by a high concentration of building materials and remains as well as technogenic pollutants in urban soils.

The results presented here on concentrations of phosphorous in soils differ from those of Meyer (1978) who found decreased levels of P and K in the substrates with increased contents of artificial materials with alkaline reaction. Street trees supply with P in Riga could be characterized as optimal till abundant. This is consistent with the studies of Ripa and Pētersons (1968) on soils and trees in Riga where high or toxic levels of phosphorous were stated. This may be explained by possible application of excessive amounts of phosphate containing fertilizers.

Soil pH also affects the availability of nutrients in the soil and on the ability of plants to take up those nutrients. Microelements Mn, B and others are quite tightly bound in the neutral and alkaline soil and so are poorly available for plants (Riņķis, Ramane, 1989; Kabata-Pendias, Pendias, 1992; Glenn et al., 1997). In accordance with this, the symptoms of manganese deficit in plants – leaf chlorosis and necrosis were observed in several sampling sites (site 1, 2, 7). On the otherhand, raised soil reaction, increased concentrations of Ca and Mg in the soils decreased accumulation of Pb in plants.

The information obtained suggests that one of the main negative factors affecting the growth and development of street trees is decreased plant supply with nitrogen.. Urban soils could be characterized as fine-textured soils with limited aeration and increased denitrification process which results in an important loss of N.

Insufficient supply of oxygen to the roots in high density soils resulted in decreased root respiration and limited active uptake of nutrients.

During our investigation on street trees it was discovered that the condition of trees has been significantly influenced by the poorly established sewer and rainwater systems, and the caved-in edges of sidewalks and streets that separate the city's greeneries from driveways. It has caused an increased accumulation of sodium in the soil and the trees growing in these areas were literally drowning. O_2 deficiency is thought to be the major determinant in the adverse effects of water logging on the plants.

Several investigations on the toxic impact of de-icing agents on plants (Kawasaki, Moritsugu, 1978; Bogemans et al., 1989; Hart, Erhart, 2002) have shown that the mixture of different salts is less harmful and phytotoxic. Sodium chloride works effectively as de-icing agent with temperatures falling to –8 °C, and $CaCl_2$ is effective down to –20 °C. Research has also shown that by increasing Ca concentrations the effects of stress from the application of NaCl can be reduced. Bogemans (Bogemans et al., 1989) demonstrated that substituting 20 to 30% of $CaCl_2$ for NaCl resulted in a decrease of Na in the needles of spruce. Although $CaCl_2$ is less phytotoxic than NaCl, $CaCl_2$ is more expensive and difficult to handle and store (Rich, 1972). It is apparent that in the near future NaCl will be the main de-icing agent used in Riga.

One of the possible ways to remove sodium from the soil absorption complex is chemical melioration with gypsum (Evers, 1971; Ruge, 1978). Gypsum $CaSO_4 \cdot 2H_2O$ consist of 23% Ca and 18% S. Such chemical melioration with neutral salt could improve the soil chemical, physical and biological properties such as aeration, texture, permeability. Applied on saline soils, gypsum causes Na^+ replacement by Ca^{++} with the soil exchange complex and formatting well soluble salt Na_2SO_4 in the soil solution. It is very important for soil colloids coagulation and soil structure improvement.

The observed decrease in the concentration of Na in the tree leaves at the end of the vegetation period (site 1, 2, 4, 5, 6, 7, 8, 10) permits us to suggest that sodium and other toxic elements move to the branches and trunk in the autumn before the trees lose their leaves. This is consistent with the studies of Holmes (1961), Bergmann and Neubert (1976) on salt damage on plants. Such accumulation of Na especially in the old trees causes sodium transmigration to leaves in the spring with transpiration flow. Therefore, debranching of the old trees would be recommended.

Riga, as every other big city, has its own special microclimate which can be characterized by a decreased average level of rain precipitation (50 to 150 mm), increased mean temperature (~2 °C), lowered relative air humidity and shorter period of winter frost prolong the vegetation period. All these factors stimulate the warming of trees and cause increased plant transpiration, elevated mineralization of soil organic matter, etc. Therefore one of the most important measures to improve the condition of street trees is providing adequate soil humidity by watering during the entire vegetation period.

In the spring, when new growth is forming, the accumulated concentration of sodium and chloride in the urban soils are especially high (the rate of NaCl application for de-icing roads is about 20–30 g m^{-2} on any one occasion). At the same time, plant supply with biogenous elements are extremely low, i.e., causes a complete imbalance in the system of plant mineral nutrition. Therefore to improve the nutrition status of street trees, balanced plant nutrition with all the macro– and microelements are vitally important.

Conclusions

The investigation showed a complete imbalance in the system of tree mineral nutrition – high concentration of Na and relative low concentration of Cl in tree leaves and soil rooting zone (from de-icing salt – NaCl); absolute deficit of N in all sampling sites and times; decreased plant supply with K (extremely harmful in combination with Na abundance); unfavorable soil pH, insufficient level of S and B in substrate and plant leaves, etc.

Based on the present work, the main measures were worked out to improve the condition of street trees in Riga:

- Application of acid peat to reduce soil pH.
- Fertilizer application based on plant and soil analyses for optimal supply of street trees with all of the biogenous elements.
- Debranching of the old and severe damaged trees.
- Watering the trees during vegetation, especially in the early spring and in the autumn before the trees lose their leaves.

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Pilsētvides ietekme uz Rīgas ielu apstādījumu koku minerālās barošanās stāvokli, problēmas un to iespējamie risinājumi

Kopsavilkums

Veikta ielu apstādījumu liepu un zirgkastaņu kompleksa izpēte pēc lapu un augsnes analīzēm 11 Rīgas centra rajona vietās ar mērķi noskaidrot koku faktisko apgādi ar biogēnajiem elementiem, piesārņojumu ar Na, Cl, Pb un izstrādāt pasākumus kaitīgo pilsētas vides faktoru negatīvās ietekmes novēršanai vai samazināšanai. Iegūtie rezultāti atspoguļo ievērojamu disbalansu ielu apstādījumu apgādē ar barības elementiem – Na pārbagātība, paaugstināta Cl koncentrācija pavasarī, būtisks K trūkums koku sakņu barošanās zonā, N un atsevišķu mikroelementu deficīts, kā arī liepām un zirgkastaņām nelabvēlīga augsnes reakcija. Papildu faktori, kas negatīvi ietekmējuši ielu apstādījumu fizioloģisko stāvokli, ir skābekļa un mitruma trūkums, liepu tīklērču *Eotetranychus tiliarum* masveida savairošanās atsevišķās vietās un to izsauktie lapu bojājumi. Ieteicamais pasākumu komplekss ielu apstādījumu stāvokļa uzlabošanai ietver augsnes pH pazemināšanu, izmantojot skābu kūdru; koku optimālu nodrošināšanu ar barības elementiem, ievērojot konkrētās vietas augsnes un lapu analīžu rezultātus; veco koku zaru apgriešanu, kā arī apdobju laistīšanu.

Atslēgvārdi: ielu apstādījumi, urbāna augsne, biogēnie elementi, nātrija hlorīds.

21.–37. lpp.

Case studies on the alien flora of the vicinity of cemeteries in Lithuania
Kapsētu apkārtnes adventīvā flora Lietuvā

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Environmental and ecological studies of cemeteries still do not receive the proper attention of researchers. This paper presents the results of investigations on alien plant species in the vicinity of 17 cemeteries in different regions of Lithuania. The dependence of alien species diversity upon the size of the cemetery, confession, and the age of the cemetery is analysed and discussed. It is supposed that the formation of alien flora in the vicinity of cemeteries is conditioned by numerous factors, both natural and social. Their influence upon this process requires further studies.
Keywords: alien species, plant invasions, invasive species, naturalisation, ornamental plants, cemetery management.

Introduction

Cemeteries are places allocated to dispose, respect, and commemorate the dead, but nowadays they have also become the subject of research interest. This is mainly for archaeologists, landscape architects, historians, sociologists, and ethnologists (Ibáñez Fernández 1993; Richter 1995; Rugg 1998, 2000, 2003; Merridale 2003; Clayden, Woustra 2003; Francis et al. 2000; Francis 2003; Reimers 1999 etc.). Even neglected cemeteries and burial grounds reflect the beliefs, tastes, interests, and even social organisation of the people who created them. In Lithuania, as in much of Europe, cemeteries are being investigated mainly as objects of cultural and historical heritage (Girininkienė, Paulauskas 1994; Milius 1999; Minkevičiūtė, Minkevičienė 2002; Lisauskaitė 2002; Purvinas, Purvinienė 2000, 2002; Paulauskas 2002; Banys 2003; Girininkienė 2003 etc.).

The environmental and ecological studies of cemeteries still do not receive the proper attention of researchers. First attempts to evaluate the general significance of cemeteries impact on the landscape, wildlife, and conservation of natural values have been made recently in England (Bowdler et al. 2002). The process of the formation of neophyte communities in the vicinity of cemeteries in Latvia was studied by Laiviņš and Jermacāne (2000).

Probably the first research on the flora of old cemeteries was made in 1928–1930 and published by Rojecka (1934). She investigated the old Karaite cemetery in Trakai and registered 161 plant species, five of them were considered as aliens. For a long time there were no other publications directly related to any botanical research of cemeteries in Lithuania.

In 1993, the author of this paper started investigating the alien flora of Aukštadvaris Regional Park (Trakai district) and noted a significantly higher diversity of alien plants in the vicinities of cemeteries (Gudžinskas 1994a). This fact was the motivation behind doing detailed investigations on alien plants occurring in the vicinities of cemeteries. As a result, cemeteries were recognised as an important primary and secondary centre for alien plant invasions (Gudžinskas 1994b). Later, some attempts to investigate the flora of the bryophytes in cemeteries were made (Tumosienė 2001).

The aim of this paper is to analyse the diversity and development of alien flora in the vicinity of cemeteries on the basis of several case studies and to discuss the urgency to conduct further investigations in order to prevent the spread of invasive species into natural or semi natural habitats.

Material and methods

Investigations on the alien flora in the vicinity of cemeteries were conducted in the period of 1995–2003. Alien plant diversity was always studied outside the area of the burial space, which is limited by any kind of fence (wooden, stone, hedge etc.). All the area surrounding the cemetery was carefully investigated within the range of up to 50 m (rarely up to 100 m) from the fence searching for escaped and accidentally introduced alien plants. Plants penetrating through the fence from the graves closest to the fence and not forming self-sustained populations outside the burial space were neglected.

The species frequently cultivated as ornamental plants and having a native distribution range within the territory of Lithuania (*Aquilegia vulgaris*, *Jovibarba globifera*, *Matteuccia struthiopteris*, and *Sedum sexangulare*) were excluded from this analysis. *Saponaria officinalis* in Lithuania also occurs as native species, but plants belonging to cultivars (*florae pleno*) were considered as aliens.

In each investigated site, a list of species was recorded around the cemetery. For each species its approximate abundance, stage of plant development, and habitat characteristics were recorded. Specimens of critical taxa or plants that could not be identified in the field were collected and dried for later identification. Specimens collected during this research are deposited at the Herbarium of the Institute of Botany, Vilnius (BILAS). The general specifics of each cemetery location and its orography, as well as the characteristics of surrounding habitats were also noted.

The application of the term *cemetery* in this paper follows definitions proposed by Rugg (2000), i. e., distinction between cemeteries, churchyards, burial grounds, etc., has been made. In the description of each investigated site the burial grounds are characterised according to the above-mentioned terminology; however, when analysing generalised data the term *cemetery* is applied for all types of burial spaces.

The nomenclature of the plant species with few exceptions follows Gudžinskas (1999).

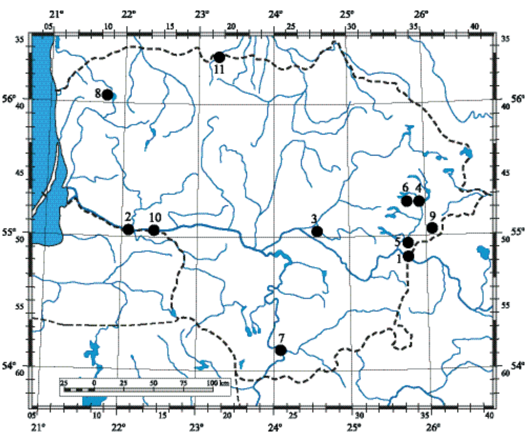
For data analysis the software *STATISTICA* (data analysis software system), version 6 was employed. Jaccard coefficient (C_J) was used to calculate the similarity of species found in each of the sampled areas (Jongman, 1995).

Investigated Cemeteries

Short characteristics (administrative position, geographical co-ordinates, relief, peculiarities of adjoining lands, area and dates of investigations) of 17 investigated cemeteries situated in different regions of Lithuania (Fig. 1) are presented below.

Figure 1

Location of the investigated cemeteries and burial grounds



1 – Balingradas, 2 – Bitėnai, 3 – Gegužinė, 4 – Kaltanėnai, 5 – Karkažiškės, 6 – Labanoras, 7 – Netiesos, 8 – Plateliai, 9 – Sariai, 10 – Viešvilė, 11 – Žagarė

Balingradas. Švenčionys district, surrounding areas of Balingradas village (N 54°52′02″; E 25°42′37″). The cemetery is located in a pine forest on a hill. Functioning. Area – 0.8 ha. July 20, 2003.

Bitėnai. Pagėgiai (part of former Šilutė) district, Rambynas Regional Park, surrounding areas of village Bitėnai (N 55°05′08″; E 22°02′07″). The cemetery is situated in a mixed forest. Functioning. Area – 0.3 ha. June 28, 2002.

Gegužinė. Kaišiadorys district. The **new** cemetery is situated in the middle of Gegužinė village (N 55°00′30″; E 24°30′26″), on a slope. It is adjoined to a dry pine forest. Functioning. Area – 0.68 ha. The **old** cemetery of Gegužinė village is situated 1 km to the Northeast of the village in a plain part of a valley (N 55°00′38″; E 24°29′33″). The cemetery is surrounded by meadows and adjoined to a road. Closed. Area – 0.45 ha. July 29, 2002.

Kaltanėnai. Švenčionys district, Aukštaitija National Park, southern part of Kaltanėnai village (N 55°14′38″; E 25°59′20″). The cemetery is on a plain surface, surrounded by cultivated meadows. Functioning. Area – 1.5 ha. July 25, 2002.

Karkažiškės. Švenčionys district, Karkažiškės village (N 54°57′04″; E 25°44′47″). The cemetery is situated in the centre of Karkažiškės village, on the top of a hill, surrounded by bushes and meadows. The eastern edge of the cemetery is adjoined to homesteads. Functioning. Area – 1,7 ha. July 22, 2003.

Labanoras. Švenčionys district, Labanoras village. The **old** cemetery is situated at the northwestern edge of the village, on a hill (N 55°16′13″; E 25°46′31″), surrounded by dry meadows. Functioning. Area – 0.8 ha. The **new** cemetery is situated at the eastern edge of the village, by the road to Lakaja (N 55°15′51″; E 25°46′46″), on the top of a hill, surrounded by meadows and bushes. Functioning. Area – 0.3 ha. July 26, 2002.

Netiesos. Varėna district, Dzūkija National Park, Netiesos village (N 54°11′10″; E 24°05′08″). The cemetery is situated at the edge of the village, on a small elevation. It is surrounded by dry meadows. Functioning. Area – 0.2 ha. August 3, 2000.

Plateliai. Plungė district, Žemaitija National Park, southwestern surrounding areas of Plateliai village (N 56°01′55″; E 21°48′31″). The cemetery is situated on the top of a hill, surrounded by meadows and bushes. Functioning. Area – 3 ha. June 27, 1995; July 8, 1997; June 17, 2002.

Sariai. Švenčionys district, eastern edge of Sariai village (N 55°03′35″; E 26°02′21″). The cemetery is situated on a small elevation. Northern and northwestern parts of the cemetery are adjoined to mixed forest, southern and eastern – to a slope meadow. Functioning. Area – 0.4 ha. July 25, 2002.

Viešvilė. Jurbarkas district, western edge of Viešvilė village (N 55°04′54″; E 22°23′11″). Northern and western sides of the cemetery are adjoined to mixed forest, eastern – to a fallow land and homestead, southern – to a road. Functioning. Area – 0.9 ha. June 24, 2002.

Žagarė. Joniškis district, Žagarė village, Žagarė Regional Park. In Žagarė village five cemeteries and burial grounds of different confessions have been investigated. The **Catholic** cemetery is situated at the southwestern edge of the village, on a small hill (N 56°21′23″; E 23°14′31″). It is surrounded mainly by cultivated meadows. Functioning. Area – 3.5 ha. The **Lutheran** cemetery is situated at the northern edge of the village (N 56°22′10″; E 23°16′01″), on a high hill. Slopes of the hill are overgrown with bushes, in several places they are being eroded. Functioning. Area – 1.2 ha. Burial grounds of **Old Believers** (closed) and **Seculars** (closed) are situated on the top of a hill at the western edge of the village (N 56°21′16″; E 23°13′36″). These burial grounds are surrounded by dry meadows. Their areas are 0.3 and 0.1 ha, respectively. Old **Jewish** burial ground (closed and abandoned) is situated in the northern part of the village (N 56°22′07″; E 23°16′00″), on a plain. Its area is ca. 0.5 ha. July 5–6, 2000.

Results

Diversity and characteristics of alien species

In vicinity of 15 studied cemeteries (The Jewish and Seculars of Žagarė burial grounds were excluded from this analysis, but these cases are described further) 71 alien plant species were registered (Table 1). The number of alien species in the surrounding areas of the investigated cemeteries varies from 7 to 26 (Table 2). The largest diversity of alien species was registered in the vicinity of the new cemetery of Gegužinė (26 species) and Viešvilė (25 species). The least number of species was registered in the vicinity of the Netiesos (8 species) cemetery and around the burial ground of the Old Believers (7 species) in Žagarė (Table 2).

Table 1

Summary table of alien species recorded in the vicinity of 15 analysed cemeteries

(Abbreviations. Naturalisation: c – casual; n – naturalised. Means of introduction: a – accidentally introduced species; e – escaped not ornamental species; o – escaped ornamental species)

Species	Number of records	Frequency (%)	Naturalisation	Mean of introduction
Conyza canadensis	13	86.7	n	a
Saponaria officinalis	13	86.7	n	o
Sedum spurium	13	86.7	n	o
Dianthus barbatus	12	80.0	n	o
Euphorbia cyparissias	11	73.3	n	o
Syringa vulgaris	11	73.3	n	o
Asparagus officinalis	9	60.0	n	o
Matricaria discoidea	8	53.3	n	e
Phalacroloma septentrionale	8	53.3	n	o
Galinsoga parviflora	7	46.7	n	a
Lupinus polyphyllus	7	46.7	n	o
Sedum album	7	46.7	n	o
Sedum rupestre	7	46.7	n	o
Spiraea chamaedryfolia	7	46.7	n	o
Galinsoga quadriradiata	6	40.0	n	a
Oxalis stricta	6	40.0	n	a
Sedum pallidum	6	40.0	n	o
Symphoricarpos albus	6	40.0	n	o
Vinca minor	6	40.0	n	o
Amelanchier spicata	5	33.3	n	e
Armoracia rusticana	5	33.3	n	e
Cerastium tomentosum	5	33.3	n	o
Impatiens parviflora	5	33.3	n	a
Rudbeckia hirta	5	33.3	n	o
Iris germanica	4	26.7	n	o
Sedum hispanicum	4	26.7	n	o
Sorbaria sorbifolia	4	26.7	n	o
Viola ×wittrockiana	4	26.7	c	o
Helianthus tuberosus	3	20.0	n	e
Hemerocallis fulva	3	20.0	n	o
Lilium bulbiferum	3	20.0	n	o
Parthenocissus quinquefolia	3	20.0	n	o
Prunus cerasifera	3	20.0	n	e
Ribes uva-crispa	3	20.0	n	e
Sempervivum tectorum	3	20.0	c	o
Bellis perennis	2	13.3	n	o
Hylotelephium spectabile	2	13.3	c	o
Physalis alkekengi	2	13.3	n	o

Species	Number of records	Frequency (%)	Naturalisation	Mean of introduction
Populus balsamifera	2	13.3	n	e
Robinia pseudoacacia	2	13.3	n	o
Sambucus racemosa	2	13.3	n	e
Sarothamnus scoparius	2	13.3	n	e
Acer pseudoplatanus	1	6.7	n	e
Amaranthus blitum	1	6.7	n	a
Amaranthus retroflexus	1	6.7	n	a
Anethum graveolens	1	6.7	c	e
Aster novi-belgii	1	6.7	n	o
Bergenia crassifolia	1	6.7	c	o
Brunnera macrophylla	1	6.7	c	o
Cannabis sativa	1	6.7	c	e
Caragana arborescens	1	6.7	n	o
Caragana fruex	1	6.7	n	o
Elsholtzia ciliata	1	6.7	n	e
Euphorbia peplus	1	6.7	n	a
Fragaria moschata	1	6.7	n	e
Gaillardia pulchella	1	6.7	c	o
Geranium sibiricum	1	6.7	n	a
Hesperis matronalis	1	6.7	n	o
Impatiens glandulifera	1	6.7	n	o
Kochia scoparia	1	6.7	c	o
Lepidium densiflorum	1	6.7	n	a
Ligustrum vulgare	1	6.7	n	o
Populus alba	1	6.7	n	e
Portulaca oleracea	1	6.7	n	e
Quercus rubra	1	6.7	n	e
Sagina saginoides	1	6.7	c	o
Sedum stoloniferum	1	6.7	c	o
Senecio vernalis	1	6.7	n	a
Solidago serotinoides	1	6.7	n	o
Spiraea alba	1	6.7	n	o
Veronica filiformis	1	6.7	n	o

The analysis of the frequency of alien species registered in the vicinity of 15 cemeteries revealed a group of species that occur in majority of the investigated areas (Table 1). The group of the most frequent species include: *Saponaria officinalis*, *Conyza canadensis*, *Sedum spurium* (frequency – 86.7%), *Dianthus barbatus* (80.0%), *Euphorbia cyparissias*, *Syringa vulgaris* (73.3%), *Asparagus officinalis* (60.0%), *Matricaria discoidea*, and *Phalacroloma septentrionale* (53.3%). All these species (except *Conyza canadensis* and *Matricaria discoidea*) are the oldest ornamental plants in Lithuania. *Conyza canadensis* is a widespread alien species which easily invades various types of habitats with destroyed or slightly disturbed exsisting plant cover. The group of alien species with low frequency, i.e., recorded in the vicinity of one cemetery (29 species), is diverse both from the point of view of immigration and naturalisation (Table 1).

Eleven species registered in the vicinity of the investigated cemeteries in Lithuania are considered as accidental immigrants (e. g., *Amaranthus retroflexus*, *Conyza canadensis*, *Galinsoga parviflora*, *Galinsoga quadriradiata*, *Impatiens parviflora*, *Lepidium densiflorum*, etc.). The other 60 registered species belong to the group of escaped cultivated plants (Table 1). Though majority of escaped species (43) belong to the group of ornamentals, 17 of them are, or formerly were, cultivated for various other purposes (e. g., *Anethum graveolens*, *Armoracia rusticana*, *Cannabis sativa*, *Elsholtzia ciliata*, *Matricaria discoidea*, *Portulaca oleracea*, etc.). *Populus balsamifera* and *Populus alba* might have been used formerly for the delimitation of cemetery grounds from the neighbouring areas or were planted as solitary trees and became naturalised.

Among 71 species registered in the vicinity of 15 investigated cemeteries, as many as 60 species are considered as naturalised to Lithuania and 11 species are ascribed to the group of casuals (Table 1). Cultivated ornamental species, compared with accidentally introduced aliens, become naturalised much easier in a new environment because the first stages of their adaptation take place under human care (Kornas 1990; Kowarik 1995). Ornamental species in the surrounding areas of all investigated cemeteries comprise major part of the registered alien species or are prevailing (Table 2). It should be noted that in cemeteries plants, resistant to various environmental factors (drought, shade, infertile soil, etc.), are cultivated intentionally and these biological peculiarities facilitate their naturalisation. A long period of plant usage for ornamental purposes also influences the degree of their naturalisation. A significant part of the most common naturalised species comprises ornamentals that have been cultivated in Lithuania for centuries, and they are among the most popular cemetery plants.

The group of ornamental species is very diverse, and the fate of these escaped plants depends on many factors, such as biological characteristics (life form, reproduction) of species, diversity and the state of habitats around the cemetery, area management, etc.

The majority of alien plants in the vicinity of cemeteries come from places of cultivation, i.e., graves, under the influence of various human activities. The primary and most important factor is the disposal of waste during the management of the cemetery (withered or removed flowers, uprooted plants, or cut vegetative parts). Plant remnants and other waste from cemeteries of the small villages and settlements are usually thrown into specially dug pits or dumped into heaps or, sometimes, simply outside the territory of the cemetery. Although at the cemeteries of larger villages and cities special containers for waste are available, small amounts of plant remnants are still being thrown into surrounding areas near to the cemetery (plants and their parts are usually called «ecologically clean waste»). Such an approach to waste disposal facilitates the dispersal of ornamental plants into the surrounding vicinity of the cemeteries or even into natural and semi natural habitats. Certainly, a part of the plants die, but some of them successfully take roots or germinate from the seeds and are able to compete with the native species.

Table 2

Summary table of the level of naturalisation and means of introduction of alien species recorded in the vicinity of 15 analysed cemeteries

Abbreviations: a – accidentally introduced species; e – escaped not ornamental species; o – escaped ornamental species; n – naturalised species; c – casual species)

Cemeteries and burial grounds	Number of species					
	Total	**n**	**c**	**o**	**a**	**e**
Balingradas	14	14	0	10	4	0
Bitėnai	15	15	0	11	1	3
Gegužinė (new)	26	23	3	13	6	4
Gegužinė (old)	15	15	0	8	5	2
Kaltanėnai	14	14	0	9	4	1
Karkažiškės	19	18	1	10	6	3
Labanoras (new)	20	17	3	17	1	2
Labanoras (old)	22	21	1	14	2	5
Netiesos	8	8	0	7	1	0
Plateliai	17	13	4	12	3	2
Sariai	22	20	2	13	4	5
Viešvilė	25	24	1	15	3	7
Žagarė (Catholic)	21	19	2	15	2	4
Žagarė (Lutheran)	22	22	0	17	1	4
Žagarė (Old Believers)	7	7	0	7	0	0

The most interesting group of plants recorded around cemeteries comprises species of the *Crassulaceae* family. Various *Sedum* species are highly valued as ornamental plants in cemeteries because they do not require constant care, are strongly adaptable. Plants of the *Sedum* genus are among the most abundant aliens in the vicinities of the investigated cemeteries. Similar occurrences were noted in vicinities of cemeteries in the surrounding areas of Aukštadvaris (Trakai district, Lithuania) (Gudžinskas 1994a) and in Latvia (Laiviņš, Jermacāne 2000).

Even if small portions of the *Sedum* plants are tossed out they easily take root. Management of surrounding areas of cemeteries, especially mowing of grasslands, accelerates the spreading over a relatively large area and considerable distances from the cemetery. In the vicinity of the cemeteries the most frequent and abundant are *Sedum spurium*, *S. rupestre*, and *S. album*. Somewhat less frequent are *S. pallidum* and *S. hispanicum*. The observations of ornamental plants cultivated with the graves sites revealed much a larger diversity of *Sedum* species, thus, their spreading outside cemeteries and naturalisation are expected. Species of the *Hylotelephium* and *Sempervivum* genera are also frequently cultivated for ornamental purposes in cemeteries, but they are much rarer compare to *Sedum* species.

It should be noted that in the vicinity of cemeteries *Sedum sexangulare* and *Jovibarba globifera* are very frequent, however, as the range of their natural distribution includes certain parts of Lithuania (Gudžinskas 1996, 1999) these species are not considered as aliens in Lithuania and were not included in this analysis. Nevertheless, they are widely cultivated in cemeteries, and in most cases within the vicinities of the cemeteries they occur outside their native range.

Natural seed dispersal also plays an important role in the formation of alien species diversity in the vicinity of cemeteries. Many of the *Asteraceae* species, which are popular in cemeteries as ornamental plants, have also been adapted for seed dispersal through wind and frequently escape into the surrounding environment.

Among the accidentally introduced species in to the vicinity of cemeteries naturalised species also prevail. This fact indicates that cemeteries and their surrounding areas are not the primary centres of their immigration.

The propagation of accidentally introduced alien species immigrate primarily from the cemeteries and their vicinities with soil brought from other localities for grave maintenance. This group includes mainly weeds of arable lands, e. g., *Amaranthus retroflexus*, *Galinsoga parviflora*, *G. quadriradiata*, etc. Some weed species are being introduced with the seedlings of ornamental plants from nurseries, e. g., *Amaranthus blitum*, etc. Some escaped species found in vicinities of cemeteries are not cultivated for ornamental purposes there, and their occurrence in these areas can be related with human activities associated with cemetery management, or they can spread and settle here under the influence of natural factors.

Time-dependent development of species diversity

The formation of the alien flora in the vicinity of a new cemetery was studied in Plateliai (Plungė district, North-West Lithuania). The new cemetery of Plateliai was opened in December 1989 (Milius 1999). It is situated on top of a hill in a vicinity of the settlement. The burial ground is surrounded by a fence. The south-western and south-eastern edges of the cemetery coincide with the edge of the hill slope, whereas the north-western edge goes through formerly cultivated meadow. The north-eastern edge of the cemetery stretches along the wooded slope of a stream. On the slope of the hill in sandy and gravely soil xerothermic grasslands are being formed in the place of sown meadow. The grasslands of the hill slopes are permanently mowed. Graves in the cemetery are managed traditionally, i. e., they are abundantly decorated with various ornamental plants.

The first investigation on alien species in the vicinity of Plateliai cemetery was conducted in 1995 and later in 1997 and 2002 were repeated. In the first year of the investigation about a quarter of the area designated for burial ground was used with wide open free spaces on all sides of the cemetery were remaining. In 2002 a major part of the burial ground had been occupied by graves.

During the investigation in the vicinity of the cemetery in 1995, four alien plant species were recorded (Table 3). Three of them (*Conyza canadensis*, *Matricaria discoidea*, and *Senecio vernalis*) are widely distributed alien species and are not directly related to the cemeteries. Thus, they might have occured in this area before the establishment of this cemetery. It was also recorded that solitary individuals of *Cerastium tomentosum* had clearly escaped from the cemetery.

Table 3

Changes of the diversity of alien plant species in the vicinity of Plateliai cemetery during 1995–2002

No.	Species	Years		
		1995	1997	2002
1.	*Cerastium tomentosum*	+	+	+
2.	*Conyza canadensis*	+	+	+
3.	*Matricaria discoidea*	+	+	+
4.	*Senecio vernalis*	+	+	+
5.	*Bellis perennis*	.	+	+
6.	*Dianthus barbatus*	.	+	+
7.	*Hylotelephium spectabile*	.	+	+
8.	*Sagina saginoides*	.	+	+
9.	*Sedum pallidum*	.	+	+
10.	*Sedum spurium*	.	+	+
11.	*Oxalis stricta*	.	.	+
12.	*Prunus cerasifera*	.	.	+
13.	*Rudbeckia hirta*	.	.	+
14.	*Sedum album*	.	.	+
15.	*Sedum stoloniferum*	.	.	+
16.	*Sempervivum tectorum*	.	.	+
17.	*Vinca minor*	.	.	+
	Number of species	4	10	17

Since 1995, the number of alien species in the vicinity of the cemetery increased by six species and all of them were ornamental plants, also cultivated on the graves. During the next 5 years (1997–2002) the number of aliens increased by 7 species. Only one of them, *Prunus cerasifera*, is not cultivated in the cemetery and might have been introduced by humans or by birds accidentally.

Surprisingly, not one of the species recorded in 1995 and 1997 became extinct until 2002. This fact is explained by the establishment or naturalisation of alien plants and the constant propagation from the cemetery to it's surrounding vicinities. In a longer time-span changes in the composition of alien species, especially of the non-established, will certainly take place. Some of them will become extinct, whereas others (established) can remain and spread not only in the vicinity of the cemetery, but over significant areas.

Alien species in the vicinity of cemeteries of different confessions

In Žagarė (North Lithuania, Joniškis district) vicinities of cemeteries and burial grounds of five confessions (Lutheran and Catholic cemeteries and burial grounds of the Old Believers, Jews, and Seculars) were investigated. In vicinities of these burial areas 33 alien plant species were registered (Table 4).

In the vicinities of the Lutheran and Catholic cemeteries alien species numbers (22 and 21 respectively) are rather similar, whereas around burial grounds of other confessions they are much lower (Table 4).

Table 4

Diversity of alien plant species in the vicinities of cemeteries of different confessions in Žagarė

No.	Species	Confession			
		Lutheran	Catholic	Old Believers	Seculars
1.	*Asparagus officinalis*	+	+	+	+
2.	*Cerastium tomentosum*	+	+	+	+
3.	*Euphorbia cyparissias*	+	+	+	+
4.	*Saponaria officinalis*	+	+	+	+
5.	*Sedum spurium*	+	+	+	.
6.	*Syringa vulgaris*	+	+	+	.
7.	*Conyza canadensis*	+	+	.	.
8.	*Dianthus barbatus*	+	+	.	.
9.	*Sedum album*	+	+	.	.
10.	*Sedum hispanicum*	+	+	.	.
11.	*Sedum rupestre*	+	+	.	.
12.	*Vinca minor*	+	+	.	.
13.	*Amelanchier spicata*	+	.	.	.
14.	*Anethum graveolens*	.	+	.	.
15.	*Armoracia rusticana*	+	.	.	.
16.	*Bellis perennis*	.	+	.	.
17.	*Caragana arborescens*	+	.	.	.
18.	*Caragana frutex*	+	.	.	.
19.	*Helianthus tuberosus*	.	+	.	.
20.	*Hemerocallis fulva*	+	.	.	.
21.	*Hesperis matronalis*	.	+	.	.
22.	*Ligustrum vulgare*	.	+	.	.
23.	*Lupinus polyphyllus*	.	+	.	.
24.	*Matricaria discoidea*	+	.	.	.
25.	*Oxalis stricta*	.	+	.	.
26.	*Parthenocissus quinquefolia*	+	.	.	.
27.	*Robinia pseudoacacia*	+	.	.	.
28.	*Sambucus racemosa*	+	.	.	.
29.	*Spiraea chamaedryfolia*	.	.	+	.
30.	*Symphoricarpos albus*	+	.	.	.
31.	*Viola ×wittrockiana*	.	+	.	.
	Number of species	22	20	7	4

At the Jewish burial ground (not included in the table) two alien species were recorded. What factors have influenced such alien species diversity?

Nowadays all the territory surrounding the Jewish burial ground is occupied by meadow communities with solitary pine trees. Graves in the burial area are almost invisible and no tombstones are remaining. Traditionally, in Jewish cemeteries ornamental plants were not planted and this fact probably explains why naturalised ornamental species are absent both inside and outside the abandoned burial ground. Recorded alien species, i. e., *Conyza canadensis* and *Matricaria discoidea* are a common naturalised species and their existence in this area depends on the presence of disturbed soil patches and paths but not related with the traditions of grave site management.

Burial grounds of the Old Believers and the Seculars are located close to each other (separated only by field track), occupy small areas (ca. 0.4 and 0.2 ha, respectively), and with only a few graves (about a dozen) in each. Dry irregularly mown grasslands surround both burial grounds. Species diversity in the vicinities of these burial grounds is similar (C_J=0.57). All four species registered in the vicinity of the burial ground of the Seculars were also found in vicinities of the burial ground of the Old Believers. Such similarity can be influenced by the closeness of these cemeteries and, therefore, almost identical ecological conditions and similar area of burial grounds.

Diversity of alien species in the vicinities of the Lutheran and Catholic cemeteries tend to be much higher due to their size, similar management traditions, and various environmental conditions; however, species diversity is more heterogeneous (C_J=0.43). Around these cemeteries 13 common alien species were registered (Table 4). All species registered at the burial ground of the Seculars and seven species registered at the burial ground of the Old Believers also occurred in vicinities of the Lutheran and Catholic cemeteries.

Alien species, such as *Asparagus officinalis*, *Euphorbia cyparissias*, and *Saponaria officinalis* are among the oldest ornamental plants in Lithuania. Recently *Euphorbia cyparissias* and *Saponaria officinalis* are not (or almost not) cultivated in neither cemeteries, nor in gardens, and in the vicinities of cemeteries they have persisted for several decades or even centuries. *Sedum spurium* and *Cerastium tomentosum* are cultivated, probably, since the first half of the 20th century and are still popular as ornamental plants, especially in cemeteries. *Dianthus barbatus*, *Sedum album*, *S. hispanicum*, *S. rupestre*, and *Vinca minor* are also widely cultivated in cemeteries and are among the most frequent or moderately frequent escaped and naturalised species in the vicinities of cemeteries in Lithuania (Table 1).

It should be noted that all species common in the vicinities of the four analysed cemeteries (except Jewish) and burial grounds in Žagarė or those which were recorded both at the Lutheran and Catholic cemeteries are considered as naturalised. Only two alien species recorded in the vicinity of the investigated cemeteries and burial grounds should be ascribed to the group of casual species (*Anethum graveolens* and *Viola ×wittrockiana*). Thus, among all alien species recorded in vicinities of cemeteries in Žagarė casual species comprise only 1.3%.

Based on the analysis of a limited set of data, it is possible to suppose that the diversity of alien species in vicinity of cemeteries and burial grounds depends on the size and management traditions. However, in order to reveal the relationships between the diversity of alien species in the vicinity of cemeteries and burial grounds of different confessions further detailed studies should be carried out and a much wider set of data should be analysed.

Discussion

Ornamental plants in Lithuania and the neighbouring countries traditionally are extensively used for grave decoration and a large diversity of species are being cultivated in cemeteries. Frequently, each grave or family grave is distinct from the others by the peculiar ornamental plants used. Even small village cemeteries contain a large diversity of introduced ornamental plants and the type of grave decoration is slowly but constantly changing. Formerly, certain plants for grave ornamentation were used as symbols (Ibáñez Fernández 1993, Richter 1995), but now symbolic meaning of plants is less important, and their selection for grave decoration is mainly based on ornamental properties.

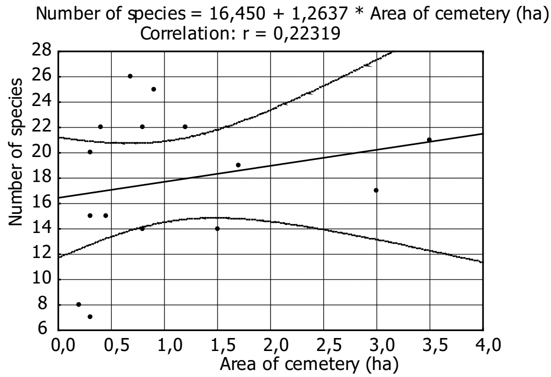
Plants cultivated in gardens, other ornamental plantations, and in cemeteries particularly, possess no danger to the environment until they remain in cultivation. However, any plant that has escaped from cultivation should not be neglected because this process can be the start of species naturalisation and future invasion (Pyšek et al., 2004). Therefore, the diversity and potential invasiveness of escaped ornamental plants should always be taken into account. The present research revealed a high diversity of alien species in the vicinity of cemeteries, thus, they should be considered as an important source of potentially invasive species.

The similarity of the diversity among alien species in the vicinity of the investigated cemeteries was evaluated employing the Jaccard coefficient (C_J). The coefficient of similarity between all pairs of cemeteries and burial grounds is rather low. The highest similarity was noted between the diversity of alien species registered in vicinity of the new and the old cemeteries of Labanoras (C_J=0.50; 14 common species), the old cemetery of Gegužinė and the cemetery of Karkažiškės (C_J=0.48; 11 common species), and between the vicinity of the old cemetery of Labanoras and the cemetery of Viešvilė (C_J=0.47; 15 common species). The lowest similarity was revealed between the diversity of alien species in the vicinity of Plateliai cemetery and the surrounding areas of burial ground of the Old Believers in Žagarė (C_J=0.09; 2 common species), between the vicinity of cemeteries of Kaltanėnai and Netiesos (C_J=0.10; 2 common species), Sariai and Netiesos (C_J=0.11; 3 common species), and between the surrounding areas of the new cemetery of Gegužinė and Bitėnai (C_J=0.11; 3 common species). A low coefficient of similarity can be explained by a different number of registered alien species. However, even between the vicinities of cemeteries with an equal number of alien species, the similarity is rather factual (e. g., in vicinities of both cemeteries in Kaltanėnai and Balingradas 14 species were registered, and 8 species were common; C_J=0.40).

The correlation of the cemetery area and the number of alien species in their vicinity is weak ($r=0.22$; $p<0.68$) (Fig. 2). Analysis of a much wider set of data can reveal different relationships between these parameters, but a strong correlation is not expected. The diversity of alien species depends on many factors. Some of the factors influencing the diversity of escaped plants are difficult to estimate and generalise, e. g. local habits of cemetery management, waste disposal practice, geographical features of a cemetery, etc. The diversity of alien species also depends on the state of the natural vegetation cover and the types of surrounding habitats, but it is the accidental factors that most significantly influence the diversity of alien species in the vicinity of cemeteries.

Figure 2

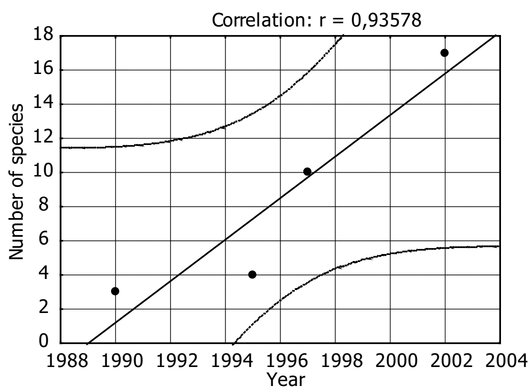
Bivariate correlation between the number of alien plant species in the vicinity of cemeteries and the area of the cemetery



Dot lines indicate limits of 95% confidence.

Figure 3

Bivariate correlation between the number of alien species and the age of Plateliai cemetery



Dot lines indicate limits of 95% confidence.

A case study on the dependence of how cemetery age affects the diversity of alien plant species in its vicinity enables to predict constant increase of the total number of species (Fig. 3) registered in the area. However, during a certain time-span the number of legitimately occurring species can remain more or less constant. Occurrence of the naturalised species only in the vicinity of closed cemetery in Gegužinė (Table 2) supports this presumption. In vicinities of functioning cemeteries casual species, unable to naturalise in certain conditions, become extinct and are replaced by new casual escaped ornamental plants that at a certain period become popular for grave decoration. Thus, it can be supposed that the diversity of alien species in the vicinity of a cemetery remains relatively constant and, if cemeteries are observed for a rather long time, alien plant diversity can reflect not only environmental conditions, but also processes in the society, such as changes of traditions and habits, cemetery culture, management practice, etc.

The present study did not attempt to give answers to all the questions concerning the diversity of alien species in the vicinity of cemeteries in Lithuania. The analysis of the results raised many new questions concerning the diversity of alien plants around such particular human made objects as cemeteries. Understanding of the processes undergoing in natural habitats and the mechanisms of alien species dispersal from cemeteries may facilitate the prevention of invasion of new alien species. This knowledge can also be employed for the creation of an environmental-friendly system of cemetery management.

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Kapsētu apkārtnes adventīvā flora Lietuvā

Kopsavilkums

Kapsētu vides un ekoloģiskiem pētījumiem līdz šim pievērsta nepietiekama uzmanība. Šajā rakstā apkopoti adventīvo augu sugu izpētes rezultāti 17 kapsētu apkārtnē dažādos Lietuvas reģionos. Analizēta adventīvo sugu daudzveidība atkarībā no kapsētas platības un vecuma, kā arī konfesijas. Rezultāti liecina, ka svešzemju floras veidošanos kapsētu apkaimē nosaka dažādi faktori – gan dabiski, gan sociāli. Lai noskaidrotu to ietekmi uz minēto procesu, nepieciešami papildu pētījumi.

Raksturvārdi: adventīvas sugas, augu invāzija, invazīvas sugas, naturalizācija, dekoratīvie augi, kapsētu apsaimniekošana.

38.–68. lpp.

Vegetation of pine forests on the Daugava riversides

Daugavas krastu priežu mežu veģetācija

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The pine forest vegetation has been researched along the Daugava River up to Krāslava as far as Ogre. 104 relevés were divided into 7 clusters by classification program TWINSPAN. 7 plant communities are described according to species composition: Association Vaccinio vitis-idaeo-Pinetum variant *Pulsatilla patens*, association Vaccinio vitis-idaeo-Pinetum variant *Polygonatum odoratum,* association Vaccinio myrtilli-Pinetum variant *Deschampsia flexuosa, Sorbus aucuparia-Pinus sylvestris* community, *Rubus saxatilis-Pinus sylvestris* community*, Agrimonia eupatoria-Pinus sylvestris* community, *Berberis vulgaris-Pinus sylvestris* community.
Keywords: pine, forest plant communities, Daugava River, TWINSPAN.

The lenght of the Daugava River in Latvia is 352 km. From Krāslava to Daugavpils the river valley is shaped into 8 big meanders. Pine forests grow on the banks in a 1–2 km wide zone. The largest forest zone is near Mežciems. Down from the Daugavpils on both sides of the Daugava River there are grasslands and other open areas, except some pine forest areas in the vicinity of Ilūkste. From Ilūkste to Jēkabpils other forest types are widespread. It is here where spruce, black alder and grey alder dominate. From Jēkabpils down the river calcareous forests and grasslands cover the bank, particulary on the left side. There are small forest areas on the right side which is more inhabited.

Investigated localities and methods

The investigations were carried out in pine forests on both riversides of the Daugava during 2001–2003 (Fig.1). There are 104 relevés on 13 localities described.

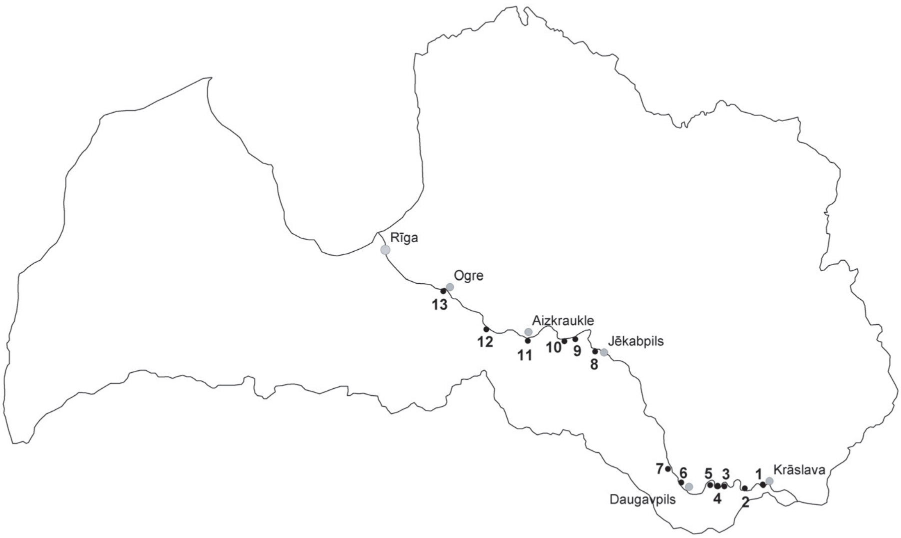
The method of Braun-Blanquet was used for vegetation description (Braun-Blanquet 1964, Dierschke 1994, Pakalne, Znotiņa 1992). The areas of relevés were 25–400 m^2.

The percentage of the cover of all species in 4 vegetation layers has been estimated: E3 – trees, E2 – shrubs and undergrowth, E1 – herbs and dwarf shrubs, tree seedlings and shrubs, E0 – mosses and lichens on soil.

An average age of pine stands, the aspects (N, NE, E, SE, S, SW, W, NW) and slope (degrees) have been carried out.

Figure 1

Investigated localities



1 – Krāslava, Dvorišče, Adamova, 2 – Tartaks, Borovka, 3 – Rozališķi, 4 – Butišķi, 5 – Elerne, 6 – Mežciems, 7 – Ilūkste, 8 – Jēkabpils, 9 – Sēlpils, 10 – Robežkrogs, 11 – Sērene, 12 – Taurkalne, 13 – Bekuciems

The data base was created in TURBO(VEG) (Hennekens 1995). The data has been grouped according to TWINSPAN (Hill 1979). The percentage of the cover was transformed to 6 grade scale: + (<1%), 1(1–5%), 2(6–25%), 3(26–50%), 4(51–75%), 5(76–100%). The constancy (I – 1–20%, II – 21–40%, III – 41–60%, IV – 61–80%, V – 81–100%) of all species in each group was estimated.

The syntaxonomy of plant communities was characterized according to the character species (Pott 1995; Dierβen 1996; Laiviņš 1998).

The satellite maps scale 1:50000, forest use maps 1:20000, orienteering maps scale 1:10000 and 1:15000 have been used. The nomenclature of species: Gavrilova, Šulcs 1999 (vascular plants); Āboliņa 2001 (mosses), Piterāns 2001 (macrolichens).

Results

The TWINSPAN divided the relevés into 7 clusters (Fig. 2). The first level divides 82 relevés with oligotrophic and mesotrophic species (*Calluna vulgaris, Vaccinium vitis-idaea, Convallaria majalis, Calamagrostis arundinacea*) from 22 relevés with eutrophic and calcareous species (*Agrimonia eupatoria, Galium album, Primula veris, Rhytidiadelphus triquetrus*). The next level divides 82 relevés into 5 clusters, characterised by a low number of species. The other 22 releves indicate high species diversity and are divided into 2 clusters by species composition in shrub layer.

Figure 2

TWINSPAN division of relevés

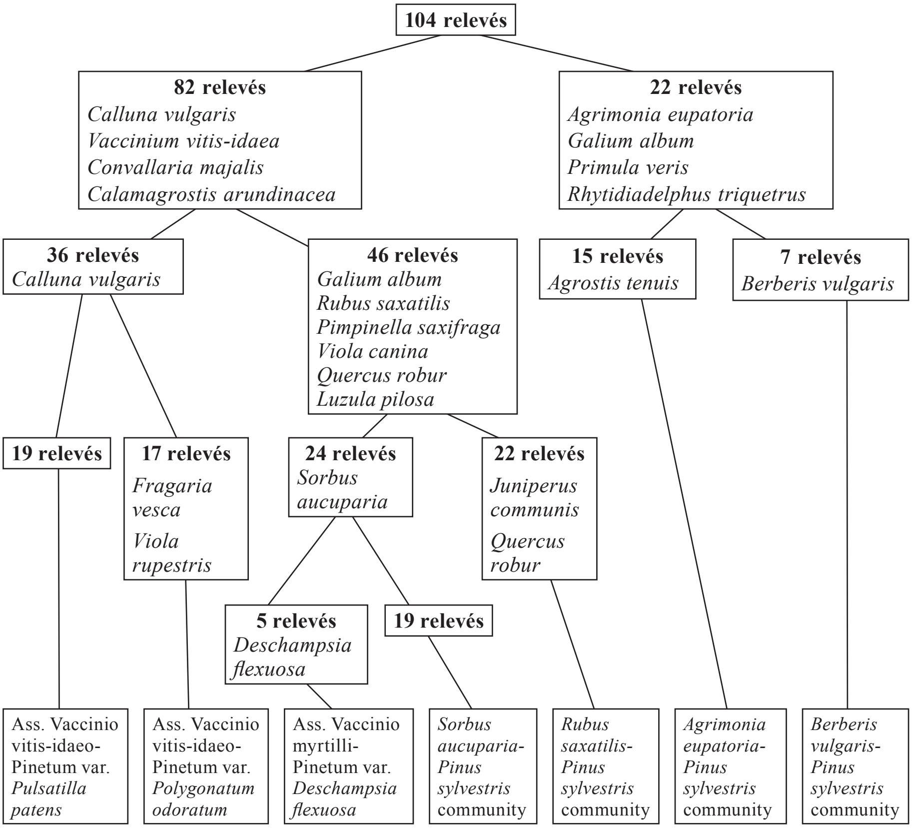


Table 1 shows the occurrence of the character species according to the associations and differential species of communities. The syntaxonomy of investigated communities:

Cl. Vaccinio-Piceetea Br.-Bl. 1939

O. Piceetalia abietis Pawl. ap Pawl. et al. 1928

All. Dicrano-Pinion Matusz. 1962 em. Oberd. 1979

1. Ass. Vaccinio vitis-idaeo-Pinetum Cajander 1921 var. *Pulsatilla patens*
2. Ass. Vaccinio vitis-idaeo-Pinetum Cajander 1921 var. *Polygonatum odoratum*
3. Ass. Vaccinio myrtilli-Pinetum (Kob. 1930) Br.-Bl. et Vliegler 1939 var. *Deschampsia flexuosa*
4. *Sorbus aucuparia-Pinus sylvestris* community
5. *Rubus saxatilis-Pinus sylvestris* community

   Cl. Pulsatillo-Pinetea (E. Schmid 1936) Oberd. in Oberd. et al. 1967

6. *Agrimonia eupatoria-Pinus sylvestris* community
7. *Berberis vulgaris-Pinus sylvestris* community

Table 1

Constancy of most distributed species

Plant communities:
1 – Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens*
2 – Ass. Vaccinio vitis-idaeo-Pinetum var. *Polygonatum odoratum*
3 – Ass. Vaccinio myrtilli-Pinetum var. *Deschampsia flexuosa*
4 – *Sorbus aucuparia-Pinus sylvestris* community
5 – *Rubus saxatilis-Pinus sylvestris* community
6 – *Agrimonia eupatoria-Pinus sylvestris* community
7 – *Berberis vulgaris-Pinus sylvestris* community

Species and layer	**Plant communities**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia							
Pinus sylvestris E3	V	V	5	V	V	V	V
Picea abies E2	IV	V	2	III	IV	IV	III
Juniperus communis E2	III	IV	1	II	V	V	V
Trientalis europaea E1	I	I	4	I	I	I	.
Pleurozium schreberi E0	V	IV	4	V	V	V	III
Dicranum polysetum E0	IV	II	1	III	I	I	.
Ptilium crista-castrensis E0	III	I	2	II	IV	II	I
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum							
Vaccinium vitis-idaea E1	V	V	3	IV	V	II	.
Festuca ovina E1	V	V		IV	IV	III	II
Solidago virgaurea E1	IV	III	3	II	II	II	V
Characteristic species of Ass. Vaccinio myrtilli-Pinetum							
Vaccinium myrtillus E1	IV	III	5	III	III	II	.
Hylocomium splendens E0	V	V	5	V	V	V	V
Differential species of plant communities							
Pulsatilla patens E1	IV	III	1	III	.	.	.
Polygonatum odoratum E1	II	IV	1	III	I	I	III
Deschampsia flexuosa E1	I	I	5	I	I	I	.
Sorbus aucuparia E2	III	II	5	V	II	III	III
Rubus saxatilis E1	II	II	3	IV	V	III	IV
Luzula pilosa E1	II	I	5	III	V	II	.
Agrimonia eupatoria E1	.	I	.	.	I	IV	III
Berberis vulgaris E2	.	.	.	I	.	I	V
Melica nutans E1	.	I	.	II	III	I	V
Primula veris E1	.	.	.	I	I	II	V
Carex digitata E1	.	.	.	.	I	II	V
Galium boreale E1	.	I	1	II	II	II	IV
Viola collina E1	.	.	.	I	I	II	IV
Viburnum opulus E1	.	I	.	.	.	I	IV
Melampyrum polonicum E1	.	I	.	I	I	I	IV

Species and layer	Plant communities						
	1	2	3	4	5	6	7
Other species							
Frangula alnus E2	II	II	5	IV	IV	IV	V
Quercus robur E2	I	II	5	II	IV	IV	V
Betula pendula E2	III	III	4	IV	III	III	I
Calluna vulgaris E1	V	V	3	II	III	.	.
Convallaria majalis E1	IV	V	5	IV	IV	.	III
Fragaria vesca E1	I	V	4	V	V	V	V
Melampyrum pratense E1	IV	IV	5	IV	III	.	I
Calamagrostis arundinacea E1	III	IV	3	III	IV	I	.
Knautia arvensis E1	.	III	.	IV	IV	V	V
Viola canina E1	I	III	2	V	V	III	.
Galium album E1	.	I	3	V	IV	V	V
Pimpinella saxifraga E1	I	II	1	V	IV	V	II
Agrostis tenuis E1	I	II	1	IV	IV	IV	.
Rhytidiadelphus triquetrus E0	.	III	.	I	I	IV	V

Composition of species of all investigated communities are shown in appendixes 1–7 but site parameters of relevés – in appendix 8.

Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens* (Appendix 1). These communities occupy flat surfaces and some where in sun-exposed southern, south-western and western slopes. There were 19 relevés were described in total. The majority of relevés were described north from Daugavpils – in Mežciems. 6 relevés were described on the Daugava's meanders. 3 relevés were described in the middle course of the Daugava River – Taurkalne, Robežkrogs. The age of pine stands is 40–110 years. The mean species number per relevé is 20.

Pinus sylvestris forms the tree layer, somewhere with *Betula pendula*. The tree layer cover is 25–60%, on average – 41%. 11 species are registered on shrub layer, most common is *Picea abies*. The shrub layer cover is 0-35%, on average – 7%.

The herb layer is species-poor, the average number of species per relevé is 12. The herb layer is formed by characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum (*Festuca ovina, Vaccinium vitis-idaea, Solidago virgaurea)*. The differential species of the community is *Pulsatilla patens.* The other species with high constancy are *Calluna vulgaris, Melampyrum pratense, Convallaria majalis. Pulsatilla patens, Diphasiastrum complanatum, D.tristachyum, Koeleria grandis, Platanthera bifolia* are rare and protected species. In total, 54 species are registered in herb layer. The average herb layer cover is 48%.

The moss layer is formed by *Pleurozium schreberi* and *Hylocomium splendens*, *Dicranum polysetum* was found as well. The average cover of moss layer is 85%. Total number of moss species is 8, of macrolichens – 8.

Ass. Vaccinio vitis-idaeo-Pinetum var. *Polygonatum odoratum* (Appendix 2). These communities occupy the south-eastern slopes and some were on flat surfaces. In total 17 relevés were described. The majority of relevés were on the left riverside in the middle course of Daugava in the vicinity of Taurkalne, some relevés were near Daugavpils (Ilūkste, Mežciems, Borovka). The age of pine stands is 40–100 years. The mean species number per relevé is 29.

Pinus sylvestris forms the tree layer. The cover of this layer is 20–50%, on average – 35%. 12 species are registered on a shrub layer. The most common are *Picea abies* and *Juniperus communis*. The shrub layer cover is 1–30%, on average – 13%.

The average number of species per relevé in herb layer is 21. The herb layer is formed by characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum (*Festuca ovina, Vaccinium vitis-idaea, Solidago virgaurea)*. The other species with high constancy are *Polygonatum odoratum, Calluna vulgaris, Melampyrum pratense, Convallaria majalis, Fragaria vesca, Calamagrostis arundinacea. Pulsatilla patens, Platanthera bifolia, Gypsophila fastigiata* are rare and protected species. In total, 81 species are registered in the herb layer. The average herb layer cover is 60%.

The moss layer is formed by *Pleurozium schreberi* and *Hylocomium splendens*, somewhere *Rhytidiadelphus triquetrus* as well. The average cover of moss layer is 79%. Total number of moss species is 9, of macrolichens – 2.

Ass. Vaccinio myrtilli-Pinetum var. *Deschampsia flexuosa* (Appendix 3). 5 relevés of this plant community were studied near Jēkabpils on flat surfaces only.

Pinus sylvestris of age 60–70 years forms the tree layer. The tree layer cover is 25–35%. 10 species are registered on shrub layer, most common are *Quercus robur, Sorbus aucuparia, Frangula alnus*. The shrub layer cover is 10–20%.

The average number of species per relevé in the herb layer is 20. In total, 46 species are registered in the herb layer. The herb layer is formed by characteristic species of Ass. Vaccinio myrtilli-Pinetum – *Vaccinium myrtillus* and other species (*Deschampsia flexuosa, Convallaria majalis, Melampyrum pratense, Luzula pilosa*). *Pulsatilla patens* and *Platanthera bifolia* are rare and protected species. The mean herb layer cover is 65%.

The moss layer is poor in species (5) but its cover is 65–90%. Most common moss species are *Hylocomium splendens* and *Pleurozium schreberi.*

***Sorbus aucuparia-Pinus sylvestris* community** (Appendix 4). 19 relevés were studied up from Krāslava to Daugavpils. These communities occupy flat surfaces and the southern and western slopes as well. The age of pine stands is 50–130 years.

The tree layer cover is 20–60%, on average – 43%. *Pinus sylvestris* forms this layer. 21 species are registered in the shrub layer. The most common are *Sorbus aucuparia, Frangula alnus, Betula pendula.* The cover of shrub species is 16% on average.

The average number of species per relevé in the herb layer is 20. In total, 89 species are registered in the herb layer. There is a high constancy of *Fragaria vesca, Galium album, Viola canina, Convallaria majalis, Rubus saxatilis, Melampyrum pratense, Pimpinella saxifraga, Vaccinium vitis-idaea, Agrostis tenuis, Festuca ovina, Knautia arvensis. Pulsatilla pratensis* and *Koeleria grandis* are rare and protected species.

8 species were found in the moss layer, the most common were *Hylocomium splendens* and *Pleurozium schreberi.*

Rubus saxatilis-Pinus sylvestris **community** (Appendix 5). These communities occupy flat surfaces on the Daugava meanders and the left riverside near Bekuciems and Taurkalne. 22 relevés were described. The age of pine stands is 40–100 years.

Pinus sylvestris forms the tree layer, somewhere with *Picea abies*. The tree layer cover is 20–60%, on average – 37%. 19 species are registered in shrub layer, most common are *Juniperus communis, Quercus robur, Frangula alnus, Picea abies.* The shrub layer cover is 5–30%.

The average number of species per relevé in the herb layer is 21. In total, 94 species are registered in the herb layer. The herb layer is formed by a characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum (*Vaccinium vitis-idaea, Festuca ovina).* Other species with a high degree of constancy are *Fragaria vesca, Luzula pilosa, Viola canina, Rubus saxatilis, Knautia arvensis, Convallaria majalis, Galium album, Calamagrostis arundinacea, Pimpinella saxifraga, Agrostis tenuis.* Some rare and protected plant species are mentioned: *Potentilla goldbachii, Helianthemum nummularium, Koeleria grandis, Trifolium alpestre, Peucedanum oreoselinum.*

7 species are registered in the moss layer. The most common are *Hylocomium splendens* and *Pleurozium schreberi,* somewhere *Ptilium crista-castrensis* as well.

Agrimonia eupatoria-Pinus sylvestris **community** (Appendix 6). 15 relevés were studied on flat surfaces, mostly in the vicinities of Sērene and Sēlpils. A separate relevé has been studied near Jēkabpils and Butišķi, too. The community is rich in species, 36 species per relevé have been found on average. These forests are formed on grasslands on dolomites with in a thin soil layer. The age of pine stands is 20–80 years.

Pinus sylvestris forms the tree layer. The tree layer cover is 20–70%, on average – 40%. 21 species are registered on shrub layer, the most common are *Juniperus communis, Frangula alnus, Quercus robur, Picea abies.* The mean shrub layer cover is 22%.

In total, 120 species are registered in the herb layer. The most common species are *Fragaria vesca, Knautia arvensis, Galium album, Pimpinella saxifraga, Agrimonia eupatoria, Agrostis tenuis.* The herb layer has signs of xerotermophilous calcareous grasslands of Cl.Festuco-Brometea – *Viola collina, Filipendula vulgaris, Helictotrichon pratense, Anemone sylvestris, Galium verum, Primula veris.* Some rare and protected plant species are registered – *Trifolium alpestre, Helianthemum nummularium, Peucedanum oreoselinum.*

In total, 13 moss species are registered, the most common are *Hylocomium splendens* and *Pleurozium schreberi,* somewhere *Rhytidiadelphus triquetrus* and *Rhytidiadelphus squarrosus* as well.

Berberis vulgaris–Pinus sylvestris **community** (Appendix 7). 7 relevés were on flat surfaces in the vicinities of Sēlpils and Rīteri. The age of pine stands is 50–70 years.

Pinus sylvestris forms the tree layer, somewhere with *Picea abies* or *Populus tremula*. The tree layer cover is 20–70%, on average – 38%. 25 species are registered in the shrub layer. The most common species are *Berberis vulgaris, Juniperus communis, Frangula alnus, Quercus robur.* The shrub layer cover is 20–40%.

In total, 67 species are registered in the herb layer. The most common are *Fragaria vesca, Knautia arvensis, Galium album, Primula veris, Carex digitata, Galium boreale, Solidago virgaurea, Viola collina, Melica nutans, Melampyrum polonicum, Viburnum opulus.* Calcareous rare and protected plant species are characteristic: *Prunella grandiflora, Peucedanum oreoselinum, Vincetoxicum hirundinaria, Anemone sylvestris.*

In total, 9 moss species are registered, the most common is *Rhytidiadelphus triquetrus. Hylocomium splendens* and *Pleurozium schreberi* are listed somewhere. The mean moss layer cover is 56% – it is the smaller of all investigated communities.

Discussion

Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens* on the Daugava riverside are similar to the ones on the hills and the hill chains of Eastern and Central Latvia described (Bambe 1999) – characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum with a high constancy are *Vaccinium vitis-idaea, Festuca ovina* and *Solidago virgaurea* but *Carex ericetorum* and macrolichens of genus *Cladina* are very rare.

The other variant of Ass. Vaccinio vitis-idaeo-Pinetum separates *Polygonatum odoratum*, besides *Thymus serpyllum, Viola rupestris, Viola canina, Knautia arvensis, Antennaria dioica, Rubus idaeus, Veronica spicata* are most common. The composition of species are at variance with Ass. Vaccinio vitis-idaeo-Pinetum var. typicum, *Festuca ovina* and *Pleurozium screberi* which have lower number of species (Laiviņš 1998, Bambe 1999, 2003).

Ass. Vaccinio myrtilli-Pinetum var. *Deschampsia flexuosa* is observed on the Daugava riverside only near Jēkabpils. *Quercus robur* is characteristic of these forests in the shrub layer. That variant is described on the islands of lakes in the Piejūra lowland (Laiviņš, Laiviņa 1988) but it differs with high constancy of *Pteridium aquilinum*.

According to the species composition there are two communities divided into the *Sorbus aucuparia-Pinus sylvestris* community and *Rubus saxatilis-Pinus sylvestris* community. These communities include characteristic species of both Ass. Vaccinio vitis-idaeo-Pinetum and Ass. Vaccinio myrtilli-Pinetum. According to the author, therefore they belong to All. Dicrano-Pinion.

Pine forests on dry calcareous soils in Sweden, Estonia and north-west of Russia are considered as Cl. Pulsatillo-Pinetea, O. Pulsatillo-Pinetalia, All. Cytiso ruthenici-Pinion Ass. Melico nutantis-Pinetum (Bjørndalen 1980, Dierβen 1996). The forests similiar to this association are described in Latvia on south-eastern slopes of Grebļukalns (Bambe 1999). Xerophytic pine forest communities of Cl. Pulsatillo-Pinetea are found in the Daugava and Abava river walleys (Laiviņš 2001). Two communities are described on calcareous soils of the Daugava riversides in the vicinities of Sērene, Sēlpils and Rīteri – *Agrimonia eupatoria-Pinus sylvestris* community and *Berberis vulgaris-Pinus sylvestris* community. Termophile species of pine forests and forest-rim communities occur here – *Brachypodium pinnatum, Vincetoxicum hirundinaria, Peucedanum oreoselinum, Anemone sylvestris, Geranium* *sanguineum, Filipendula vulgaris, Primula veris, Viola collina.* The presence of *Melica nutans* in *Berberis vulgaris-Pinus sylvestris* community make it possible to consider them as Ass. Melico nutantis-Pinetum but characteristic species (*Pyrola chlorantha, Diphasiastrum complanatum, Pulsatilla patens, Chimaphila umbellata, Carex ericetorum, Viola rupestris)* are short of class and order.

Plant communities on calcareous soils of the Daugava riversides occur on flat surfaces. They are described on middle course of the Daugava – up Jēkabpils to Sērene. The other plant communities are not so homogeneous, they occur both on flat surfaces and slopes, along the river up to Krāslava as far as Ogre. The age of pine stands is variable in all of the investigated communities.

Conclusions

1. The majority of forest plant communities of the Daugava riversides belong to Cl. Vaccinio-Piceetea, O. Piceetalia abietis, All. Dicrano-Pinion. The smallest number of species is characterised by Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens* – 20 species per relevé on average. 28–30 species per relevé are mentioned in other communities of All. Dicrano-Pinion.
2. The forests on calcareous soils – communities *Agrimonia eupatoria-Pinus sylvestris* and *Berberis vulgaris-Pinus sylvestris* – are characterised by a high diversity of species (in average 36-37 species per relevé) and signs of other vegetation classes – Festuco-Brometea, Trifolio-Geranietea, Pulsatillo-Pinetea.
3. Rare and protected plant species are mentioned in all of the investigated communities.
4. The ages of pine stands are variable in all of the investigated communities. It proves that these divided communities are not succesional stages.

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Appendix 1

Species composition of the Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens*

Nr. of relevé	330	420	458	459	390	402	451	142	143	396	397	398	399	400	401	410	413	469	463	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																				
Pleurozium schreberi E0	2	2	2	3	3	2	3	3	2	4	2	3	2	2	2	3	2	3	4	V
Dicranum polysetum	1	3	1	1	+	.	.	.	+	+	+	+	+	+	3	+	.	2	2	IV
Picea abies E2	.	+	.	+	1	1	+	1	1	1	1	1	2	2	1	.	.	+	1	IV
Picea abies E1	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Trientalis europaea	.	.	.	.	.	.	.	.	2	1	.	.	1	.	.	.	.	.	.	I
Orthilia secunda	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Goodyera repens	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Lycopodium annotinum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Pleurozium schreberi E0	2	2	2	3	3	2	3	3	2	4	2	3	2	2	2	3	2	3	4	V
Dicranum polysetum	1	3	1	1	+	.	.	.	+	+	+	+	+	+	3	+	.	2	2	IV
Ptilium crista-castrensis	.	.	.	.	+	.	1	.	.	.	+	+	2	2	3	.	2	1	.	III
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum																				
Festuca ovina E1	+	.	1	1	2	2	2	1	+	1	+	1	1	1	1	+	1	1	2	V
Vaccinium vitis-idaea	1	2	1	1	3	+	+	1	2	2	2	2	2	2	.	2	2	1	1	V
Solidago virgaurea	.	+	+	+	+	+	+	.	.	.	+	.	+	+	+	.	+	.	+	IV
Carex ericetorum	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Cladina arbuscula E0	1	+	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Cladina rangiferina	2	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	II
Cladina stellaris	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Characteristic species of Ass. Vaccinio myrtilli-Pinetum																				
Vaccinium myrtillus E1	+	.	.	+	2	1	.	3	1	2	.	.	2	.	2	2	2	2	.	IV
Hylocomium splendens E0	2	3	3	3	3	4	4	2	5	2	4	4	4	4	2	3	4	.	2	V
Other species																				
Betula pendula E3	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	1	I
Betula pendula E2	.	.	+	.	+	+	.	.	.	.	+	+	1	.	2	.	.	+	+	III
Betula pendula E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Sorbus aucuparia E2	.	+	.	.	.	.	+	+	1	.	.	+	1	+	+	1	.	.	.	III

Nr. of relevé	330	420	458	459	390	402	451	142	143	396	397	398	399	400	401	410	413	469	463	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																				
Sorbus aucuparia E1	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	I
Juniperus communis E2	.	.	1	1	1	3	1	.	.	.	.	.	.	.	.	1	2	.	2	III
Juniperus communis E1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Frangula alnus E2	.	.	.	.	+	.	.	.	1	1	.	1	+	+	.	.	.	+	.	II
Populus tremula E2	.	.	.	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.	+	II
Quercus robur E2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	I
Quercus robur E1	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Calluna vulgaris E1	2	2	1	1	+	+	1	1	1	1	2	2	.	2	2	1	1	1	1	V
Convallaria majalis	.	.	3	.	.	.	+	2	1	+	+	2	.	2	2	+	+	1	2	IV
Pulsatilla patens	.	.	+	1	.	.	.	+	1	+	+	+	+	+	.	+	+	+	+	IV
Melampyrum pratense	1	.	1	1	1	+	1	.	.	1	1	1	1	.	.	1	1	.	.	IV
Calamagrostis arundinacea	.	.	.	.	1	.	.	.	.	2	1	1	1	.	.	1	1	1	2	III
Hieracium umbellatum	.	.	+	+	.	+	.	+	+	+	+	.	.	+	.	+	.	.	.	III
Pinus sylvestris	+	+	.	.	.	.	.	.	.	+	.	+	.	+	+	+	.	.	+	III
Calamagrostis epigeios	.	+	+	+	.	1	.	+	+	.	.	.	.	+	.	.	.	.	.	II
Scorzonera humilis	.	.	+	+	.	.	.	+	.	+	+	.	.	.	+	.	.	1	.	II
Frangula alnus	.	.	.	.	+	.	.	.	.	+	.	+	+	.	+	.	.	.	.	II
Luzula pilosa	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	+	+	.	.	II
Polygonatum odoratum	.	.	.	.	+	+	.	.	.	+	.	.	.	.	+	.	.	.	+	II
Rubus saxatilis	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	+	+	.	1	II
Sieglingia decumbens	.	.	.	.	.	.	.	+	+	.	.	.	.	+	+	.	.	.	.	II
Arctostaphylos uva-ursi	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1	I
Diphasium complanatum	.	3	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	I
Polytrichum juniperinum E0	+	.	.	.	.	+	.	.	.	+	.	.	.	.	+	.	.	+	.	II

Rare species: E2: *Acer platanoides 1(399), Amelanchier spicata 1(451), Rubus idaeus +(451, 399)*

E1: *Acer platanoides +(451), Agrostis tenuis+(142), Antennaria dioica 1(458, 463), Astragalus arenarius +(402), Chimaphila umbellata 1(451), Corylus avellana +(459), Deschampsia flexuosa 1(410), Diphasium tristachyum 1(401), Dryopteris carthusiana +(451, 400), Fragaria vesca 1(413), Hepatica nobilis +(451), Hieracium vulgatum +(451), Koeleria grandis +(400, 401), Molinia caerulea (142), Mycelis muralis +(451), Pilosella officinarum 1(463), Pimpinella saxifraga +(413), Platanthera sp.+(390), Potentilla erecta +(142, 401), Pteridium aquilinum +(469), Rubus idaeus 1(451), +(399), Rumex acetosella +(463), Thymus serpyllum +(458, 402), Viola canina +(469)*

E0: *Cetraria islandica +(330, 458), Cladonia fimbriata +(330, 402), Aulacomnium palustre +(400), Cladonia cornuta +(458), Cladonia crispata +(330), Cladonia furcata +(330), Dicranum montanum +(463), Dicranum scoparium +(469)*

Appendix 2

Species composition of the Ass. Vaccinio vitis-idaeo-Pinetum var. *Polygonatum odoratum*

Nr. of relevé	328	329	394	385	393	486	387	388	389	391	392	414	146	147	148	418	416	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																		
Pinus sylvestris E3	3	2	3	2	3	3	3	2	3	3	3	3	3	3	3	2	3	V
Pinus sylvestris E1	+	+	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	II
Picea abies E3	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Picea abies E2	2	2	.	2	1	1	2	2	1	1	+	1	2	1	1	.	1	V
Picea abies E1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Orthilia secunda E1	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Goodyera repens	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	I
Trientalis europaea	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Pleurozium schreberi E0	2	2	2	.	.	2	2	.	2	.	.	2	2	4	2	3	2	IV
Dicranum polysetum	.	.	+	.	.	.	.	.	.	.	+	+	.	.	.	1	.	II
Ptilium crista-castrensis	2	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	I
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum																		
Festuca ovina E1	1	2	1	+	1	1	1	1	1	1	2	2	2	1	2	1	1	V
Vaccinium vitis-idaea	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	V
Solidago virgaurea	+	+	.	+	.	1	+	+	.	+	.	+	+	.	+	.	.	III
Carex ericetorum	.	.	1	.	+	.	+	+	+	.	.	+	.	.	.	.	.	II
Cladina arbuscula	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Characteristic species of Ass. Vaccinio myrtilli-Pinetum																		
Vaccinium myrtillus	.	.	.	.	.	1	.	.	2	1	1	.	2	+	.	2	.	III
Hylocomium splendens	3	2	3	4	4	4	3	5	5	5	4	5	4	2	4	3	4	V
Other species																		
Juniperus communis E2	1	1	3	2	2	1	1	2	2	2	2	.	.	.	.	2	.	IV
Betula pendula	.	.	.	.	.	+	.	+	+	.	.	1	1	.	.	1	1	III
Frangula alnus E2	.	.	.	.	.	.	+	.	+	+	+	1	.	.	.	1	.	II
Frangula alnus E1	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
Sorbus aucuparia E2	.	.	.	.	.	.	+	.	+	+	.	1	.	.	.	+	1	II
Sorbus aucuparia E1	.	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Rubus idaeus E2	.	.	.	.	.	.	.	+	+	.	+	.	+	.	.	.	+	II
Rubus idaeus E1	.	.	.	.	.	+	.	1	+	.	1	+	.	.	+	.	+	III
Populus tremula E2	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.	+	+	II
Quercus robur	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	+	II
Calluna vulgaris E1	1	1	1	2	1	2	2	1	1	1	1	1	2	1	1	1	1	V
Fragaria vesca	1	2	+	1	1	2	1	2	+	1	1	2	.	1	1	2	2	V
Convallaria majalis	1	.	1	2	3	2	2	+	2	2	3	+	1	.	2	1	.	V
Polygonatum odoratum	1	2	2	.	.	.	1	+	+	+	1	.	1	+	+	+	1	IV
Calamagrostis arundinacea	2	2	.	1	1	2	1	+	.	.	.	.	2	1	1	1	1	IV

Nr. of relevé	328	329	394	385	393	486	387	388	389	391	392	414	146	147	148	418	416	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																		
Melampyrum pratense	.	.	+	1	.	1	1	1	1	+	2	1	.	2	1	1	.	IV
Thymus serpyllum	1	1	1	1	+	.	.	+	1	.	.	.	.	1	1	1	.	III
Viola rupestris	1	1	+	.	+	.	+	+	.	+	.	.	+	.	.	+	+	III
Knautia arvensis	+	+	.	.	.	.	+	.	+	.	.	+	1	1	+	+	.	III
Antennaria dioica	1	1	1	.	.	.	1	+	.	.	.	.	1	1	.	+	.	III
Pulsatilla patens	1	1	1	.	+	.	.	.	.	.	.	.	.	1	1	+	1	III
Viola canina	.	.	+	.	+	.	+	+	+	+	+	+	.	.	.	.	.	III
Veronica spicata	1	1	+	.	+	.	.	+	+	.	.	.	.	.	.	.	+	III
Agrostis tenuis	.	.	.	.	.	.	.	+	+	+	+	+	1	.	.	.	.	II
Calamagrostis epigeios	.	.	.	.	.	.	.	.	+	1	+	1	.	1	.	+	.	II
Hieracium umbellatum	.	+	.	+	.	.	+	+	+	.	.	+	.	.	.	.	.	II
Sieglingia decumbens	.	.	.	.	.	.	.	+	+	.	.	.	1	+	2	+	.	II
Chimaphila umbellata	+	.	.	.	.	.	.	.	+	+	1	.	+	.	.	.	.	II
Pilosella officinarum	.	.	.	.	.	.	.	+	+	.	.	.	+	.	.	+	+	II
Arctostaphylos uva-ursi	.	1	1	.	.	1	.	.	.	.	.	1	.	.	.	.	.	II
Astragalus arenarius	+	.	.	.	.	.	.	.	+	+	.	+	.	.	.	.	.	II
Epipactis helleborine	.	.	.	.	.	.	+	+	+	.	.	+	.	.	.	.	.	II
Juniperus communis	+	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	II
Pimpinella saxifraga	.	+	.	.	.	.	.	+	.	.	.	+	.	.	.	+	.	II
Platanthera bifolia	.	.	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	II
Rubus saxatilis	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	1	2	II
Taraxacum officinale	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	II
Achillea millefolium	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	+	I
Campanula rotundifolia	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Galium album	.	.	.	.	.	.	.	+	.	.	.	1	.	+	.	.	.	I
Luzula pilosa	.	.	.	.	.	1	.	+	.	.	.	+	.	.	.	.	.	I
Melica nutans	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Rhytidiadelphus triquetrus E0	+	+	.	1	1	.	1	.	.	+	2	+	.	.	.	.	1	III
Aulacomnium palustre	+	.	.	+	.	1	.	.	.	.	+	.	.	.	.	1	.	II
Thuidium abietinum	2	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	I

Rare species: E2: *Amelanchier spicata +(389), Salix caprea +(486, 388), Acer platanoides +(393), Ulmus glabra +(388).* **E1:** *Acer platanoides +(391), Agrimonia eupatoria 1(416), Amelanchier spicata +(385), Anthoxanthum odoratum +(388), Artemisia vulgaris +(328, 329), Briza media +(329), Dactylis glomerata +(418), Deschampsia flexuosa 1(146, 418), Dianthus arenarius 1(394), +(393), Dianthus deltoides 1(329), Festuca trachyphylla +(146), Galium boreale +(418), 1(416), Geranium sanguineum 1(486), Geum rivale +(388), Gypsophila fastigiata (+(328, 393), Hypericum perforatum +(146, 147), Lathyrus sylvestris +(416), Melampyrum polonicum +(486), Mycelis muralis (392), Plantago lanceolata +(393), Plantago media +(416), Polygala vulgaris +(329), Potentilla arenaria 1(393), +(388), Prunella vulgaris +(329), Pulsatilla pratensis +(394), Pyrola chlorantha +(389, 392), Ranunculus acris +(393), Rumex acetosa +(418), Scorzonera humilis +(329, 385), Seseli libanotis 1(416), Succisa pratensis 1(486), Trifolium montanum +(416), Trommsdorfia maculata 1(147), Veronica chamaedrys +(393), Veronica officinalis +(146), Viburnum opulus +(387).* **E0:** *Cladonia furcata +(393, 387), Plagiomnium cuspidatum +(393), 1(416), Brachythecium oedipodium +(393)*

Appendix 3

Species composition of the Ass. Vaccinio myrtilli-Pinetum var. *Deschampsia flexuosa*

Nr. of relevé	346	341	343	344	345	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia						
Pinus sylvestris E3	2	3	3	3	3	5
Pinus sylvestris E1	+	.	.	.	.	1
Picea abies E3	.	.	+	.	.	1
Picea abies E2	1	1	.	.	.	2
Trientalis europaea E1	1	.	1	1	1	4
Goodyera repens	+	+	.	.	+	3
Pleurozium schreberi E0	3	.	2	2	2	4
Ptilium crista-castrensis	.	1	.	.	+	2
Dicranum polysetum	.	.	+	.	.	1
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum						
Vaccinium vitis-idaea	.	.	1	+	+	3
Solidago virgaurea	1	.	+	+	.	3
Characteristic species of Ass. Vaccinio myrtilli-Pinetum						
Vaccinium myrtillus E1	2	2	3	3	2	5
Hylocomium splendens E0	3	2	4	3	4	5
Other species						
Betula pendula E3	.	.	+	.	.	1
Sorbus aucuparia E2	1	1	+	1	1	5
Frangula alnus	+	1	+	+	1	5
Betula pendula	.	1	+	1	+	4
Quercus robur	2	2	2	2	2	5
Populus tremula	.	.	+	+	.	2
Convallaria majalis E1	+	1	1	1	1	5
Melampyrum pratense	1	+	1	1	1	5
Luzula pilosa	1	1	+	+	1	5
Deschampsia flexuosa	2	3	2	2	2	5
Fragaria vesca	1	.	1	+	+	4
Galium album	+	+	.	+	.	3
Rubus saxatilis	.	1	1	.	1	3
Calamagrostis arundinacea	.	2	1	.	1	3
Calluna vulgaris	1	.	+	1	.	3
Chamerion angustifolium	+	+	.	+	.	3
Sorbus aucuparia	+	.	+	.	+	3
Thymus serpyllum	+	.	+	+	.	3
Viola canina	+	.	+	.	.	2
Achillea millefolium	+	.	+	.	.	2

Nr. of relevé	346	341	343	344	345	Constancy
Trommsdorfia maculata	.	.	+	.	+	2
Scorzonera humilis	.	.	1	+	.	2
Quercus robur	+	.	+	.	.	2
Acer platanoides	+	+	.	.	.	2
Populus tremula	.	.	.	+	+	2
Pimpinella saxifraga	+	.	.	.	.	1
Aulacomnium palustre E0	+	.	2	.	1	3

Rare species:

E2: *Salix caprea +(343), Corylus avellana 1(343), Juniperus communis 1(346), Acer platanoides +(346)*

E1: *Agrostis tenuis +(345), Polygonatum odoratum +(343), Pulsatilla patens +(343), Veronica officinalis +(346), Calamagrostis epigeios 1(344), Galium boreale +(346), Pilosella officinarum +(346), Campanula rotundifolia +(343), Galium verum +(346), Taraxacum officinale +(341), Aegopodium podagraria +(346), Angelica sylvestris 1(341), Arctostaphylos uva-ursi +(344), Corylus avellana +(343), Grossularia reclinata +(341), Lycopodium clavatum +(346), Platanthera bifolia +(346), Poa nemoralis +(346), Tilia cordata +(346), Vaccinium uliginosum +(346)*

Appendix 4

Species composition of the S*orbus aucuparia–Pinus sylvestris* community

Nr. of relevé	144	145	415	417	395	419	456	460	139	140	141	421	423	467	468	138	407	455	466	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																				
Pinus sylvestris E3	4	3	3	3	3	3	3	3	3	4	3	2	2	3	3	3	3	4	4	V
Pinus sylvestris E2	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	I
Picea abies E3	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	I
Picea abies E2	.	1	2	.	.	1	.	+	.	1	.	+	.	1	1	1	.	1	1	III
Trientalis europaea E1	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	I
Pleurozium schreberi E0	4	.	1	3	.	2	3	2	4	4	4	3	3	3	3	3	2	3	4	V
Dicranum polysetum	+	1	.	+	1	+	1	.	.	1	+	+	.	.	.	.	.	2	.	III
Ptilium crista-castrensis	.	1	.	.	.	.	.	+	.	1	.	+	+	.	.	1	.	.	.	II
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum																				
Vaccinium vitis-idaea E1	.	1	.	1	1	.	2	2	1	1	.	2	2	.	1	2	1	1	1	IV
Festuca ovina	2	.	+	2	2	1	1	1	+	+	1	1	+	.	1	.	.	.	1	IV
Solidago virgaurea	.	+	.	.	.	.	.	1	.	.	.	.	+	+	.	.	.	+	1	II
Carex ericetorum	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Characteristic species of Ass. Vaccinio myrtilli-Pinetum																				
Vaccinium myrtillus E1	2	.	.	.	1	.	.	1	1	1	.	.	.	2	.	2	3	2	1	III
Hylocomium splendens E0	.	4	5	4	4	4	2	3	.	1	2	3	3	3	3	.	3	2	2	V
Other species																				
Betula pendula E3	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	I
Betula pendula E2	.	1	1	+	1	1	1	1	1	2	1	.	.	.	.	1	2	.	.	IV
Sorbus aucuparia E2	1	1	1	+	+	+	+	+	1	1	+	1	1	2	1	1	1	1	+	V
Sorbus aucuparia E1	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Frangula alnus E2	.	.	.	+	1	1	+	+	+	.	+	1	1	.	.	1	1	.	1	IV
Quercus robur E2	.	.	+	+	.	.	+	.	.	.	.	1	.	.	2	.	.	3	+	II
Quercus robur E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I

Nr. of relevé	144	145	415	417	395	419	456	460	139	140	141	421	423	467	468	138	407	455	466	Constancy
Rubus idaeus	+	.	+	+	1	.	.	+	+	.	.	.	.	.	.	1	.	.	.	II
Populus tremula	.	.	.	.	.	.	.	1	.	1	+	.	1	.	.	1	.	.	.	II
Salix caprea	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	1	1	1	.	II
Corylus avellana	.	.	.	.	.	.	.	.	.	.	.	+	2	.	1	.	+	.	.	II
Juniperus communis	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.	1	.	1	II
Acer platanoides	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	1	I
Amelanchier spicata	.	.	.	.	.	1	.	.	.	.	+	.	.	1	.	.	.	.	.	I
Fragaria vesca E1	1	2	2	2	1	2	2	2	1	.	1	1	1	.	2	2	1	2	2	V
Viola canina	+	1	+	1	1	+	+	+	1	.	.	+	+	+	+	+	+	+	+	V
Galium album	1	+	+	+	1	1	+	+	1	.	.	.	+	1	1	1	1	1	1	V
Pimpinella saxifraga	+	+	1	1	.	1	1	1	1	.	+	.	+	+	+	1	+	1	1	V
Rubus saxatilis	.	2	2	1	.	.	2	2	2	3	1	2	2	2	2	2	2	2	.	IV
Agrostis tenuis	+	+	.	1	1	1	1	.	1	.	1	1	+	1	.	+	.	+	+	IV
Convallaria majalis	+	+	1	.	+	.	.	.	+	1	2	2	1	1	2	1	1	.	.	IV
Melampyrum pratense	1	1	1	1	.	.	.	1	1	.	2	2	1	.	1	.	1	1	.	IV
Knautia arvensis	1	2	1	1	.	1	.	1	1	.	+	.	.	.	.	1	+	1	+	IV
Calamagrostis arundinacea	.	.	1	.	.	.	.	.	.	1	1	1	2	1	2	1	2	2	1	III
Luzula pilosa	+	.	.	.	.	.	+	.	+	1	+	.	.	1	+	+	.	.	1	III
Pteridium aquilinum	.	.	.	.	1	.	.	+	3	1	.	1	1	2	+	2	.	.	.	III
Polygonatum odoratum	1	+	.	.	.	.	.	+	+	.	.	+	.	+	+	.	.	+	.	III
Pulsatilla patens	2	+	2	.	.	.	.	.	+	+	1	.	+	.	.	+	.	.	.	III
Veronica officinalis	.	.	.	.	+	.	.	.	.	.	+	+	.	+	+	1	+	1	.	III
Calluna vulgaris	.	.	2	2	.	.	1	1	.	.	+	2	1	.	.	.	.	.	.	II
Geranium sanguineum	.	.	.	.	.	.	.	.	1	1	1	+	.	.	.	1	1	1	.	II
Calamagrostis epigeios	.	2	.	1	+	.	.	+	.	.	1	.	.	.	.	.	.	.	1	II
Sieglingia decumbens	.	1	+	1	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	II
Achillea millefolium	.	.	+	.	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	II
Trommsdorfia maculata	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	II
Galium boreale	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	1	1	.	.	II
Pilosella officinarum	.	.	.	1	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	II

Nr. of relevé	144	145	415	417	395	419	456	460	139	140	141	421	423	467	468	138	407	455	466	Constancy
Hypericum perforatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	II
Melica nutans	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	II
Potentilla erecta	.	.	.	.	.	.	.	.	.	.	+	.	+	1	.	+	.	.	.	II
Trifolium alpestre	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	+	+	.	II
Veronica chamaedrys	.	.	.	.	+	.	.	+	.	.	.	.	.	.	+	+	.	.	.	II
Scorzonera humilis	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	I
Antennaria dioica	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Dactylis glomerata	1	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Hepatica nobilis	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	I
Rubus idaeus	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Succisa pratensis	.	.	.	.	.	.	.	.	+	.	+	1	.	.	.	.	.	.	.	I
Viola rupestris	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I

Rare species:

E2: *Alnus incana 1(421), Berberis vulgaris 1(468), +(466), Cotoneaster lucidum +(417), Euonymus verrucosa +(455, 466), Lonicera xylosteum +(455), Padus avium 1(407), +(466), Rhamnus cathartica +(407), Viburnum opulus +(395, 460)*

E1: *Agrimonia eupatoria +(138, 466), Campanula glomerata +(139), Campanula rotundifolia +(417), Carex hirta +(407), Carex panicea +(395), Centaurea jacea +(138, 466), Centaurea scabiosa +(466), Chamerion angustifolium +(140, 421), Clinopodium vulgare +(467, 455), Deschampsia cespitosa +(395), Deschampsia flexuosa 1(419), +(141), Dryopteris carthusiana +(455), Equisetum arvense +(395), Galium verum +(417), Heracleum sibiricum +(407), Hieracium umbellatum +(140, 421), Koeleria grandis +(421), Lathyrus pratensis +(415, 466), Lathyrus sylvestris +(415), Linaria vulgaris +(415, 417), Melampyrum polonicum 1(467, 468), Moehringia trinervia 1(455), Molinia caerulea +(141), Oxalis acetosella +(468), Pinus sylvestris +(456), Plantago media 1(415), +(466), Poa pratensis +(138), Potentilla impolita +(419), Primula veris +(407), Prunella vulgaris +(415), Pulsatilla pratensis +(395), Ranunculus acris +(138), Rumex acetosa +(419), Silene nutans +(421, 468), Silene vulgaris +(419, 138), Taraxacum officinale +(395), Thymus serpyllum +(415, 141), Trifolium medium +(145), Trifolium montanum +(415), Trifolium pratense +(467), Valeriana officinalis +(395), Veronica spicata +415, 417), Vicia cracca +(419, 407), Viola collina +(467), 1(466), Viscaria vulgaris +(419)*

E0: *Aulacomnium palustre +(395, 423), Brachythecium oedipodium 1(466), Rhytidiadelphus triquetrus 1(138), Thuidium abietinum +(466)*

Appendix 5

Species composition of the *Rubus saxatilis–Pinus sylvestris* community

Nr. of relevé	269	270	271	272	276	422	483	484	485	487	488	386	403	404	405	406	412	461	273	274	275	457	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																							
Pinus sylvestris E3	3	3	3	2	3	2	3	3	3	3	3	2	3	4	3	3	3	3	3	3	3	3	V
Pinus sylvestris E2	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	3	.	.	.	I
Picea abies E3	.	.	+	+	.	2	.	+	.	2	1	.	.	.	.	1	+	.	.	.	.	.	II
Picea abies E2	1	1	1	1	.	2	1	1	1	1	1	2	.	.	.	.	2	2	.	1	1	1	IV
Picea abies E1	.	+	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Trientalis europaea E1	.	.	.	+	1	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Orthilia secunda	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I
Goodyera repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Pleurozium schreberi E0	2	2	2	2	2	2	3	2	2	2	1	.	1	2	2	2	1	2	2	2	2	2	V
Ptilium crista-castrensis	1	1	2	2	1	.	+	3	1	.	1	.	1	1	1	.	2	1	1	1	1	.	IV
Dicranum polysetum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	I
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum																							
Vaccinium vitis-idaea E1	2	2	2	2	2	1	2	1	2	1	2	1	2	2	1	2	1	+	2	2	2	2	V
Festuca ovina	.	.	+	1	+	+	1	1	1	1	.	1	1	1	.	.	1	1	1	+	2	1	IV
Solidago virgaurea	.	.	.	+	+	.	.	1	.	+	.	.	+	.	+	.	.	.	.	.	+	+	II
Carex ericetorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	I
Characteristic species of Ass. Vaccinio myrtilli-Pinetum																							
Vaccinium myrtillus E1	.	.	.	1	2	1	.	.	2	1	.	2	2	2	.	.	2	1	.	.	2	1	III
Hylocomium splendens E0	3	4	3	3	3	4	3	3	4	5	4	5	5	3	4	4	5	4	3	3	3	4	V
Other species																							
Betula pendula E3	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	I
Betula pendula E2	.	.	.	+	1	.	1	.	1	1	.	+	.	.	1	1	+	.	.	.	.	1	III
Betula pendula E1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Quercus robur E3	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Quercus robur E2	1	1	1	2	2	2	.	1	+	1	.	.	1	.	+	2	+	1	1	2	2	.	IV
Juniperus communis E2	2	1	1	1	1	.	1	1	1	1	1	+	+	2	2	1	2	1	2	1	2	1	V
Frangula alnus	1	1	1	.	1	.	1	.	.	.	1	.	+	2	.	+	+	+	1	.	1	1	IV

Nr. of relevé	269	270	271	272	276	422	483	484	485	487	488	386	403	404	405	406	412	461	273	274	275	457	Constancy
Rubus idaeus E2	.	.	.	.	.	+	1	.	.	.	.	1	.	+	.	.	.	.	1	.	.	+	II
Rubus idaeus E1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	1	1	+	II
Populus tremula	.	.	.	.	.	.	1	.	.	.	.	.	+	.	+	.	.	.	1	+	.	+	II
Sorbus aucuparia E2	.	.	.	.	.	+	+	.	.	1	.	1	+	.	.	.	.	+	.	.	.	.	II
Sorbus aucuparia E1	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Corylus avellana	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	1	+	.	+	.	.	.	II
Amelanchier spicata	.	1	.	.	.	+	.	.	.	.	.	2	.	.	1	.	.	.	.	.	1	.	II
Alnus incana	1	1	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Acer platanoides E2	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	I
Acer platanoides E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Salix caprea E2	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	.	.	I
Salix caprea E1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Luzula pilosa E1	.	+	1	1	1	.	1	1	1	+	1	+	+	1	+	+	+	1	1	1	1	1	V
Fragaria vesca	2	1	1	2	.	.	.	1	1	2	1	1	1	1	2	.	2	2	2	1	1	2	V
Viola canina	+	+	.	+	+	+	+	+	+	1	.	+	.	.	+	+	+	+	+	+	+	+	V
Rubus saxatilis	2	2	2	.	1	2	2	1	2	.	2	1	+	1	2	2	+	1	.	1	.	2	V
Galium album	+	+	+	.	+	+	.	.	+	.	+	1	1	1	1	1	1	+	.	+	+	1	IV
Convallaria majalis	1	1	2	1	1	1	2	2	2	3	.	1	1	.	1	1	+	.	+	.	.	.	IV
Knautia arvensis	.	1	1	1	1	+	1	.	.	.	.	+	+	+	.	1	1	+	1	1	1	.	IV
Calamagrostis arundinacea	2	2	1	2	2	2	1	2	2	2	2	2	.	1	2	.	.	.	.	1	.	.	IV
Pimpinella saxifraga	+	1	1	+	+	+	.	.	.	+	.	+	.	+	+	+	+	+	+	.	.	.	IV
Agrostis tenuis	1	1	1	.	1	+	.	.	.	.	.	.	1	1	1	1	.	+	1	1	1	1	IV
Calluna vulgaris	.	+	1	1	1	+	1	.	1	1	.	.	.	.	.	.	.	.	2	1	1	1	III
Potentilla erecta	1	1	1	.	1	1	.	+	+	+	1	.	.	.	+	+	.	.	.	1	.	.	III
Geranium sanguineum	2	2	2	2	.	1	2	+	+	.	+	+	+	.	.	.	.	.	.	.	.	.	III
Melampyrum pratense	.	.	.	.	.	1	.	+	1	+	.	.	1	1	1	1	1	1	.	.	.	.	III
Veronica chamaedrys	1	.	+	.	.	.	+	.	.	+	.	1	.	+	+	+	.	.	.	+	.	+	III
Veronica officinalis	.	+	+	.	1	.	1	.	1	+	.	.	+	+	.	.	.	.	+	+	.	.	III
Peucedanum oreoselinum	+	1	2	1	2	.	1	.	.	.	2	1	.	.	.	.	.	.	1	1	.	.	III
Melica nutans	1	1	1	1	.	.	.	.	.	.	.	+	.	1	.	+	.	1	1	.	.	.	III
Quercus robur	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	1	.	II
Frangula alnus	+	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	+	+	+	.	1	.	II

Nr. of relevé	269	270	271	272	276	422	483	484	485	487	488	386	403	404	405	406	412	461	273	274	275	457	Constancy
Galium boreale	+	.	.	1	.	.	.	.	.	.	.	.	.	+	+	1	.	.	1	.	.	.	II
Juniperus communis	+	.	.	.	+	.	+	.	.	.	.	.	+	.	.	.	.	.	1	.	.	+	II
Hieracium umbellatum	.	.	.	.	.	+	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	I
Hypericum perforatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	.	I
Mycelis muralis	.	.	.	.	+	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Trifolium alpestre	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	.	.	.	.	.	I
Pinus sylvestris	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	+	I
Succisa pratensis	1	1	.	.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	I
Thymus serpyllum	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	+	.	+	I
Achillea millefolium	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	I
Dryopteris carthusiana	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	+	.	.	.	I
Koeleria grandis	.	.	.	.	.	.	.	+	1	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Sieglingia decumbens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	I
Amelanchier spicata	.	.	.	.	.	.	.	.	.	+	.	1	+	.	.	.	.	.	.	.	.	.	I
Chimaphila umbellata	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I
Pteridium aquilinum	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3	1	.	.	.	.	.	.	I
Ranunculus acris	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I
Silene nutans	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	I
Veronica spicata	.	.	+	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Vicia cracca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	I
Aulacomnium palustre E0	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	I

Rare species:
E2: *Viburnum opulus 1(269), +(404), Rhamnus cathartica +(270, 404), Lonicera xylosteum 1(386), Malus sylvestris +(461), Cotoneaster lucidum +(274)*
E1: *Agrimonia eupatoria +(386, 461), Hepatica nobilis +(422), 1(404), Scorzonera humilis +(272, 422), Anthoxanthum odoratum +(273, 275), Campanula persicifolia +(269, 271), Filipendula vulgaris 1(406), +(274), Rumex acetosa +(276, 422), Trifolium medium +(276), 1(483), Dactylis glomerata +(406), Galium verum +(405), Carex digitata +(386), Geranium sylvaticum +(404), Melampyrum polonicum 1(272), Aegopodium podagraria 1(386), Agrostis gigantea +(461), Alchemilla sp. +(406), Anthriscus sylvestris +(406), Aquilegia vulgaris +(422), Carex hirta 1(461), Cerastium holosteoides +(403), Clinopodium vulgare 1(386), Deschampsia flexuosa +(412), Equisetum hyemale +(275), Helianthemum nummularium +(412), Lathyrus pratensis 1(461), Lathyrus sylvestris +(386), Leucanthemum vulgare +(406), Poa pratensis +(272), Polygonatum odoratum +(403), Populus tremula +(274), Potentilla goldbachii +(406), Primula veris 1(406), Prunella vulgaris +(274), Ranunculus polyanthemos +273), Stellaria longifolia +(276), Taraxacum officinale +(485), Veronica teucrium +(386), Vicia sepium +(461), Viola collina +(404), Viscaria vulgaris +(461)*
E0: *Rhytidiadelphus triquetrus 1(386, 274), Rhodobryum roseum 1(269)*

Appendix 6

Species composition of the *Agrimonia eupatoria–Pinus sylvestris* community

Nr. of relevé	342	411	444	480	481	352	353	443	446	445	447	448	449	355	441	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia																
Pinus sylvestris E3	2	3	3	3	4	3	3	3	2	3	3	3	3	2	4	V
Pinus sylvestris E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Picea abies E3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Picea abies E2	.	1	1	1	1	1	1	1	.	+	1	2	.	2	.	IV
Picea abies E1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	I
Orthilia secunda E1	.	.	.	+	.	1	+	+	.	1	.	+	1	.	.	III
Pyrola rotundifolia	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Trientalis europaea	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	I
Pleurozium schreberi E0	3	2	3	2	2	1	.	2	2	2	2	2	3	1	1	V
Ptilium crista-castrensis	.	+	.	+	.	.	.	.	.	1	.	.	.	+	.	II
Dicranum polysetum	.	.	+	.	.	.	.	.	.	1	.	+	.	.	.	I
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum																
Festuca ovina E1	.	.	2	.	.	+	+	+	.	1	1	1	1	1	.	III
Solidago virgaurea	.	+	.	.	.	.	1	.	.	+	.	+	.	.	+	II
Vaccinium vitis-idaea	.	.	1	.	.	.	.	2	2	.	1	2	.	.	.	II
Carex ericetorum	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Characteristic species of Ass. Vaccinio myrtilli-Pinetum																
Vaccinium myrtillus	3	.	.	+	.	.	.	3	1	.	.	.	.	.	.	II
Hylocomium splendens	2	3	2	2	3	3	4	3	4	4	4	5	3	4	2	V
Other species																
Betula pendula E3	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Betula pendula E2	.	.	+	.	.	.	1	1	1	+	1	1	1	+	.	III
Betula pendula E1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I

Nr. of relevé	342	411	444	480	481	352	353	443	446	445	447	448	449	355	441	Constancy
Acer platanoides E3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Acer platanoides E2	1	.	+	2	.	1	.	.	.	.	.	1	.	.	.	II
Acer platanoides E1	1	.	.	.	+	.	.	.	.	+	.	.	.	.	.	I
Juniperus communis E2	+	2	+	+	+	+	1	1	1	2	1	2	2	2	2	V
Juniperus communis E1	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	I
Frangula alnus	+	.	1	+	1	1	.	1	2	1	1	1	1	+	.	IV
Quercus robur E2	1	.	2	+	2	1	2	1	+	.	.	1	.	1	.	IV
Quercus robur E1	.	.	.	.	.	1	.	+	.	.	.	.	.	+	.	I
Populus tremula	.	.	.	.	.	.	+	1	+	1	1	+	.	+	.	III
Sorbus aucuparia E2	1	+	1	1	.	+	+	.	+	.	.	.	.	.	.	III
Corylus avellana E2	.	.	.	+	2	1	.	1	.	1	1	.	.	.	.	II
Corylus avellana E1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Lonicera xylosteum E2	.	.	.	+	.	+	+	+	+	.	.	.	.	.	.	II
Salix caprea	.	.	.	.	.	.	.	.	1	1	1	.	.	+	.	II
Rhamnus cathartica	.	.	.	.	.	.	.	.	+	.	+	.	.	.	+	I
Amelanchier spicata	.	.	1	.	1	.	.	.	.	.	.	.	+	.	.	I
Malus sylvestris	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Rubus idaeus E2	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Rubus idaeus E1	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	II
Knautia arvensis E1	1	+	1	1	1	+	1	1	+	1	1	1	1	+	1	V
Pimpinella saxifraga	+	+	1	+	+	1	1	+	1	1	1	1	1	1	1	V
Fragaria vesca	1	1	1	3	2	2	2	2	1	2	2	2	2	2	.	V
Galium album	1	2	1	1	1	1	1	1	1	1	.	1	1	1	1	V
Agrostis tenuis	+	+	1	1	1	+	+	.	+	1	.	1	1	.	.	IV
Agrimonia eupatoria	.	+	.	.	+	.	.	+	1	1	1	+	1	+	+	IV
Galium verum	.	.	+	.	+	+	.	+	+	+	+	.	1	.	+	III

Nr. of relevé	342	411	444	480	481	352	353	443	446	445	447	448	449	355	441	Constancy
Achillea millefolium	.	+	+	+	+	+	.	+	+	.	.	.	+	.	+	III
Rubus saxatilis	2	1	.	.	.	2	.	2	2	1	1	.	.	.	.	III
Helictotrichon pratense	.	.	+	.	.	.	.	.	2	1	2	2	1	.	+	III
Anemone sylvestris	.	.	.	.	.	+	.	.	1	1	.	+	+	1	**1**	III
Viola canina	+	+	+	+	1	.	+	+	.	.	.	.	.	.	.	III
Galium boreale	+	1	.	+	.	.	1	.	.	+	+	.	.	.	.	II
Filipendula vulgaris	.	.	+	.	.	.	.	.	+	+	+	.	1	.	1	II
Luzula pilosa	+	.	+	.	.	+	.	.	+	+	+	.	.	.	.	II
Primula veris	.	.	.	.	.	1	.	.	+	+	+	.	1	.	.	II
Carex digitata	.	.	+	.	.	.	.	.	.	1	+	1	.	+	.	II
Viola collina	.	.	.	.	.	.	.	.	+	+	1	+	+	.	.	II
Veronica chamaedrys	+	.	+	1	1	.	.	.	.	+	.	.	.	.	.	II
Leontodon hispidus	.	.	.	.	.	+	.	.	.	1	1	+	+	.	.	II
Plantago media	.	.	.	.	.	.	+	.	.	+	.	+	.	1	+	II
Vicia cracca	+	.	.	.	+	+	.	+	+	.	.	.	.	.	.	II
Dactylis glomerata	+	.	.	+	.	+	+	.	.	1	.	.	.	.	.	II
Pteridium aquilinum	2	2	.	.	.	.	.	.	.	.	2	1	.	+	.	II
Ranunculus polyanthemos	.	.	.	1	+	.	+	.	.	.	.	+	.	+	.	II
Frangula alnus	.	.	.	.	.	.	+	.	.	.	.	+	.	1	+	II
Taraxacum officinale	+	.	.	.	.	+	.	.	.	+	.	+	.	.	.	II
Medicago falcata	.	.	.	.	.	1	.	.	.	+	.	.	.	1	1	II
Veronica officinalis	1	1	1	.	+	.	.	.	.	.	.	.	.	.	.	II
Potentilla erecta	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	I
Prunella vulgaris	.	.	.	+	.	+	.	.	+	.	.	.	.	.	.	I
Calamagrostis arundinacea	1	2	.	.	.	.	+	.	.	.	.	.	.	.	.	I
Carex hirta	.	+	.	1	1	.	.	.	.	.	.	.	.	.	.	I

Nr. of relevé	342	411	444	480	481	352	353	443	446	445	447	448	449	355	441	Constancy
Centaurea scabiosa	.	.	.	.	.	.	.	.	.	+	.	.	1	.	2	I
Geum rivale	.	.	.	.	.	+	.	.	.	+	.	.	+	.	.	I
Ranunculus acris	+	.	+	.	.	.	.	.	+	.	.	.	.	.	.	I
Silene nutans	.	.	1	.	.	.	+	.	.	.	.	.	.	.	+	I
Thymus serpyllum	.	.	+	.	.	.	.	.	.	+	.	.	.	.	+	I
Rhytidiadelphus triquetrus E0	2	.	+	+	1	1	2	1	.	.	2	.	.	1	1	IV
Rhytidiadelphus squarrosus	+	.	.	3	1	3	.	.	.	.	.	.	2	.	3	II
Plagiomnium cuspidatum	+	.	.	+	.	.	.	.	+	.	.	.	.	.	3	II
Rhodobryum roseum	+	.	.	+	.	.	.	.	.	.	+	.	.	.	.	I

Rare species:

E2: *Berberis vulgaris 1(411), Viburnum opulus +(445), Padus avium 1(342), Tilia cordata 2(444), Ulmus glabra 2(352), Ulmus laevis +(342)*

E1: *Anthyllis arenaria +(441), Aquilegia vulgaris +(449), Brachypodium pinnatum +(355), Briza media +(441), Campanula glomerata +(441), Campanula persicifolia +(411, 355), Campanula rotundifolia +(447, 441), Carlina vulgaris +(441), Centaurea jacea 1(447), +(441), Cerastium arvense +(355), Chamerion angustifolium +(353), Chimaphila umbellata +(352, 353), Clinopodium vulgare +(449), Dactylorhiza incarnata +(446), Deschampsia cespitosa +(411), Deschampsia flexuosa 1(342), Dryopteris carthusiana +(480), Epipactis helleborine +(481), Equisetum hyemale 1(444), Festuca rubra 1(441), Fragaria viridis 3(441), Fraxinus excelsior +(353), Geranium robertianum +(481), Geranium sylvaticum +(411), Helianthemum nummularium +(444), Hepatica nobilis +(355), Heracleum sibiricum +(342), Hieracium vulgatum +(355), Hypericum maculatum +(411), Hypericum perforatum +(480), Leucanthemum vulgare +(481), Linaria vulgaris +(481), Lonicera xylosteum +(352), Melampyrum polonicum 1(444, 355), Melica nutans +(353, 449), Moehringia trinervia 1(481), Monotropa hypopitys +(441), Mycelis muralis +(481), Oxalis acetosella +(480), Padus avium +(352), Peucedanum oreoselinum +(355), Phleum pratense +(446), Poa angustifolia +(480), Poa compressa +(441), Poa nemoralis +(342), Poa pratensis +(446), Polygala vulgaris +(355), Polygonatum odoratum +(352), Populus tremula +(443), Rhamnus catharticus +(445), Rumex acetosa +(444), 1(481), Rumex acetosella +(441), Silene vulgaris +(441), Stachys sylvatica 1(411), Stellaria longifolia +(481), Thalictrum flavum +(441), Thymus ovatus +(352, 353), Trifolium alpestre +(411), Trifolium medium 1(443, 447), Trifolium montanum +(411), 1(441), Trifolium pratense (355, 441), Trifolium repens +(481), Viburnum opulus +(448), Vicia sepium +(342), Viola rupestris +(355)*

E0: *Brachythecium oedipodium 1(443), Cirriphyllum piliferum 1(480), Climacium dendroides +(480), Plagiomnium affine +(443, 447), Thuidium abietinum 1(342)*

Appendix 7

Species composition of the *Berberis vulgaris–Pinus sylvestris* community

Nr. of relevé	358	359	350	351	354	478	479	Constancy
Characteristic species of Cl. Vaccinio-Piceetea, O. Vaccinio-Piceetalia								
Pinus sylvestris E3	2	3	2	2	2	2	3	V
Pinus sylvestris E2	.	.	.	.	.	+	.	I
Pinus sylvestris E1	+	.	.	.	.	.	.	I
Picea abies E3	1	.	.	+	.	.	1	III
Picea abies E2	.	1	1	.	1	.	.	III
Picea abies E1	.	+	.	.	.	.	.	I
Orthilia secunda E1	+	.	+	.	.	.	1	III
Pleurozium schreberi E0	3	2	2	.	.	+	.	III
Ptilium crista-castrensis	1	.	.	.	.	.	.	I
Characteristic species of Ass. Vaccinio vitis-idaeo-Pinetum								
Solidago virgaurea	+	.	+	+	+	1	+	V
Festuca ovina	.	1	.	.	+	.	.	II
Characteristic species of Ass. Vaccinio myrtilli-Pinetum								
Hylocomium splendens E0	3	3	2	3	3	.	1	V
Other species								
Betula pendula E3	.	.	1	.	.	+	.	II
Betula pendula E2	.	.	1	.	.	.	.	I
Betula pendula E1	.	.	+	.	.	.	.	I
Populus tremula E3	.	.	.	.	.	3	2	II
Juniperus communis E2	1	2	+	+	1	+	+	V
Frangula alnus E2	1	1	1	3	2	2	1	V
Frangula alnus E1	+	.	.	+	.	.	+	III
Berberis vulgaris E2	2	2	+	1	+	1	2	V
Quercus robur	+	+	.	+	+	1	1	V
Populus tremula	+	+	+	.	+	.	.	III
Sorbus aucuparia	+	+	.	.	.	1	1	III
Lonicera xylosteum	1	.	.	.	+	1	1	III
Acer platanoides	.	.	.	.	.	1	2	II
Rhamnus cathartica	.	.	+	.	.	1	.	II
Malus sylvestris	.	.	.	+	.	1	.	II
Viburnum opulus E2	.	1	+	.	.	.	.	II
Viburnum opulus E1	+	.	+	+	.	+	+	IV
Alnus incana E2	.	.	1	.	+	.	.	II
Crataegus sp.	.	.	.	.	.	1	1	II
Euonymus verrucosa	.	.	.	.	.	+	1	II
Rosa sp.	+	.	.	.	.	.	+	II
Fragaria vesca E1	1	2	1	2	2	2	2	V
Primula veris	+	+	+	1	1	+	1	V
Knautia arvensis	+	1	.	+	+	+	+	V
Galium album	.	1	+	+	1	1	1	V
Carex digitata	+	1	+	+	.	1	1	V
Melica nutans	+	1	+	+	+	+	.	V

Nr. of relevé	358	359	350	351	354	478	479	Constancy
Rubus saxatilis	1	1	1	1	1	.	.	IV
Galium boreale	.	1	2	2	1	.	+	IV
Viola collina	1	.	+	+	.	1	2	IV
Melampyrum polonicum	2	1	+	1	+	.	.	IV
Agrimonia eupatoria	.	.	.	+	+	1	1	III
Convallaria majalis	.	+	1	.	+	1	.	III
Galium verum	+	+	.	.	+	.	.	III
Filipendula vulgaris	.	.	.	.	+	1	1	III
Veronica chamaedrys	.	.	.	.	+	+	+	III
Taraxacum officinale	+	.	.	+	+	.	.	III
Acer platanoides	.	+	.	.	.	+	+	III
Juniperus communis	+	+	.	+	.	.	.	III
Thymus ovatus	+	+	.	.	+	.	.	III
Brachypodium pinnatum	.	.	3	3	3	.	.	III
Hepatica nobilis	.	.	+	1	1	.	.	III
Peucedanum oreoselinum	.	.	+	.	.	1	+	**III**
Polygonatum odoratum	.	.	2	.	+	.	+	III
Geranium sanguineum	.	.	+	1	1	.	.	III
Pimpinella saxifraga	1	.	.	.	+	.	.	II
Helictotrichon pratense	1	2	.	.	.	.	.	II
Medicago falcata	.	+	.	.	+	.	.	II
Potentilla erecta	.	+	+	.	.	.	.	II
Clinopodium vulgare	.	.	+	+	.	.	.	II
Hypericum perforatum	.	.	.	.	+	.	+	II
Listera ovata	+	+	.	.	.	.	.	II
Prunella grandiflora	.	.	.	.	.	1	1	**II**
Stachys officinalis	.	.	.	+	+	.	.	II
Rhytidiadelphus triquetrus E0	2	3	2	3	1	2	2	V
Thuidium philibertii	.	.	.	.	.	+	+	II

Rare species:

E3: *Salix caprea 1(358), Tilia cordata +(478)*

E2: *Euonymus europaea +(478), Padus avium +(358), Ribes spicatum +(358), Rubus idaeus 1(478), Salix caprea 1(354), Tilia cordata 2(478), Ulmus glabra +(479)*

E1: *Achillea millefolium +(354), Anemone nemorosa +(350), Anemone sylvestris +(358), Astragalus glycyphyllos +(478), Campanula rotundifolia (+358), Carex vaginata 1(359), Chaerophyllum aromaticum +(358), Chamerion angustifolium +(358), Cirsium acaule +(359), Deschampsia cespitosa +(351), Festuca pratensis +(359), Fraxinus excelsior +(478), Leontodon hispidus +(358), Leucanthemum vulgare +(354), Maianthemum bifolium +(358), Melampyrum pratense +(359), Plantago lanceolata +(359), Plantago media 1(359), Poa angustifolia +(479), Prunella vulgaris +(354), Rhamnus catharticus +(354), Trifolium medium +(351), Trifolium montanum +(354), Veronica officinalis +(351), Vicia cracca +(351), Vincetoxicum hirundinaria +(478)*

E0: *Cirriphyllum piliferum +(478), Eurhynchium angustirete +(478), Fissidens osmundoides +(478), Hypnum cupressiforme +(478)*

Appendix 8

Site parameters of relevés

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Number of relevé	**Locality**	**Area of relevé, m^2**	**Aspect**	**Slope, degrees**	**Age of pine stands**	**Tree layer cover (%)**	**Shrub layer cover (%)**	**Herb layer cover (%)**	**Moss layer cover (%)**	**Total number of species**	**Number of species in tree layer**	**Number of species in shrub layer**	**Number of species in herb layer**	**Number of species in moss layer**
Ass. Vaccinio vitis-idaeo-Pinetum var. *Pulsatilla patens*														
330	Taurkalne	100	W	5	60	40	0	20	60	21	1	0	9	11
420	Adamova	400	S	2	90	25	1	65	80	16	1	4	7	6
458	Rozališķi	400	-	-	40	40	2	55	80	23	1	2	13	8
459	Rozališķi	200	-	-	65	50	1	20	85	20	1	2	12	5
390	Taurkalne	400	SE	15	70	25	2	70	90	21	2	4	11	4
402	Mežciems	400	NW	10	70	50	35	30	80	21	2	3	14	4
451	Robežkrogs	400	-	-	85	50	10	35	95	26	1	5	18	3
142	Mežciems	100	SW	2	100	35	3	70	75	22	1	4	16	2
143	Mežciems	25	-	-	80	60	8	40	90	19	1	4	12	3
396	Mežciems	400	E	1	100	40	3	45	95	21	1	3	15	4
397	Mežciems	400	-	-	90	35	3	35	90	19	1	2	12	4
398	Mežciems	400	-	-	90	40	2	65	90	17	1	4	10	4
399	Mežciems	400	-	-	75	45	10	50	90	19	1	6	10	4
400	Mežciems	400	-	-	70	45	10	55	95	21	1	3	14	5
401	Mežciems	400	-	-	70	30	10	60	80	22	1	4	13	5
410	Butišķi	400	-	-	110	50	5	35	90	18	1	2	13	3
413	Butišķi	400	-	-	95	30	25	50	90	19	1	2	13	3
469	Tartaks	400	S	15	90	55	1	35	80	19	1	3	10	5
463	Rozališķi	400	-	-	80	30	10	80	80	24	2	6	14	5
			Average		81	41	7	48	85	20	1	3	12	**5**
Ass. Vaccinio vitis-idaeo-Pinetum var. *Polygonatum odoratum*														
328	Taurkalne	100	E	20	60	30	20	40	70	32	1	2	23	6
329	Taurkalne	200	E	15	60	20	15	70	55	32	1	2	26	4
394	Taurkalne	400	SE	10	65	40	30	50	60	24	2	2	17	3
385	Taurkalne	400	-	-	70	30	25	50	85	24	2	3	16	4
393	Taurkalne	400	SE	10	50	30	15	50	75	30	1	3	20	6
486	Taurkalne	400	-	-	75	40	8	75	85	25	1	5	17	3
387	Taurkalne	400	SE	5	50	30	15	75	70	27	1	4	17	5
388	Taurkalne	200	-	-	80	25	20	45	90	39	1	7	30	1
389	Taurkalne	400	SE	10	50	35	10	60	90	36	1	7	26	2
391	Taurkalne	400	-	-	65	45	15	55	95	26	1	4	21	2
392	Taurkalne	400	SE	3	60	40	10	75	85	25	1	4	18	4
414	Ilūkste	400	-	-	70	35	10	50	90	31	1	4	22	4
146	Mežciems	100	-	-	50	40	10	85	85	26	1	4	20	2
147	Mežciems	25	S	2	60	50	1	48	81	24	1	1	19	3
148	Mežciems	25	S	3	40	45	1	75	70	19	1	1	15	2
418	Borovka	400	E	2	50	20	10	60	70	34	1	6	23	4

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
416	Ilūkste	400	-	-	100	40	10	50	90	31	1	6	21	4
			Average		62	35	13	60	79	29	1	4	21	**3**
Ass. Vaccinio myrtilli-Pinetum var. *Deschampsia flexuosa*														
346	Jēkabpils	400	-	-	65	25	10	65	65	36	1	6	30	3
341	Jēkabpils	400	-	-	70	30	20	65	90	22	1	5	14	2
343	Jēkabpils	400	-	-	60	30	10	65	90	33	3	7	23	4
344	Jēkabpils	400	-	-	70	35	15	70	70	24	1	5	17	2
345	Jēkabpils	400	-	-	60	35	20	60	70	23	1	4	15	4
			Average		65	31	15	65	77	28	1	5	20	**3**
***Sorbus aucuparia-Pinus sylvestris* community**														
144	Mežciems	25	S	5	80	60	1	70	60	20	1	2	15	2
145	Mežciems	100	-	-	100	45	5	60	70	25	1	3	19	3
415	Ilūkste	200	-	-	80	30	13	60	85	35	1	5	28	2
417	Ilūkste	400	-	-	80	35	1	65	95	29	1	6	20	3
395	Mežciems	400	W	2	50	30	6	45	95	29	1	5	20	3
419	Borovka	400	-	-	70	40	10	40	90	27	1	5	18	3
456	Elerne	400	-	-	110	40	5	55	70	22	1	7	13	3
460	Rozališķi	400	-	-	60	50	20	65	70	30	1	9	18	3
139	Mežciems	30	-	-	80	50	10	90	70	29	2	5	21	1
140	Mežciems	25	-	-	80	60	15	70	70	22	1	4	13	4
141	Mežciems	100	-	-	100	50	3	85	80	32	1	5	23	3
421	Adamova	400	W	2	110	20	20	85	70	32	1	7	20	4
423	Adamova	400	-	-	70	25	15	70	75	28	2	4	18	4
467	Krāslava	400	-	-	90	40	30	60	85	27	1	4	20	2
468	Krāslava	400	SW	15	90	40	30	70	80	27	1	5	19	2
138	Mežciems	100	-	-	80	40	20	85	50	37	1	7	26	3
407	Butišķi	400	-	-	110	50	30	70	60	32	1	8	21	2
455	Elerne	400	-	-	130	60	45	60	50	33	1	7	22	3
466	Dvorišče	200	-	-	100	55	30	50	85	37	1	8	25	4
			Average		88	43	16	66	74	29	1	6	20	**3**
***Rubus saxatilis – Pinus sylvestris* community**														
269	Bekuciems	100	-	-	90	40	20	80	50	29	1	7	20	4
270	Bekuciems	100	-	-	90	30	16	85	70	30	1	7	20	4
271	Bekuciems	100	-	-	80	30	8	85	70	28	2	4	20	3
272	Bekuciems	100	-	-	80	25	20	80	65	31	2	4	23	4
276	Bekuciems	100	-	-	60	50	15	70	75	34	1	7	25	3
422	Adamova	400	-	-	90	20	25	70	70	33	2	6	25	2
483	Taurkalne	400	-	-	40	40	15	80	80	29	2	7	18	3
484	Taurkalne	400	-	-	80	40	8	65	85	24	2	3	18	3
485	Taurkalne	400	-	-	70	45	5	85	90	26	1	4	20	3
487	Taurkalne	400	-	-	80	50	15	80	90	28	2	5	20	2
488	Taurkalne	400	-	-	85	40	15	45	85	17	2	3	10	3
386	Taurkalne	200	SE	5	70	20	30	50	85	35	2	7	26	2
403	Butišķi	400	-	-	70	35	5	60	90	29	1	6	20	3
404	Butišķi	400	-	-	90	60	30	50	70	30	1	7	21	3
405	Butišķi	400	-	-	60	50	20	85	70	29	2	6	19	3
406	Butišķi	400	-	-	70	40	30	65	80	35	2	5	26	2
412	Butišķi	400	-	-	90	30	20	45	95	29	2	6	20	3

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
461	Rozališķi	400	-	-	70	40	15	35	90	35	1	6	27	3
273	Bekuciems	50	-	-	50	30	26	80	60	29	1	7	22	3
274	Bekuciems	100	-	-	70	30	23	55	70	36	1	7	27	4
275	Bekuciems	100	-	-	80	40	20	65	75	26	1	5	18	4
457	Elerne	400	-	-	100	35	12	65	90	29	1	6	21	4
			Average		76	37	18	67	78	30	2	6	21	**3**
***Agrimonia eupatoria–Pinus sylvestris* community**														
342	Jēkabpils	400	-	-	75	30	10	65	70	39	3	8	23	7
411	Butišķi	400	-	-	60	45	20	60	70	31	1	5	22	3
444	Sērene	400	-	-	75	35	25	55	75	38	1	9	24	4
480	Sērene	400	-	-	70	45	25	55	60	38	1	9	20	9
481	Sērene	400	-	-	60	60	30	45	75	37	2	6	25	4
352	Sēlpils	400	-	-	70	40	20	50	90	40	1	9	28	4
353	Sēlpils	400	-	-	80	30	10	50	85	31	1	7	23	2
443	Sērene	400	-	-	55	40	25	75	65	30	1	8	18	5
446	Sērene	400	-	-	80	25	15	75	75	36	1	9	23	3
445	Sērene	400	-	-	55	40	30	55	90	43	1	8	30	4
447	Sērene	400	-	-	75	40	20	85	75	36	1	8	22	5
448	Sērene	400	-	-	70	45	30	70	90	32	1	7	23	3
449	Sērene	400	-	-	60	40	30	50	90	30	1	4	22	3
355	Sēlpils	400	-	-	90	20	20	30	70	37	1	7	28	4
441	Sērene	400	-	-	20	70	15	70	80	40	1	3	31	5
			Average		66	40	22	59	77	36	1	7	24	**4**
***Berberis vulgaris–Pinus sylvestris* community**														
358	Sēlpils	400	-	-	50	20	30	30	80	40	3	10	26	4
359	Sēlpils	400	-	-	70	40	40	50	85	37	1	8	26	3
350	Sēlpils	400	-	-	65	25	20	80	70	33	2	9	22	3
351	Sēlpils	200	-	-	70	25	35	70	85	32	2	5	25	2
354	Sēlpils	400	-	-	50	25	35	75	45	42	1	9	30	2
478	Rīteri	400	S	3	50	70	40	60	10	43	4	15	19	7
479	Rīteri	400	-	-	50	60	35	60	20	35	3	11	20	3
			Average		58	38	34	61	56	37	2	10	24	**3**

Daugavas krastu priežu mežu veģetācija

Kopsavilkums

Priežu mežu augu sabiedrības aprakstītas Daugavas krastos no Krāslavas līdz Ogrei. Ar TWINSPAN klasifikācijas programmas palīdzību 104 apraksti sadalīti 7 grupās. Aprakstītas 7 augu sabiedrības, kas atšķiras pēc sugu sastāva: asociācijas Vaccinio vitis-idaeo-Pinetum variants ar *Pulsatilla patens,* asociācijas Vaccinio vitis-idaeo-Pinetum variants ar *Polygonatum odoratum,* asociācijas Vaccinio myrtilli-Pinetum variants ar *Deschampsia flexuosa, Sorbus aucuparia-Pinus sylvestris* sabiedrība, *Rubus saxatilis-Pinus sylvestris* sabiedrība*, Agrimonia eupatoria-Pinus sylvestris* community, *Berberis vulgaris-Pinus sylvestris* sabiedrība.

Atslēgvārdi: priede, meža augu sabiedrības, Daugava, TWINSPAN.

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Diagnostic species of mesophylous and xerophylous grassland plant communities in Latvia
Mezofīto un kserofīto zālāju augu sabiedrību diagnostiskās sugas Latvijā

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Hitherto species defined as diagnostic for particular vegetation units in other European regions were used as a diagnostic in the classification of Latvian grassland plant communities. However large scale comparative phytosociological investigations have shown that diagnostic species should not be simply overtaken from one to another region without detailed geographical and ecological analysis. Instead, diagnostic species should be delimited preferably in large data sets with formalized, consistent and repeatable methods.

In this paper diagnostic species were delimited in a data set of 1,373 relevés of mesophilous and xerophilous grassland vegetation. Firstly, sociological species groups were formed by means of JUICE software using the H.Bruelheide's u-value algorithm. As a result 23 sociological species groups were delimited. Logic combinations of these groups were used to divide relevés into five higher vegetation units – the class Molinio-Arrhenatheretea (order Arrhenatheretalia), Calluno-Ulicetea (order Nardetalia), Trifolio-Geranietea (order Origanetalia), Koelerio-Corynephoretea (order Festuco-Sedetalia), and Festuco-Brometea (order Brometalia). The u-value and the Indicator value index were calculated for each species in relation to each vegetation unit. Species with an u-value exceeding 6.0 were considered to be diagnostic for particular vegetation unit. The analysis yielded in 10 diagnostic species for the class Calluno-Ulicetea, 8 species for the class Trifolio-Geranietea, 26 species for the class Festuco-Brometea, 28 species for the class Koelerio-Corynephoretea, and 53 species for the class Molinio-Arrhenatheretea. Several species in each set of diagnostic species can be used as a diagnostic at the class or order level only for particular data set; these cases are discussed in details.

Keywords: diagnostic species, semi-natural grassland vegetation, class, Braun-Blanquet method, sociological species group.

Introduction

Semi-natural grasslands (pastures and meadows) are very important for the conservation of biological diversity in Europe. They are the most species-rich habitats at small spatial scales (0.01 to 1 m^2) (Kuul, Zobel 1991; Klimeš 1999). Grasslands belong to the most endangered vegetation types because the characteristic structure and species composition can be maintained only by traditional management or imitating it (Gibson et al. 1987; Berendse et al. 1992; Ryser et al. 1995; Myklestad, Saetersdal 2003 etc.). This is the reason for active phytosociological as well as conservation research in this field.

In Latvia, along with the sweeping changes in nature protection (harmonization with the EU legislation, inventory and conservation of protected habitats of the European Union, etc.), there is an increasing need for information on diversity and structure of grassland plant communities, their similarities and differences from bordering regions. The vegetation classification has to be harmonized with the European Union.

The geographical position of Latvia on the eastern shore of the Baltic Sea and consequently on the continental gradient from the west to the east determines peculiarities of species distribution, as well as the differences in plant community structure and floristic composition in the territory of Latvia (Kupffer 1925; Laiviņš, Melecis 2003). Therefore biogeographically, some regions of Latvia are more similar to the vegetation found in Central Europe, others to that of Eastern Europe.

The biogeographical differences are also clearly expressed in grassland vegetation. Already G. Sabardina (1957) found that though the greatest part of grassland plant communities are distributed all over Latvia, others occur only in some regions. For example, the *Sesleria caerulea* community is known only in Western Latvia (Сабардина 1957), but the *Centaurea scabiosa-Fragaria vesca* community only in Eastern Latvia (Jermacāne, Laiviņš 2002). However, a detailed comparative biogeographical analysis of the grassland vegetation of Latvia in the Baltic and European context have not been carried out yet. Only starting with a vegetation description and classification using Braun-Blanquet approach has such analysis became available (Jermacāne, Laiviņš 2001).

The basis for the floristic-ecological classification is floristic features – species composition, frequency, abundance etc. The main criterion is a diagnostic species, character species and differential species. Hitherto species considered as character species in other European regions (Poland, Lithuania, Germany) were used as a diagnostic also in the classification process of Latvian grassland communities (Jermacāne 1999; Jermacāne Laiviņš 2002). However, such an approach often leads to a dead-end classification. Along with a broader use of syntaxonomy initially worked out on the basis of the Central European vegetation in other parts of Europe, particularly in Northern and Eastern Europe, it was found that plant communities frequent in Central Europe in the northern and eastern direction became species poor and with less character species. So the floristic differences among the different syntaxa become less apparent. It is difficult to classify such communities into the existing classification schema (Diekmann 1995; Jermacāne, Laiviņš 2002; Bambe 2003 etc.).

During the last few years, there has been an increasing interest in the comparative regional analysis of vegetation in large territories (Bruelheide 1995; Dierschke 1997, Evers 1997; Jandt 1999; Bruelheide, Chytry 2000). This leads to new ideas and conclusions. It was ascertained that certain diagnostic species groups defined for a particular region can not be applied without changes to another region unless it is known what set of plant communities the author of original research used for determining these diagnostic species (i. e. pertaining to what diversity of vegetation this group of diagnostic species is associated with) and whether the researcher had taken into account a large enough geographical or simply a local ecological context (Chytry et al. 2002a).

Usually diagnostic species are determined in the data set containing only one vegetation class, order or alliance. Such diagnostic species turn out not to be diagnostic in a larger context, if several vegetation classes are to be compared (Chytry et al. 2002b). It should be specifically taken into account concerning grassland classification. Semi-natural grasslands are very heterogeneous and most grassland vegetation classes are characterized as «bad» in terms of stability of character species combinations and their quality in delimitation of vegetation units, especially in the periphery of a class distribution area (Pignatti et al. 1995).

Commonly, the distribution area of a species is larger than of a plant community, and vice versa – the species is a good diagnostic species for a particular plant community only in a small part of the distribution area of the plant community. In some cases the species has a wide ecological amplitude in the centre of its distribution area, but it uses only very specific habitats in the periphery of this area, allowing it to be used as a good diagnostic species for particular plant communities (Diekmann 1995; Diekmann, Lawesson 1999; Bruun, Ejrnaes 2000). This is the reason why diagnostic species are divided into groups according to the scale in which these species can be used as a diagnostic. Local (diagnostic only in small part of plant community distribution area), regional (the major part of diagnostic species – they can be used as diagnostic all over the uniform physiogeographic or climatic region), over-regional (in several regions or a part of the world) and absolute diagnostic species can be distinquished (Dierschke 1994).

Numerical classification methods are becoming increasingly advanced and make it possible to proof the validity of different diagnostic species groups over a larger regional scale, as well as to determine such species for regions not yet investigated (Bruelheide 2000; Chytry et al. 2002a, b). Such investigations can provide a larger geographic perspective and result in new ideas for how to explain species co-occurrences as well as ecological and geographical differentiation of plant communities (Diekmann 1997; Ewald 2003).

The aim of this paper is to determine the diagnostic species for higher vegetation units of mesophilous and xerophilous semi-natural grasslands in Latvia.

Material and methods

Vegetation data

Traditionally, mesophilous and xerophilous grasslands are included into five non-forest vegetation classes. The order Arrhenatherealia of the class Molinio-Arrhenatheretea joins the mesophilous grasslands on weak acid and neutral soils, the order Nardetalia of the class Calluno-Ulicetea – mesophilous grasslands on very acid soils. Xerophilous sandy grasslands are included into the class Koelerio-Corynephoretea, order Festuco-Sedetalia, but xerophilous calcareous grasslands are in the class Festuco-Brometea, order Brometalia. This data set also includes thermophilous fringe vegetation from the class Trifolio-Geranietea. Further in the text, vegetation units will be refered as *classes*, bearing in mind that the paper deals only with grassland vegetation and consequently named orders and not with the classes on the whole.

1,373 phytosociological relevés collected by the author in the period of 1997 to 2003 all over Latvia have been used in this analysis. Vegetation description follows the Braun-Blanquet approach (Braun-Blanquet 1964; Dierschke 1994). The numbers of relevés in different vegetation classes differ significantly. This is a common situation for such data sets, because the regional distribution as well as territories covered with different plant communities are highly uneven.

Delimitation of diagnostic species

The first step to determine diagnostic species for mesophilous and xerophilous grasslands was the creation of sociological species groups. For this purpose computer program JUICE was used (Tichy 2002). The theoretical basis has been developed by H.Bruelheide (1995; 2000). The program creates species groups by combining species which occur together more frequently than it would be if these species were distributed randomly in the data set. The tendency of the species co-occurrence is characterised by an u-value, which is derived from normal distribution and is complementary with the concept of fidelity. Joint fidelity (showing both the fidelity of species to the vegetation unit and the fidelity of vegetation unit to the species) is measured by u_{hyp}, where $_{hyp}$ denotes that the value is derived form hypergeometric distribution (Chytry et al. 2002b). Perfect joint fidelity is the case when the species occurs only in the vegetation unit and in all relevés of this unit. U-value changes in the interval form –% to + %, but in the JUICE program this interval is from –1000 to 1000. U-values larger than 1.96 are statistically significant at $P<0.05$ (Chytry et al., 2002b).

The maximum value of u_{hyp} depends on the size of the database: $u_{hyp} = \sqrt{N-1}$ The size of the current database was 1,373, so the maximum value of u_{hyp} can reach 37.04 showing the perfect joint fidelity of the species and the vegetation unit.

Two considerations were taken into account when optimising the species group (i. e. to determine the number of species to be included into the group): 1) the new species is not included into the group if its inclusion disintegrates the group; 2) the new species is rejected if its ecology is strongly different from the species already included into the group (Koči et al. 2003).

The sociological species group analysis resulted in 23 sociological species groups (further in text referred as SSG).

The second step to determine diagnostic species was to classify the relevés into vegetation classes. This was done by using logic combinations of SSG (for details see chapter *Results*). As a result five vegetation units corresponding to five syntaxa (Table 1) were developed. No SSG was present in 171 relevé, so they were omitted from the further analysis.

The final step was to calculate the species u_{hyp}-values once more but now for all five vegetation units. The species with the highest u_{hyp}-values for the corresponding vegetation unit are the diagnostic species for this unit. As diagnostic we used only species with u_{hyp}-value equal or higher to 6.0. Such u-value threshold was selected because species with lower u-values had the same u-values in several vegetation units, so they could not be used as diagnostic for one particular vegetation unit.

Species nomenclature: Gavrilova, Šulcs 1999.

Table 1

Number of relevés in higher grassland vegetation syntaxa classified by sociological species groups

Vegetation unit	Nr. of relevés
Class Calluno-Ulicetea, order Nardetalia	32
Class Trifolio-Geranietea, order Origanetalia	80
Class Festuco-Brometea, order Brometalia	374
Class Koelerio-Corynephoretea, order Festuco-Sedetalia	270
Class Molinio-Arrhenatheretea, order Arrhenatheretalia	446
Not classified (omitted from further analysis)	171

Results

Sociological species groups

As a whole 23 SSG were created in the data set of 1,373 relevés. 11 of them represent mesophilous grasslands (Table 2), another 12 – xerophilous grasslands (Table 3).

The most frequent SSG in the data set was the *Anthoxanthum odoratum* group (452 relevés), *Festuca pratensis* group (337), *Fragaria vesca* group (245), *Helictotrichon pratense* group (243), and *Festuca ovina* group (236).

At least one SSG was present in 1,202 relevés (88% of the all relevés in the database). Most of them contained only one or two SSG (Fig. 1). There was a weak relationship between the total number of species per relevé and the number of SSG per relevé (Fig. 2). So it can be concluded that the data set is differentiated fairly well by SSG and that SSG are ecologically and/or geographically meaningful. In other words, any SSG present in a relevé shows certain ecological or geographical affinities of the vegetation and are not drived only by trivial relationship that increasing species richness in a relevé will yield also more SSG in that relevé.

Table 2

Sociological species groups of mesophilous grasslands

* – the first figure in brackets is the number of relevés included into the (+) group of the data set, the second figure – the minimal number of sociological species group species to be present in a relevé to include it into the (+) group

Species	u-value	Frequency in (+) group, %	Frequency in (-) group, %
SSG of the class Molinio-Arrhenatheretea			
Anthoxanthum odoratum* group (452; 5)			
Anthoxanthum odoratum	25,57	83,8	13,0
Ranunculus acris	23,67	76,8	12,4
Alchemilla vulgaris	21,69	60,8	6,9
Luzula campestris	20,24	69,0	14,4
Rumex acetosa	19,03	74,3	21,0
Veronica chamaedrys	17,51	80,1	29,8
Deschampsia cespitosa	17,50	41,8	4,2
Plantago lanceolata	16,82	84,1	35,6
Agrostis tenuis	15,95	76,5	30,7
***Festuca pratensis* group (337; 3)**			
Festuca pratensis	22,10	78,9	14,9
Taraxacum officinale	20,89	78,0	16,8
Lathyrus pratensis	20,70	73,6	14,5
Dactylis glomerata	17,06	89,0	35,3
Tragopogon pratensis	13,78	29,7	3,6
***Primula veris* group (220; 3)** (the group is characteristic also for the class *Festuco-Brometea*)			
Leontodon hispidus	22,13	74,5	9,4
Primula veris	20,87	65,5	7,6
Plantago media	20,46	75,0	12,1
Leucanthemum vulgare	17,58	73,2	16,5
Medicago lupulina	17,12	59,5	10,5
Linum catharticum	15,60	30,5	1,9
***Cynosurus cristatus* group (136; 2)**			
Cynosurus cristatus	24,03	56,6	1,4
Prunella vulgaris	23,61	83,8	7,4
Trifolium repens	21,29	90,4	12,6
***Holcus lanatus* group (124; 2)**			
Holcus lanatus	22,68	62,9	22,68
Potentilla anserina	22,26	57,3	22,26

Species	u-value	Frequency in (+) group, %	Frequency in (-) group, %
Galium uliginosum	22,10	41,9	22,10
Deschampsia cespitosa	21,73	86,3	21,73
***Anthriscus sylvestris* group (87; 2)**			
Heracleum sibiricum	20,64	82,8	7,4
Anthriscus sylvestris	20,01	74,7	6,1
Geranium pratense	16,20	28,7	0,6
Aegopodium podagraria	14,23	43,7	4,0
***Cirsium heterophyllum* group (34; 2)**			
Trollius europaeus	28,66	79,4	0,5
Angelica sylvestris	21,80	76,5	2,0
Cirsium heterophyllum	21,55	50,0	0,4
Crepis paludosa	15,65	23,5	0,1
Geranium sylvaticum	12,61	38,2	1,7
***Alopecurus pratensis* group (26; 2)**			
Alopecurus pratensis	20,33	88,5	2,9
Polygonum bistorta	19,89	65,4	1,3
Cirsium arvense	17,03	76,9	3,3
***Succisa pratensis* group (17; 2)**			
Succisa pratensis	23,18	88,2	1,2
Cirsium palustre	19,42	64,7	0,9
Epipactis palustris	19,31	41,2	0,1
Listera ovata	11,90	47,1	1,6
SSG of the class Calluno-Ulicetea			
***Nardus stricta* group (46; 2)**			
Nardus stricta	29,47	84,8	0,8
Sieglingia decumbens	23,07	67,4	1,4
Potentilla erecta	16,55	78,3	6,5
SSG of the class Trifolio-Geranietea			
***Trifolium medium* group (144; 2)**			
Agrimonia eupatoria	21,23	81,3	9,9
Veronica teucrium	20,60	49,3	2,2
Trifolium medium	20,18	68,8	7,2
Origanum vulgare	18,15	38,9	1,7

Table 3

Sociological species groups of xerophilous grasslands

* – the first figure in brackets is the number of relevés included into the (+) group of the data set, the second figure – the minimal number of sociological species group species to be present in a relevé to include it into the (+) group

Species	u-value	Frequency in (+) group, %	Frequency in (-) group, %
SSG of the class Festuco-Brometea			
Fragaria vesca* group (245; 3)			
Centaurea scabiosa	23,56	85,3	12,6
Medicago lupulina	22,48	69,0	7,4
Agrimonia eupatoria	20,41	62,4	7,6
Polygala comosa	18,74	41,6	2,6
Pimpinella saxifraga	15,96	86,9	31,3
Fragaria vesca	15,95	33,5	2,6
***Helictotrichon pratense* group (243; 3)**			
Filipendula vulgaris	22,69	64,2	5,4
Helictotrichon pratense	21,54	58,8	5,0
Phleum phleoides	20,96	47,3	2,2
Trifolium montanum	19,58	59,7	7,6
Fragaria viridis	19,34	72,8	13,9
Galium verum	16,83	80,2	23,7
***Carex flacca* group (49; 3)**			
Carex flacca	25,28	95,9	3,3
Cirsium acaule	22,24	59,2	1,1
Festuca arundinacea	18,02	67,3	3,8
Inula salicina	17,11	40,8	1,1
Carlina vulgaris	16,54	51,0	2,3
Sesleria caerulea	16,54	61,2	3,8
SSG of the class Koelerio-Corynephoretea			
***Festuca ovina* group (236; 2)**			
Dianthus deltoides	24,48	80,1	8,6
Festuca ovina	23,53	73,3	7,4
Rumex acetosella	21,58	63,1	6,2
Campanula rotundifolia	15,20	29,2	1,9
***Artemisia campestris* group (118; 4)**			
Arenaria serpyllifolia	21,24	66,9	4,8
Berteroa incana	20,00	44,9	1,5
Sedum acre	19,36	73,7	8,4
Trifolium arvense	19,20	72,0	8,1
Artemisia campestris	17,90	88,1	16,0
Acinos arvensis	15,98	38,1	2,5

Species	**u-value**	**Frequency in (+) group, %**	**Frequency in (-) group, %**
Cerastium semidecandrum	14,34	37,3	3,3
Potentilla argentea	13,02	61,0	13,1
Carex arenaria **group (90; 2)**			
Carex arenaria	23,99	54,4	0,8
Festuca ovina	18,07	91,1	13,6
Deschampsia flexuosa	17,95	35,6	0,9
Thymus serpyllum	17,84	53,3	3,6
Festuca trachyphylla **group (23; 2)**			
Festuca trachyphylla	24,17	91,3	1,6
Potentilla arenaria	22,00	82,6	1,6
Vicia tetrasperma	17,27	78,3	3,0
Equisetum hyemale **group (23; 2)**			
Equisetum hyemale	23,00	73,9	1,0
Hylothelepium maximum	22,54	56,5	0,4
Oenothera biennis	17,83	47,8	0,7
Veronica spicata	17,74	95,7	4,5
Saxifraga granulata **group (15; 2)**			
Trifolium dubium	29,53	93,3	0,4
Saxifraga granulata	20,18	80,0	1,3
Vicia hirsuta	15,38	93,3	3,9
Saxifraga tridactylites **group (11; 4)**			
Saxifraga tridactylites	27,38	63,6	0,0
Erophila verna	22,85	63,6	0,2
Vincetoxicum hirundinaria	18,85	90,9	1,5
Anthemis tinctoria	17,23	100,0	2,5
Myosotis micrantha	13,66	36,4	0,3
Jovibarba globifera	13,09	72,7	2,3
Allium vineale	12,26	54,5	1,3
Armeria maritima **group (9; 3)**			
Festuca sabulosa	27,68	66,7	0,0
Armeria maritima	25,30	77,8	0,2
Dianthus arenarius	24,64	100,0	0,7
Pulsatilla pratensis	20,59	77,8	0,6
Koeleria glauca	18,76	77,8	0,8
Tragopogon heterospermus	17,76	33,3	0,0
Silene otites **group (3; 3)**			
Astragalus arenarius	22,66	66,7	0,0
Koeleria glauca	12,50	100,0	1,1
Helichrysum arenarium	11,85	100,0	1,2
Silene otites	10,66	33,3	0,0
Pulsatilla patens	10,66	33,3	0,0

Figure 1

Distribution of relevés according to the number of sociological species groups per relevé

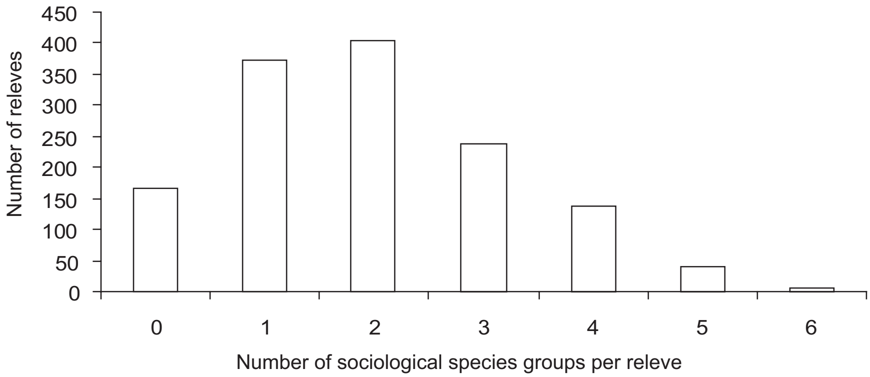
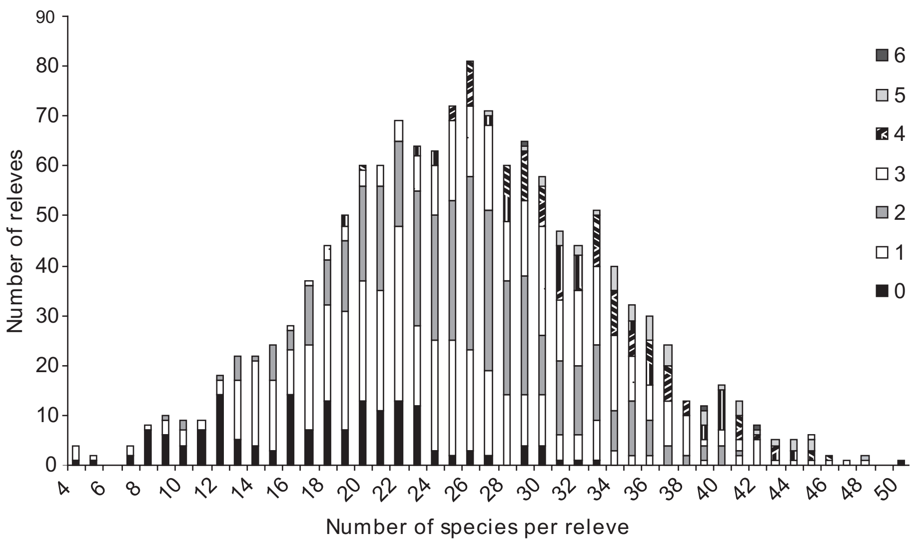


Figure 2

Distribution of relevés according to the total number of species per relevé and the number of sociological species groups per relevé



Classification of relevés into higher grassland vegetation units

All the SSG according to their species ecology and sociology were ascribed to the particular vegetation class (Table 2, 3). Relevés were classified according to the set of SSG present in them. Analysis of the occurrence of different SSG in a data set led to the conclusion that only a presence of a species is not yet a satisfactory diagnostic feature. It is particularly true for contact communities of xerophilous and mesophilous grasslands where the number of character species of several vegetation classes are rather equal but in the same time the dominants are species faithful to a particular class. Therefore, to determine such relevés and ascribe them to the right vegetation class, the dominance of a particular species was used as an additional criterion for classification.

Relevés containing the *Nardus stricta* group and at the same time containing one or more dominants like *Nardus stricta, Sieglingia decumbens* or *Festuca ovina* were joined into the class Calluno-Ulicetea.

Relevés of the class Trifolio-Geranietea were delimited mainly according to the dominant species, because only one SSG characteristic for this class – *Trifolium medium* group – was present throughout the data set, especially in the relevés of the classes Molinio-Arrhenatheretea and Festuco-Brometea. Therefore only those relevés with *Trifolium medium* group were taken which dominants were typical fringe species – *Trifolium medium, Veronica teucrium, Geranium sanquineum, Brachypodium pinnatum, Vicia cassubica* etc. Consequently, also relevés without *Trifolium medium* group but with named dominants were included into this vegetation unit. For relevés containing the class Festuco-Brometea SSG an additional criterion was applied – dominants should not be typical Festuco-Brometea species like *Helictotrichon pratense* or *Filipendula vulgaris.*

For a relevé to be classified into the class Festuco-Brometea one of following SSG should be present: *Carex flacca* group, *Helictotrichon pratense* group and *Fragaria vesca* group. For relevés containing the class Molinio-Arrhenatheretea SSG as an additional criterion was: a relevé should not contain *Festuca pratensis* and *Anthoxanthum odoratum* group simultaneously, but, if one of them is present then dominants should be typical Festuco-Brometea species.

Relevés containing at least one SSG of the class Koelerio-Corynephoretea were classified into this class. From these – the relevés containing also some of the class Molinio-Arrhenatheretea SSG were included only if their dominants were species characteristic for the class Koelerio-Corynephoretea (*Poa angustifolia, Festuca ovina, Thumus serpyllum, Carex arenaria*). Also relevés containing only *Anthoxanthum odoratum* group but having *Poa angustifolia* as dominant species were included into this vegetation unit.

All the other relevés not fulfilling the demands of previously described vegetation units and having at least one of the class Molinio-Arrheantheretea SSG were included into this class.

Diagnostic species

Diagnostic species (species with u_{hyp}-value exceeding 6.0) are listed in the Table 4.

Table 4

Diagnostic species of the higher mesophilous and xerophilous grassland units

* --- dashes indicate negative u-value

CU – Calluno-Ulicetea, Nt –Nardetalia
TG – Trifolio-Geranietea, Tm – Trifolion medii, Gs – Geranion sanquinei
FB – Festuco-Brometea, Bt – Brometalia, Bo – Bromion
KC – Koelerio-Corynephoretea, Ct – Corynephoretalia, Co – Corynephorion, St – Sedo-Scleranthetalia, Ft – Festuco-Sedetalia, PlF – Plantagini-Festucion, Ko – Koelerion glaucae
MA – Molinio-Arrhenatheretea, Mt – Molinietalia, Mo – Molinion, At – Arrhenatheretalia, Ao – Arrhenatherion, Cy –Cynosurion, Cal – Calthion, Al – Alopecurion, De – Deschampsion
References: 1 – Ellenberg 1996; 2 – Schaminee et al. 1996; 3 – Pott 1995; 4 – Dierssen 1996; 5 – Mucina et al. 1993; 6 – Balevičiene et al. 1998; 7 – Matuszkiewicz 1981

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
	u-value					Frequency, %					Indicator value index			
Vegetation unit	**CU**	**TG**	**FB**	**KC**	**MA**	**CU**	**TG**	**FB**	**KC**	**MA**	**Vegetation unit**	**Indicator value index**	**Statistical signifi-cance**	**Reference where the species is named as a character species**
Number of relevés in vegetation unit	**32**	**80**	**374**	**270**	**446**	**32**	**80**	**374**	**270**	**446**				
Nardus stricta	**27,0**	---*	---	---	---	**94**	.	.	3	2	CU	93,3	0,001	Nt 1;3-7
Sieglingia decumbens	**16,5**	---	---	---	---	**59**	.	1	4	3	CU	57,6	0,001	CU 1;3-5;7
Potentilla erecta	**14,9**	---	---	---	5,2	**84**	8	5	0	15	CU	74,4	0,001	CU 1;3-5;7
Carex nigra	**10,1**	---	---	---	5,9	**38**	.	0	.	8	CU	30,5	0,001	Cal 3
Vaccinium vitis-idaea	**9,5**	---	---	---	---	**16**	.	.	0	1	CU	15,2	0,001	
Succisa pratensis	**8,2**	---	---	---	---	**25**	2	3	.	2	CU	22	0,001	Mt 1;3;5 Mo 5;6;7
Carex pilulifera	**7,7**	---	---	---	---	**16**	1	1	1	1	CU	11	0,001	CU 1;3-5;7
Cirsium palustre	**6,9**	---	---	---	2,7	**19**	.	1	.	3	CU	15,9	0,001	Mt 1;3-5;7
Selinum carvifolia	**6,4**	---	---	---	---	**16**	.	1	.	2	CU	10,2	0,001	Mt 1;7 Mo 3-6 At 3
Calluna vulgaris	**6,2**	---	---	1,6	---	**16**	1	1	3	1	CU	11,6	0,001	CU 1;3-5

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Veronica teucrium	---	**17,8**	4,0	---	---	.	**58**	12	.	1	TG	53,7	0,001	Gs 1;5;7
Trifolium medium	---	**14,3**	---	---	---	12	**68**	15	1	12	TG	62,3	0,001	Tm 3-5;7
Origanum vulgare	---	**11,5**	4,9	---	---	.	**35**	11	1	0	TG	28	0,001	TG 1-5;7
Agrimonia eupatoria	---	**11,4**	**10,3**	---	---	.	**65**	**35**	1	9	TG	33,2	0,001	Tm 1-5;7
Brachypodium pinnatum	---	**9,5**	1,4	---	---	.	**19**	3	.	.	TG	17,1	0,001	
Bromopsis inermis	---	**8,5**	---	---	---	.	**19**	2	.	2	TG	17,6	0,001	
Geranium pratense	---	**7,2**	---	---	1,4	.	**15**	2	.	3	TG	12,6	0,002	Ao 1;3;4;6;7
Quercus robur	---	**6,6**	---	---	---	6	**14**	3	1	1	TG	11,1	0,001	
Helictotrichon pratense	---	---	**15,5**	---	---	9	14	**39**	8	3	FB	27,3	0,001	FB 2;4;5;7
Fragaria viridis	---	4,0	**15,5**	---	---	3	44	**54**	12	11	FB	26,9	0,001	
Filipendula vulgaris	---	1,5	**15,3**	---	---	9	22	**41**	4	6	FB	25,1	0,001	FB 1;4-7
Trifolium montanum	---	---	**14,8**	---	---	.	21	**41**	11	4	FB	23,7	0,002	FB 1;3;4;6
Phleum phleoides	---	---	**14,7**	---	---	.	8	**30**	6	.	FB	25,8	0,001	FB 1;5 PlF 4
Centaurea scabiosa	---	5,8	**14,3**	---	---	.	54	**53**	10	13	FB	27,9	0,001	FB 1;2;4-7
Polygala comosa	---	---	**13,2**	---	---	.	8	**27**	4	2	FB	16,1	0,001	FB 1;2;4;6;7
Pimpinella saxifraga	---	2,5	**11,6**	---	---	3	55	**67**	40	25	FB	30	0,007	FB 1;4;5
Medicago lupulina	---	---	**11,2**	---	---	.	15	**38**	6	16	FB	20	0,001	Bt 4 Bo 1
Carex caryophyllea	---	---	**10,3**	1,3	---	3	6	**28**	15	2	FB	14,6	0,002	FB 3-7
Ranunculus polyanthemos	---	---	**9,6**	---	---	6	15	**30**	11	7	FB	13,6	0,006	
Carlina vulgaris	---	1,3	**9,6**	---	---	.	8	**13**	1	.	FB	7,1	0,012	Bt 3
Poa angustifolia	---	2,3	**8,7**	**6,5**	---	3	59	**65**	**63**	18	*KC*	*28*	*0,001*	FB 1;4;5
Galium verum	---	1,3	**8,6**	1,6	---	12	41	**52**	38	18	FB	18,3	0,009	FB 1;5
Daucus carota	---	---	**8,4**	---	---	.	5	**18**	1	6	FB	11,7	0,003	At 7
Knautia arvensis	---	---	**8,4**	---	---	31	51	**69**	44	42	FB	20	0,028	At 1;5 Ao 3;4;7

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Poa compressa	---	---	**8,2**	---	---	.	5	**17**	7	1	FB	6,2	0,045	FB 7
Primula veris	---	2,5	**7,8**	---	---	.	28	**30**	3	18	FB	12,2	0,027	Bo 3;4;6
Carex flacca	---	2,4	**7,7**	---	---	.	14	**15**	.	4	FB	9,2	0,008	
Cirsium acaule	---	1,9	**7,4**	---	---	3	8	**9**	.	1	FB	4,1	0,049	Bo 1;3;4
Briza media	1,9	---	**7,3**	---	**6,1**	56	25	**54**	16	**50**	FB	17,3	0,027	Bt 4;5
Campanula rapunculoides	---	3,2	**7,2**	---	---	.	16	**15**	1	3	FB	9,3	0,01	Gs 1;3;4;7
Plantago media	---	---	**6,8**	---	2,7	.	24	**35**	8	27	FB	12,3	0,046	FB 7
Fragaria vesca	---	1,3	**6,5**	---	---	6	12	**16**	3	6	FB	10,3	0,009	
Astragalus danicus	---	---	**6,2**	---	---	.	5	**7**	.	.	FB	6,5	0,007	
Sesleria caerulea	---	---	**6,1**	---	---	3	5	**12**	.	7	FB	8,3	0,015	
Rumex acetosella	1,6	---	---	**16,9**	---	28	1	9	**50**	5	KC	28,8	0,001	KC 1;3;5;7 Ct 4 St 5
Sedum acre	---	---	---	**15,7**	---	.	1	11	**44**	1	KC	36,9	0,001	KC 1;3-5;7 St 3
Artemisia campestris	---	---	---	**15,6**	---	6	5	24	**58**	2	KC	40,4	0,001	KC 1 PlF 3;4
Dianthus deltoides	---	---	---	**15,5**	---	12	1	19	**56**	10	KC	39,8	0,001	PlF 1;3;4;7
Festuca ovina	7,1	---	---	**15,3**	---	**69**	4	13	**51**	7	*CU*	*40,1*	*0,001*	Ct 1 KC 7
Trifolium arvense	---	---	---	**14,2**	---	.	1	15	**40**	1	KC	30,9	0,001	KC 1;5;7 Ft 2 Ct 3;4
Potentilla argentea	---	---	---	**13,8**	---	.	11	15	**46**	4	KC	26,8	0,001	KC 1; 4; 5; 7 Ft 2
Berteroa incana	---	---	---	**11,4**	---	.	.	4	**19**	0	KC	16	0,001	
Carex arenaria	1,0	---	---	**11,3**	---	9	.	1	**17**	0	KC	14,7	0,001	Ct 1-4; 7 KC 2
Arenaria serpyllifolia	---	---	1,5	**10,4**	---	.	1	12	**27**	.	KC	12,2	0,015	KC 3-5; 7
Potentilla impolita	---	---	---	**9,8**	---	.	1	2	**15**	0	KC	12,4	0,001	
Jasione montana	---	---	---	**9,3**	---	.	.	3	**15**	0	KC	12,1	0,001	KC 3; 4; 7
Pilosella officinarum	1,2	---	3,5	**8,9**	---	34	15	31	**45**	7	KC	22,8	0,001	KC 7

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Veronica spicata	---	---	---	**8,9**	---	3	.	6	**18**	0	KC	12,6	0,002	FB 1; 3; 6; 7
Koeleria glauca	---	---	---	**8,3**	---	.	.	.	**7**	.	KC	6,7	0,004	Ko 1; 3; 4; 7
Vicia hirsuta	---	---	---	**8,3**	---	.	2	3	**15**	2	KC	10,7	0,005	
Thymus serpyllum	---	---	2,9	**8,1**	---	.	.	10	**18**	0	KC	12,6	0,001	Ct 1; 3-5 Ft 7
Festuca trachyphylla	---	---	---	**8,0**	---	.	.	2	**11**	0	KC	9,6	0,002	Ft 7 PlF 1
Cerastium semidecandrum	---	---	1,0	**7,7**	---	.	.	7	**17**	1	KC	11	0,002	Ct 3; 4 KC 2; 7
Veronica verna	---	---	---	**7,6**	---	.	.	1	**9**	0	KC	8,3	0,003	KC 1; 4; 5; 7
Deschampsia flexuosa	3,6	---	---	**7,4**	---	16	1	1	**10**	0	*CU*	*9,5*	*0,003*	
Dianthus arenarius	---	---	---	**7,1**	---	.	.	1	**6**	.	KC	5,6	0,004	Ko 7
Acinos arvensis	---	---	2,1	**7,0**	---	.	4	8	**14**	.	KC	8,1	0,015	KC 1; 4; 5
Oenothera biennis	---	---	---	**6,6**	---	.	.	0	**6**	0	KC	5,5	0,012	
Scleranthus perennis	---	---	---	**6,5**	---	.	.	1	**5**	.	KC	4,7	0,018	KC 1; 3; 4; 7 Ft 2; St 5
Hylothelepium maximum	---	---	---	**6,5**	---	3	.	1	**6**	.	KC	3,5	0,022	Ft 3;7
Vicia tetrasperma	---	---	---	**6,1**	---	.	.	5	**11**	1	KC	8,2	0,006	
Armeria maritima	---	---	---	**6,0**	---	.	.	.	**4**	.	KC	3,7	0,019	
Ranunculus acris	3,3	---	---	---	**20,6**	62	6	17	12	**72**	MA	38,1	0,001	MA 1; 3-7
Alchemilla vulgaris	---	---	---	---	**16,7**	31	11	13	10	**53**	MA	38	0,001	MA 4; 5 At 1
Poa pratensis	---	---	---	---	**16,3**	31	9	9	9	**53**	MA	38,9	0,001	MA 1; 4-7 At 5
Lathyrus pratensis	---	---	---	---	**16,0**	16	29	22	5	**57**	MA	33,3	0,001	MA 1; 3-7
Deschampsia cespitosa	4,4	---	---	---	**16,0**	47	8	4	2	**40**	*CU*	*24,5*	*0,001*	Mt 3-5; 7 MA 5; 6
Geum rivale	---	---	---	---	**15,4**	19	5	3	0	**32**	MA	21,9	0,001	Mt 1 Cal 3-5
Anthoxanthum odoratum	**7,0**	---	---	---	**15,1**	**97**	5	20	29	**65**	*CU*	*37,7*	*0,001*	Cy 6
Trifolium pratense	---	---	---	---	**14,9**	12	8	26	4	**52**	MA	32,2	0,001	MA 1; 3-7

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Festuca pratensis	---	---	---	---	**13,6**	9	35	30	4	**55**	MA	35	0,001	MA 1; 3-7
Veronica chamaedrys	1,0	---	---	---	**13,5**	56	24	35	31	**73**	MA	31,5	0,003	
Taraxacum officinale	---	---	---	---	**13,2**	6	21	26	13	**56**	MA	39,9	0,001	MA 3-5 At 7
Rumex acetosa	---	---	---	---	**12,9**	47	18	29	30	**63**	MA	25,6	0,022	MA 1; 3-7 At 5
Cerastium holosteoides	---	---	---	---	**12,3**	19	5	17	7	**42**	MA	19,1	0,002	MA 1; 3; 5; 7
Trifolium repens	---	---	---	---	**11,7**	6	.	14	12	**39**	MA	22,6	0,001	MA 3; 5 Cy 1; 3-5; 7
Cynosurus cristatus	---	---	---	---	**11,6**	3	.	3	.	**18**	MA	16,5	0,001	Cy 1; 3-5; 7 At5 MA5
Carex pallescens	1,7	---	---	---	**11,4**	22	5	6	1	**25**	*CU*	*14,1*	*0,002*	
Filipendula ulmaria	2,2	---	---	---	**11,3**	22	8	4	.	**22**	MA	15,4	0,002	Mt 3; 5-7 Cal 1; 4; 5
Hypericum maculatum	2,4	---	---	---	**11,1**	25	4	4	1	**24**	*CU*	*11,2*	*0,008*	Cal 4 CU 1 Nt 3; 5-7
Lychnis flos-cuculi	---	---	---	---	**10,7**	3	.	2	.	**15**	MA	12	0,002	Mt 1; 4-7 MA 5 Mo3
Heracleum sibiricum	---	2,0	---	---	**10,4**	.	20	6	1	**26**	MA	14,3	0,005	MA 5; 6 At 1; 3; 4
Potentilla anserina	2,2	---	---	---	**10,4**	19	1	2	1	**18**	MA	10,1	0,01	
Phleum pratense	---	---	---	---	**10,2**	16	30	35	24	**57**	MA	28,4	0,001	MA 6; 7 At5 Cy1; 4; 5
Anthriscus sylvestris	---	1,5	---	---	**10,1**	.	16	4	1	**23**	MA	12	0,013	At 1; 7 MA 5
Agrostis tenuis	3,9	---	---	2,6	**9,7**	81	20	27	53	**65**	MA	27	0,001	MA 5 Cy 6
Luzula campestris	3,5	---	---	1,4	**9,6**	62	5	23	36	**50**	MA	16,9	0,026	CU 1; 4; 5; 7
Plantago lanceolata	---	---	---	---	**9,4**	59	20	49	51	**70**	MA	30,5	0,001	MA 1; 4-7
Stellaria graminea	---	---	---	---	**9,4**	34	12	22	30	**48**	MA	17,5	0,012	MA 4; 5 At 5
Alopecurus pratensis	---	---	---	---	**9,3**	.	1	0	2	**12**	MA	10,7	0,005	MA 3-5; 7 Al 6
Ranunculus repens	---	---	---	---	**9,2**	9	1	1	0	**13**	MA	8,9	0,013	MA 5
Prunella vulgaris	---	---	1,6	---	**8,9**	9	9	18	1	**27**	MA	15,3	0,004	MA 1; 3; 5; 6 Cy 4; 5

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Dactylis glomerata	---	4,8	---	---	**8,4**	3	75	49	21	**65**	MA	28,7	0,003	At 3; 4; 6; 7 MA 5
Helictotrichon pubescens	---	---	---	---	**8,4**	31	20	27	29	**49**	MA	27,8	0,002	At 1; 3-6 MA 7
Rhinanthus minor	---	---	---	---	**8,1**	.	1	2	1	**12**	MA	9,2	0,009	MA 4; 5; 7 At 5
Holcus lanatus	**6,9**	---	---	---	**8,0**	**44**	5	.	5	**17**	*CU*	*14,7*	*0,002*	MA 1; 3-5; 7
Vicia cracca	---	1,7	2,6	---	**7,9**	53	69	65	32	**74**	MA	21,6	0,061	MA 1; 3-7
Centaurea jacea	---	---	5,0	---	**7,8**	28	38	45	7	**49**	MA	20,2	0,017	MA 3-7
Campanula patula	---	---	---	---	**7,7**	6	.	7	2	**18**	MA	9,6	0,011	At 5; 6 Ao 1; 3-5; 7
Galium uliginosum	**6,5**	---	---	---	**7,7**	**28**	.	1	.	**10**	*CU*	*19,6*	*0,001*	Mt 1; 3-7
Leucanthemum vulgare	---	---	2,5	---	**7,5**	12	16	30	11	**38**	MA	13,3	0,056	At 1; 3; 7 MA 4; 5
Rumex crispus	---	---	---	---	**7,3**	.	.	1	1	**9**	MA	7,6	0,006	
Carex leporina	4,5	---	---	---	**7,2**	22	.	0	1	**10**	*CU*	*12,3*	*0,001*	
Carum carvi	---	---	---	---	**7,1**	.	6	10	0	**16**	MA	9,7	0,015	MA 4; 5 At 1; 7 Cy 6
Leontodon hispidus	---	---	4,0	---	**7,0**	19	11	27	4	**31**	MA	12,1	0,044	MA 4-7
Vicia sepium	---	1,1	---	---	**6,9**	.	8	2	0	**10**	MA	5,4	0,035	At 4; 5
Juncus conglomeratus	4,1	---	---	---	**6,8**	16	.	.	.	**7**	*CU*	*6,4*	*0,012*	Mt 1; 4; 5; 7 Cal3 De5
Carex panicea	5,8	---	---	---	**6,8**	38	4	6	1	**15**	*CU*	*25,1*	*0,001*	
Cirsium heterophyllum	---	---	---	---	**6,7**	.	.	.	.	**5**	MA	5,2	0,012	
Ophioglossum vulgatum	---	---	---	---	**6,6**	3	.	1	.	**7**	MA	5	0,043	Mt 1 Mo 1; 4; 5; 7
Ranunculus auricomus	1,4	---	---	---	**6,6**	9	1	1	0	**8**	*CU*	*4*	*0,065*	Mo 3
Angelica sylvestris	2,1	---	---	---	**6,4**	12	2	2	.	**9**	MA	4,3	0,065	Mt 1; 4; 5; 7 Cal 1; 3
Cirsium arvense	---	---	---	---	**6,3**	.	2	2	.	**10**	MA	7,9	0,004	
Polygonu)m bistorta	3,0	---	---	---	**6,3**	12	.	1	.	**7**	MA	4,7	0,028	Mt 5; 6 MA 5 Cal 1; 3
Leontodon autumnalis	2,3	---	---	---	**6,1**	19	2	6	3	**13**	*CU*	*6*	*0,061*	Cy 1; 4-6

Discussion

As it is shown in Table 2, 3 and 4, not all the species of SSG are also diagnostic for the class level vegetation units. There are only some SSG that could be used as a diagnostic species group at the class level. One of these SSG is *Nardus stricta* group whose u-value is 30 for the class Calluno-Ulicetea. It means that the group is present almost only in the class Calluno-Ulicetea and in all of these relevés. There are no one so faithful SSG for other classes.

To develop SSG which reliably produce higher syntaxa are possible only if these syntaxa would be highly differentiated one from another without spatial or temporal continuum and consequently without common species. These syntaxa should be also homogeneous with their character species frequent in all the lower syntaxa.

Grassland vegetation posses none of these features (Pignatti et al. 1995). As a rule, different grassland vegetation types have tight spatial and temporal links. For example, in a catena across of a floodplain both the moist Molinietalia and wet Caricetalia nigrae as well as fresh Arrhenatheretalia and dry sandy Festuco-Sedetalia or calcareous Brometalia can be found within a mosaic pattern (Šeffer, Stanova (eds.) 1999; Сабардина 1952). Therefore gradual transition from one class to another is a common feature both in floristic as well as in structural terms. The same is true for temporal changes. For example, abandonment of dry calcareous grasslands leads to development of forest fringe communities (Brometalia → Trifolio-Geranietea), but intensive grazing in formerly mowed fresh grasslands drives to formation of heathly plants (Arrhenatherion → Cynosurion → Nardetalia) (Dierschke 1993; Сабардина 1957).

As an alternative for the classification of the higher syntaxa, SSG corresponding to lower syntaxa and their combinations with particular dominant species are used instead of trying to develop the class or order level SSG.

Diagnostic species derived a posteriori for the five vegetation units delimited by such an approach corresponded well to the diagnostic species of these vegetation units mentioned in literature for different regions of Europe. Observed discrepancies can be explained, firstly, by the character of the database, secondly, by regional differences in the ecology and sociology of species and communities.

The influence of the database character on the classification result is well known (Bruelheide, Jandt 1994; Dufrene, Legendre 1997; Chytry et al. 2002b). Diagnostic capacity of the species strongly varies depending on the degree of representation of the target vegetation and other closely related vegetation types where the species is present.

The specific feature of the current database is that no one vegetation class is fully represented (see Material and Methods) with the only exception of Festuco-Brometea communities. For this reason, diagnostic species delimited in this research can be extrapolated only in the frame of mesophilous and xerophilous grasslands. By enlarging the database with other grassland types (for instance, low sedge beds or pioneervegetation on sands) the diagnostic capacity of many species will change. For example, it is clear that the species *Succisa pratensis, Cirsium palustre* and *Selinum carvifolia* which are a diagnostic for the class Calluno-Ulicetea in this paper reach their ecological optimum in the Molinietalia communities. The same is true for the species

Angelica palustris, Polygonum bistorta, Galium uliginosum and *Lychnis flos-cuculi*, which are diagnostic for the mesophilous grasslands of the order Arrhenatheretalia in the current database.

To characterize the ecological and geographical peculiarities of diagnostic species in details vegetation surveys of several European countries were used. To be short, references will be mentioned further in the text as follows: [1] – Ellenberg 1996 (Central Europe); [2] – Schaminee et al. 1996 (The Netherlands); [3] – Pott 1995 (Germany); [4] – Dierssen 19996 (Nothern Europe); [5] – Mucina et al. 1993 (Austria); [6] – Balevičiene 1998 (Lithuania); [7] – Matuszkiewicz 1981 (Poland).

Diagnostic species of the class Calluno-Ulicetea, order Nardetalia

Half of the class Calluno-Ulicetea diagnostic species are mentioned as diagnostic for the class or order also in other European countries – *Nardus stricta, Sieglingia decumbens, Potentilla erecta, Carex pilulifera,* and *Calluna vulgaris* (Table 4). *Potentilla erecta* is rather problematic in Latvia. One of its ecological optimum is also the class Molinio-Arrhenatheretea (it is confirmed also by rather high u-value for the cluster of this class in the current database). Therefore, *Potentilla erecta* can not be used in differentiation of classes Molinio-Arrhenatheretea and Calluno-Ulicetea.

Three species – *Succisa pratensis, Cirsium palustre* and *Selinum carvifolia* are the diagnostic for the class Calluno-Ulicetea only in the current database, because they reach the real ecological optimum in the class Molinio-Arrhenahteretea order Molinietalia [1; 3; 4; 5; 6; 7].

Carex nigra and *Vaccinium vitis-idaea* are good diagnostic species in Latvia. Although *Carex nigra* optimally grows in fens (it is the character species of the class Scheuchzerio-Caricetea nigrae), similarly to *Nardus stricta*, it is confined to very acid nutrient poor moist to wet soils (The Ellenberg figures for reaction is 3, nitrogen – 2, moisture – 8; for *Nardus stricta* these values are 2,2, and x~ (indifferent to moisture and tolerates periodical saturation)). Therefore, *Carex nigra* together with another Calluno-Ulicetea species clearly differentiate Calluno-Ulicetea communities from poorest and wettest Molinio-Arrhenatheretea communities.

Vaccinium vitis-idaea grows mainly in pine forests in Latvia (Laiviņš 1998). In Western and Northern Europe the second habitat group is brown dunes and heaths (class Calluno-Ulicetea, order Ulicetalia minoris). Also in Latvia, the species grow only in the class Calluno-Uliceta communities outside the forests. Some of the class and order character species – *Cuscuta epithymum* [1; 4; 7], *Botrychium lunaria* [1; 3; 4; 6; 7] and *Antennaria dioica* [1; 3; 4; 5; 7] are very rare in the current database (0, 7 and 12 relevés, respectively), so it is impossible to clarify the sociological status of these species.

Three more species are mentioned in literature as character species of the class or order – *Luzula campestris* [1; 4; 5; 7], *Carex pallescens* [1; 4; 5] and *Hypericum maculatum* [3; 5; 6; 7]. They appear as diagnostic for the class Molinio-Arrhenatheretea in the current database (u-values 9.6, 11.4 and 11.1, respectively). On the other hand they have positive u-values also for the class Calluno-Ulicetea but *Carex pallescens* and *Hypericum maculatum* also an indicator value index is the highest for the class Calluno-Ulicetea relevés. So these species can be used only for differentiation of the lower syntaxa inside the class but not between classes.

Diagnostic species of the class Trifolio-Geranietea order Origanetalia

Four out of eight fringe diagnostic species *Origanum vulgare, Trifolium medium, Agrimonia eupatoria* and *Veronica teucrium* are widely recognized as the diagnostic for the class Trifolio-Geranietea and its syntaxa. *Trifolium medium* and *Agrimonia eupatoria* traditionally are recognized as character species of the alliance Trifolion medii, but *Veronica teucrium* – of the alliance Geranion sanquinei. In Latvia, these species occur together frequently (Jermacāne, Laiviņš 2001b; Laiviņš, Rūsiņa 2002). Co-occurrence of the character species of both alliances is also documented in Scandinavia (Diekmann, 1997).

Brachypodium pinnatum has a double nature. The species is frequent in polydominant subcontinental steppe-like communities (class Festuco-Brometea, alliance Cirsio-Brachypodion) and is considered as a character species of this alliance (Mucina et al. 1993; Evers 1997). On the other hand, it expands in most of the mesophilous communities of Festuco-Brometea (alliance Bromion) after abandonment of mowing or grazing resulting in species poor derivate communities which turn gradually into fringe vegetation (Bobbink, Willems 1987; Bobbink 1991; Dierschke 1993). In Latvia *Brachypodium pinnatum* is observed only as expansive species in abandoned dry calcareous grassland, so it indicates the vegetation transformation process from grassland to fringe.

Bromopsis inermis is referred as a character species of the alliance Alopecurion (class *Molinio-Arrhenahteretea*) [7], and also as a character species of xerothermophilous perennial ruderal vegetation (class *Artemisietea vulgaris*, alliance *Convolvulo-Agropyrion repentis*) [5]. As the current database does not include optimum vegetation for *Bromopsis inermis,* the sociology of the species remains unclear.

It is uncommon that *Geranium pratense* appears as the diagnostic for the class Trifolio-Geranietea. In other regions of Europe it is mostly referred as a character species of the alliance Arrhenatherion, class Molinio-Arrheantheretea [1; 3; 4; 6; 7]. In the current database the species is more frequent in fringe vegetation (15% of the fringe relevés) than in mesophilous grasslands (3% of the class Molinio-Arrhenahteretea relevés). Nevertheless, the diagnostic capacity of *Geranium pratense* should be investigated further, especially because the frequency of occurrences of the species slightly decreases in Latvia from the east to the west (Табака и др. 1988; Gavrilova 2004), but it is rather atypical for all other Arrhenatherion species (for example, *Arrhenatherum elatius, Crepis biennis, Pastinaca sativa*) which frequency decreases in the direction from the west to the east.

Quercus robur is present as seedlings in most cases in the relevés of the database. As it is shown by Walker et al. (2003) also information on structure such as vertical layering of vegetation or life form spectra is of high importance for classification of forest/non-forest ecotones besides floristical features. So the occurrence of broad-leaved tree seedlings is helpful for delimitation of fringe communities.

Several fringe character species (*Astragalus glycyphyllos, Clinopodium vulgare, Lathyrus sylvestris, Anemone sylvestris, Seseli libanotis*) which are common both in Central Europe and in Latvia do not appear as such in the current paper. It can be explained by the rather small number of relevés in the fringe cluster and not with any differences in ecology of species comparing to Central Europe.

A different situation is with *Medicago falcata* which is treated as a character species of the class Trifolio-Geranietea by several authors [1; 3; 4]. In Latvia *Medicago falcata* is common in the class Festuco-Brometea (51 relevé) as well as in the class Molinio-Arrhenatheretea (28 relevés). It forms also almost monodominant derivate communities with unclear syntaxonomical status (29 relevés with *Medicago falcata* as dominant were omitted from the analysis because they did not include any SSG). So *Medicago falcata* can not be used as a diagnostic species at the class level.

Diagnostic species of the class Festuco-Brometea order Brometalia

17 out of 26 diagnostic species of the class Festuco-Brometea relevés are referred as the diagnostic also for other regions of Europe. In Latvia only the most mesophilous part of the class (alliance Bromion) is present. So it is not surprising that several species (*Cirsium acaule, Primula veris*) diagnostic for the alliance Bromion in Central Europe became diagnostic for the class in Latvia.

Analysing overall diagnostic capacity of these 17 species in European context it is evident that most of them are weak diagnostic species. Some of them (*Carlina vulgaris, Poa compressa, Plantago media*) are mentioned only in one, some (*Briza media, Phleum phleoides*) – in two literature sources (Table 4). The same appears within the current database – the highest u-value is only 15.5 (but for other classes it ranges from 16.9 to 27). For example, a weak diagnostic species is *Pimpinella saxifraga*- its frequency reaches 40% also in the cluster of the class Molinio-Arrhenahteretea, but in the class Koelerio-Corynephoretea – even 55%; there are some more such species – C*entaurea scabiosa, Galium verum, Briza media*. In my opinion, with the same importance as the floristic composition also the dominance of diagnostic species should be involved when delimiting communities of the class Festuco-Brometea.

Poa angustifolia should not be used as the class Festuco-Brometea diagnostic species. With almost the same frequency and u-values it is present both in the class Festuco-Brometea and Koelerio-Corynephoretea (65%, u_{hyp} = 8.7 un 63%, u_{hyp} = 6.5, respectively). Moreover, according to the Indicator Value Index (which takes the dominance of the species into account) it appears to be the diagnostic for the class Koelerio-Corynephoretea. It is true when considering the dominance tendency of the species, because it is a frequent dominant in dry sandy grasslands of the alliance Plantagini-Festucion in Latvia (Jermacāne 2000). Dierssen (1996) mentions it as characteristic dominant species for the same alliance in Northern Europe.

Several species are closely connected both with the class Festuco-Brometea and the class Trifolio-Geranietea. *Fragaria viridis* has the highest u-value (15.5) in the class Festuco-Broemetea. It has positive u-value also for the class Trifolio-Geranietea (4.0). *Agrimonia eupatoria* has almost the same diagnostic capacity for fringe as well as for dry calcareous communities (u_{hyp} = 11.4 and 10.3). *Campanula rapunculoides* and *Fragaria vesca* exceeds the threshold u-value of 6.0 for the class Festuco-Brometea, too. *Veronica teucrium* and *Origanum vulgare* has a high frequency and positive u-value both in fringe communities and in dry calcareous grasslands. All the mentioned species are referred as character species of the class Trifolio-Geranietea in Europe (Table 4).

Occurrence of fringe species in calcareous grasslands are associated with the abandonment of grasslands that leads to expansion of fringe species and driving the community to the forest (Dierschke, 1993; Jandt, 1999).

In Latvia, this opinion can not explain the observed patterns. *Fragaria viridis* is the ninth most constant and the second most frequently dominating species in the data set of the class Festuco-Brometea cluster – so it is considered to be faithful diagnostic species of the class. Also in Northern Europe the species is particularly characteristic for dry calcareous grasslands and even the community *Fragario viridis-Helictotrichetum* is described (Hallberg, 1971). *Origanum vulgare, Agrimonia eupatoria* and especially *Fragaria vesca* are very frequent in dry calcareous grasslands of Eastern Latvia. Most of these grasslands are mowed and/or grazed until now. So this pattern is maintained due to climatic conditions rather than by management cessation.

Daucus carota and *Knautia arvensis* are mostly the character species of Arrhenatheretalia and Arrhenatherion [1; 3; 4; 5; 7]. They have positive u-values (for both species u_{hyp} = 8.4) only in the class Festuco-Brometea cluster in the current database. According to Hulten, Fries (1986) *Daucus carota* is growing close to the eastern border of its distribution range in Latvia. It is possible that this species changes its ecology and sociology on the border of distribution, but there are no detailed investigations carried out on this question.

Astragalus danicus has double nature in Latvia. In the Abava River valley it appears as typical dry grassland species, but in other parts it grows mostly in man-made habitats – roadverges and railway embankments (Fatare 1992; Табака, Клявиня 1981). In Central Europe it is supposed to be a character species of subcontinental calcareous grasslands of the order Festucetalia valesiacae, alliance Cirsio-Brachypodion [1; 5; 7]. So the occurrence of the species in Latvian calcareous grasslands indicates some affinities of these communities to subcontinental Festucetalia valesiacae communities.

Sesleria caerulea is very plastic in relation to moisture, but it strongly requires calcareous soils. Therefore, it is common both in moist Molinion and dry Bromion grasslands as well as in wet Caricion davallianae calcareous fens. So the species can be used as diagnostic for the class Festuco-Brometea only within the mesophilous and xerophilous grassland vegetation.

Diagnostic species of the class Koelerio-Corynephoretea, order Festuco-Sedetalia

Analysis yielded 29 diagnostic species. The most of them are character species of the class Koelerio-Corynephoretea and order Festuco-Sedetalia (rarely also Corynephoretalia) and alliance Plantagini-Festucion (rarely also Koelerion glaucae) in Europe (Table 3). Some of delimited diagnostic species have somewhat ruderal character. *Berteroa incana, Vicia hirsuta, Oenothera biennis* and *Vicia tetrasperma* occur more commonly in thermophilous ruderal communities such as the class Artemisietea vulgaris order Onopordetalia. Therefore without broader phytosociological investigations these species can not be included into the diagnostic species group of the class Koelerio-Corynephoretea.

Festuca ovina and *Deschampsia flexuosa* have high u-value both in the class Koelerio-Corynephoretea and Calluno-Ulicetea, Indicator value index for these species shows their close affinity to the class Calluno-Ulicetea. So these species can not be used as diagnostic at the class level.

Armeria maritima is a character species of saline marshes (the class Asteretea tripolii, alliance Armerion maritimae) [1; 2; 3]. This data set contains only relevés from Vecdaugava where the species abundantly grows in sandy grasslands, so this species can be considered as diagnostic only for the current data set.

From species named as character species for this class at least in three literature sources used in current comparison only four species do not appear as diagnostic in Latvia's data set. *Androsace septentrionalis* is represented only in one relevé and *Myosotis micrantha* in eight relevés. Possibly, these species are found more frequently in dry grasslands in Latvia but their frequency is underestimated due to their phenology – they are spring ephemera disappearing already in June. Other two species are more frequent (*Helichrysum arenarium* in 20 relevés and *Trifolium campestre* in 22 relevés) but they are distributed with the same constancy both in the class Koelerio-Corynephoretea and Festuco-Brometea.

Diagnostic species of the class Molinio-Arrhenatheretea order Arrhenatheretalia

The class Molinio-Arrhenatheretea is the most representative grassland vegetation in Latvia and it contains the highest number of relevés in this data set. Consequently, the number of diagnostic species is the highest – 53 species. All of them with exception of *Carex pallescens, Potentilla anserina, Luzula campestris, Rumex crispus, Carex leporina, Carex panicea, Hypericum maculatum, Cirsium heterophyllum* and *Cirsium arvense* are widely used as diagnostic for the class Molinio-Arrhenatheretea and lower syntaxa.

Carex pallescens, Luzula campestris, and *Hypericum maculatum* have been discussed in previous sections. *Rumex crispus* and *Cirsium arvense* are ruderal species, so they are diagnostic for the class Molinio-Arrhenatheretea only in the current data set.

Several species, for example, *Filipendula ulmaria, Geum rivale, Ophioglossum vulgatum, Carex panicea* etc., have their ecological optimum in hygrophylous part of the class (order Molinietalia) or even in low sedge communities. So complementing the data base with relevés of corresponding vegetation will result in decreasing of diagnostic capacity of these species in the class level.

Some species traditionally used as the diagnostic for the class Molinio-Arrhenatheretea can not be used as such in Latvia. *Achillea millefolium* (as class character species used in 1; 5; 7) has positive but very low u-value and high frequencies in three classes – Molinio-Arrhenatheretea (u_{hyp} = 1.8; frequency 76%), Koelerio-Corynephoretea (u_{hyp} = 2.4; frequency 79%) and Festuco-Brometea (u_{hyp} = 1.6; frequency 76%). The same situation is with *Festuca rubra* (as class character species mentioned in 4; 5; 7) and *Galium album* (as Arrhenatherion character species mentioned in 1; 3; 5, Arrhenatheretalia – 4; 6).

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Mezofīto un kserofīto zālāju augu sabiedrību diagnostiskās sugas Latvijā

Kopsavilkums

Līdz šim Latvijas zālāju augu sabiedrību klasifikācijā izmantoja diagnostisko sugu kopas, kas bija izdalītas un lietotas citos Eiropas reģionos. Tomēr pēdējo gadu Eiropas mēroga fitosocioloģiskie pētījumi ir pierādījuši, ka bez atbilstošas ģeogrāfiskas un ekoloģiskas analīzes diagnostisko sugu kopas nedrīkst pārņemt no viena reģiona un lietot cita reģiona veģetācijas pētījumos. Tās katrā reģionā ir jāizdala, izmantojot formalizētas un atkārtojamas metodes un pamatojoties uz plašu un reprezentatīvu datu materiālu.

Šajā rakstā diagnostiskās sugas nodalītas, izmantojot 1373 mezofīto un kserofīto zālāju veģetācijas aprakstu datu bāzi. Vispirms ar datorprogrammas JUICE (tās pamatā ir H. Bruelhaides u-vērtības algoritms) izveidotas socioloģiskās sugu grupas (kopskaitā 23). Šo grupu loģiskas kombinācijas izmantotas, lai sagrupētu veģetācijas aprakstus lielākās fitosocioloģiskās vienībās – klasē *Molinio-Arrhenatheretea* (rinda *Arrhenatheretalia*), *Calluno-Ulicetea* (rinda *Nardetalia*), *Trifolio-Geranietea* (rinda *Origanetalia vulgaris*), *Koelerio-Corynephoretea* (rinda *Festuco-Sedetalia*) un *Festuco-Brometea* (rinda *Brometalia*). Katrai augu sugai aprēķināta u-vērtība un indikatorvērtības indekss. Sugas, kurām u-vērtība pārsniedza 6.0 slieksni, izdalītas kā diagnostiskas sugas. Rezultātā klasei *Calluno-Ulicetea* noteiktas 10 diagnostiskas sugas, klasei *Trifolio-Geranietea* – 8 sugas, klasei *Festuco-Brometea* – 26 sugas, klasei *Koelerio-Corynephoretea* – 28 sugas un klasei *Molinio-Arrhenatheretea* – 53 sugas. Vairākas sugas var izmantot kā diagnostiskas klases un rindas līmenī tikai šajā rakstā izmantotā datu masīva ietvaros. Šie gadījumi rakstā apskatīti detālāk.

Atslēgvārdi: diagnostiskas sugas, dabisko zālāju veģetācija, klase, Brauna-Blankē metode, socioloģiskā sugu grupa.

96.–111. lpp.

New fen communities in Latvia
Jaunas zāļu purvu sabiedrības Latvijā

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The floristic composition and ecology of rich and moderately rich fen communities found in limnogenous mires in Latvia were studied. Five plant communities were obtained in a cluster analysis used in vegetation data classification. An indicator species analysis was applied to describe plant communities and determine the best indicator species for each community. Three new associations for Latvia, Caricetum buxbaumii, Chrysohypno-Trichophoretum alpini and Eleocharitetum quinqueflorae and two already known associations, Caricetum lasiocarpae and Schoenetum ferruginei, were distinguished. Caricetum buxbaumii was mainly found in rich fens in the Coastal Lowland like Schoenetum ferruginei, while Chrysohypno-Trichophoretum alpini and Eleocharitetum quinqueflorae occurred in moderately rich fens throughout Latvia. The Ellenberg indicator values were used to study the ecological differences among the plant communities. Results of the canonical correspondence analysis (CCA) indicated that differences among the five fen communities are determined mainly by soil reaction (R), nitrogen content (N), and supported by such factors as moisture (F), light (L) and climate (K).

Keywords: Ellenberg indicator values, fen vegetation.

Nomenclature: Gavrilova & Šulcs and Pētersone & Birkmane for vascular plants (Pētersone, Birkmane 1980; Gavrilova, Šulcs 2000), Āboliņa for bryophytes (Āboliņa 2001) and for syntaxa – Dierssen (Dierssen 1996; Ellenberg 1996).

Introduction

A common goal in a community analysis is to describe different communities and identify species characteristic for each community, for which purpose indicator species analysis can be used. Indicator species analysis combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. So it is based on concepts of both abundance and frequency. The indicator values range from zero (no indication) to 100 (perfect indication) (Dufrêne, Legendre 1997). If compared to the traditional Central European vegetation classification, statistically significant indicators with the highest indicator values can be compared with the characteristic species of an association.

Descriptive vegetation studies are often supported by an analysis of environmental factors, such as soil reaction, soil chemical analysis etc. The Ellenberg indicator values are used in studies of plant or plant community responses to different factors when the direct environmental data is lacking or in case study aims to compare the results of direct measurements and results based on the calculations of the Ellenberg indicator values (Diekmann, Dupré 1997; Dupré, Diekmann 1998; Schaffers, Sykora 2000; Exner et al. 2002; Chytry et al. 2003). The Ellenberg indicator values can be successfully used in Central Europe, also in Latvia for forests and grasslands (Bambe, 2002; Jermacāne 2002; Kreile 2002), but they should be calibrated for regions outside Central Europe (Hawkes et al. 1997; Lawesson et al. 2003). And what is more, the latest findings suggest using the Ellenberg indicator values for comparison only within one vegetation type (Wamelink et al. 2002).

Mire vegetation has been studied in Latvia since the 1990-ies, but still the list of mire communities is not complete and little is known about the ecology of mire communities in Latvia. The limnogenous mire vegetation has been studied from 2000 until 2003. The limnogenous mires are mires, where the water supply is caused by inundation from rivers and lakes (Økland 1989). I studied the limnogenous mires of lake origin. Despite their small size, they often comprise a high diversity of plant species, including rare ones (Zimmerli 1989; Pakalne et al. in press).

The aim of the study is to describe and analyse rich fen and moderately rich fen communities of the limnogenous mires in Latvia and determine the main factors responsible for the differences in species composition among plant communities.

Materials and methods

Site characteristics

The fen vegetation of 14 limnogenous mires was studied. The limnogenous mire vegetation depends largely on the lake biolimnological type (Mäemets 1997) and water chemical composition. Six lakes, Engure, Liepāja, Kaņieris, Dreimaņa, Baltezera, and Dūņieris lakes respectively, are eutrophic lakes with high calcium concentration in the water, and three lakes, Slokas, Pelcenes, and Aizdumbles lakes are dyseutrophic (http://www.ezeri.lv), while nothing is known on lake chemical composition of Koškina, Mazais Kugriņu, Pētera, Pūrics, and Tauns lakes. All lakes, except Koškina Lake (mean depth 5.8 m) are shallow (mean depth 0.3–2.8 m) (http://www.ezeri.lv). The studied lakes are located in the following geobotanical regions: Coastal Lowland, West Latvia, South-East Latvia, East Latvia, Central Vidzeme and North Vidzeme geobotanical region (Fig. 1).

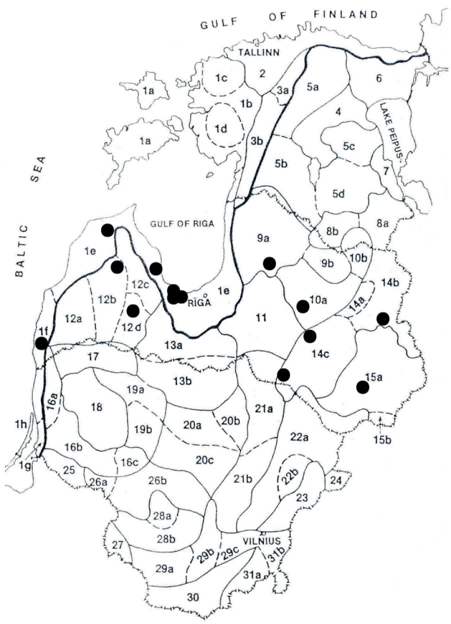
Data sampling and analysis

The stratified random sampling (Kent, Coker 1992) followed by the Braun-Blanquet approach (Mueller-Dombois, Ellenberg 1974) (relevés of 1 m^2 size in the floristically homogeneous area) was used in the vegetation data sampling. All of the vascular plant and moss species were recorded, estimating their approximate cover in percentage.

For vegetation classification a cluster analysis (Lance, Williams 1967, 1968) was used. The Sørensen distance and flexible beta ($\beta = -0.25$) were used for grouping of relevés. Seven initial groups were chosen.

Figure 1

Location of the study sites. Map of geobotanical districts in Baltic countries (after Laasimer et al. 1993)



The final data set included 175 relevés and 119 species. The indicator species analysis (Dufrêne, Legendre 1997) by means of PC ORD 4 was used to describe the groups and determine the best indicator species for each group. All 119 species were used in indicator species analysis. A synoptic table was made by means of MEGATAB (Hennekens 1996). The mean Ellenberg indicator values (Ellenberg et al. 1992) for each reléve were calculated. The association between species composition and mean Ellenberg indicator values were examined using a canonical correspondence analysis (Cajo, ter Braak 1987; Palmer 1993). The main matrix included 175 relevés and 119 species and the second – 175 relevés and six of the mean Ellenberg indicator values (moisture, soil reaction, nitrogen content, light, and continentality) for each relevé. Scores for vegetation relevés are derived from the scores of species and are weighted according to average (WA) scores. The null hypothesis, that there is no relationship between matrices was tested using the Monte Carlo test.

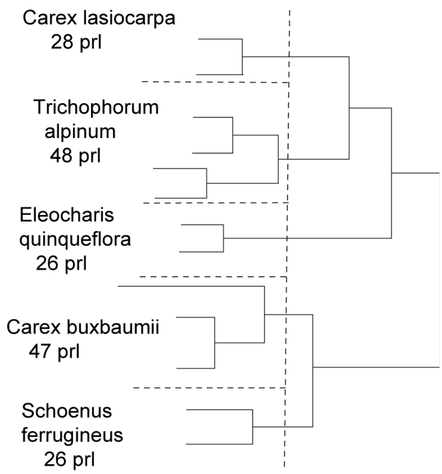
Results

Vegetation classification

Five end groups of relevés were distinguished from seven initial groups (Fig. 2). The dendrogram was cut at the level when 37% of information remained. The end groups were as follows (after the dominant species): *Carex buxbaumii* community (Group I, 47 relevés), *Eleocharis quinqueflora* community (Group II, 26 relevés), *Trichophorum alpinum* community (Group III, 48 relevés), *Schoenus ferrugineus* community (IV, 26 relevés), and *Carex lasiocarpa* community (V, 28 relevés). Species richness was largest in the *Trichophorum alpinum* community, where the mean species richness was 16, followed by *Schoenus ferrugineus* (13.8), *Eleocharis quinqueflora* (13.5), *Carex lasiocarpa* (12.4), and *Carex buxbaumii* (11.5) communities.

Figure 2

Dendrogram showing five end groups obtained in cluster analysis



Plant communities

Indicator species analysis (Dufrêne, Legendre 1997) showed that the *Carex buxbaumii* and *Calliergonella cuspidata* species had the highest indicator values for Group I (Table 1). Statistically significant indicators were also *Lysimachia vulgaris* ($p < 0.0030$) and *Scorzonera humilis* ($p < 0.0020$). The group was assigned to the association of Caricetum buxbaumii and eight rare and protected plant species were found in this plant community (App. 1). Cluster homogeneity was 0.40. The *Carex buxbaumii* community covered small areas in the fens and are formed in the process of terrestrialization of lakes with high a calcium content, such as Engure, Liepāja, Sloka, and Kaņieris lakes in the Coastal Lowland, and on peninsula of Dreimaņu Lake consisting of the calcareous gyttja in eastern Latvia. It occurred together with the *Carex lasiocarpa, Carex elata*, and *Schoenus ferrugineus* communities.

Group II had six highly significant indicators, such as *Eleocharis quinqueflora, Drosera anglica, Scorpidium scorpioides, Carex bergothii,* and *Calliergon trifarium* (Table 1). *Eleocharis quinqueflora* had the highest indicator value (99) and is a characteristic species of the community. Cluster homogeneity was 0.57. This plant community was found in depressions surrounded by other limnogenous mire communities, such as *Carex lasiocarpa, Carex elata, Cladium mariscus* and *Trichophorum alpinum* communities. Consequently, species preferring wet conditions, such as *Scorpidium scorpioides, Utricularia intermedia* and *Utricularia minor* were found in abundance there. The group was assigned to the association Eleocharitetum quinqueflorae, and four rare and protected plant species were present in this plant community (App. 2). The *Eleocharis quinqueflora* community was found in three limnogenous mires (Engure, Pelcene and Pūrics lakes) where it occupied small depressions among other fen communities. Only in the fen of Engure Lake it formed in areas up to several square meters.

The best indicators for the *Trichophorum alpinum* community were *Trichophorum alpinum, Oxycoccus palustris, Andromeda polifolia*, *Equisetum fluviatile*, and *Carex limosa* (Table 1) and it was assigned to the association Chrysohypno-Trichophoretum alpini. The community occupied quite remarkable areas of limnogenous mires of Pūrica, Aizdumble, Pelcene, Pētera, Baltezera, and Tauns lakes and supported ten rare and protected plant species (App. 3). The cluster homogeneity was 0.30. The *Rhynchospora alba, Carex lasiocarpa* and *Eleocharis quenquiflora* communities were the next laying communities. The *Trichophorum alpinum* community formed both hummocks and lawns. In the first case the basophilous *Sphagnum* species dominated in the moss layer, but in the second – brown mosses, such as *Scorpidium scorpioides, Drepanocladus revolvens* and *Campylium stellatum*.

Group IV represents a rich fen community with *Schoenus ferrugineus,* and the best indicators were as follows: *Schoenus ferrugineus, Campylium stellatum, Drepanocladus revolvens,* and *Parnassia palustris*. It was assigned to the association of Schoenetum ferruginei where *Schoenus ferrugineus* is the dominant and characteristic species and determines the physiognomy of the community. The cluster homogeneity was 0.61. The community occupied quite remarkable areas of rich fens together with *Carex buxbaumii, Carex lasiocarpa* and *Carex elata* communities at Liepājas, Kaņieris and Dūņieris lakes. The number of rare plant species in *Schoenus ferrugineus* community reached eleven (App. 4).

Group V encompasses fen vegetation with *Carex lasiocarpa,* and the best indicators were *Carex lasiocarpa, Menyanthes trifoliata, Salix rosmarinifolia, Calliergon giganteum*, and *Peucedanum palustre* (Table 1). The cluster homogeneity was 0.29. *Carex lasiocarpa* community was distinguished at Liepājas, Mazais Kugriņu and Koškina lakes. Like in the *Trichophorum alpinum* community, ten rare and protected plant species were found in the *Carex lasiocarpa* community (App. 5). The studied *Carex lasiocarpa* community belonged to a moderately rich fen and rich fen vegetation, and three bryophyte synusiae reflecting site conditions were distinguished. They were as follows: *Scorpidium scorpioides* synusia (wet and calcium-rich sites), *Hamatocaulis vernicosus – Cinclydium stygium* synusia (moderately wet and moderately acid), and *Drepanocladus revolvens* synusia (moderately wet and basic), respectively. However, only *Hamatocaulis vernicosus* and *Cinclydium stygium* turned out to be a statistically significant indicator species for the *Carex lasiocarpa* community.

Besides the differences in floristical composition among the five plant communities, there were species, which they all had in common, such as *Scorpidium scorpioides, Drepanocladus revolvens, Campylium stellatum, Bryum pseudotriquetrum, Eriophorum angustifolium*, *Peucedanum palustre*, and *Carex panicea,* and only their frequency and coverage differed among the plant communities (Table 2).

Table 1

Indicator species of five end clusters

The number is the percentage of perfect indication (IV)

	IV	**Mean**	**St. Dev**	***p***
Group I				
Carex buxbaumii	95.7	11.8	2.9	0.0010
Calliergonella cuspidata	30.3	10.9	3.83	0.0030
Group II				
Eleocharis quinqueflora	99	9.4	2.67	0.0010
Scorpidium scorpioides	54.6	14.9	2.99	0.0010
Drosera anglica	44.7	9.9	2.90	0.0010
Carex bergothii	32.8	4.4	2.19	0.0010
Calliergon trifarium	27.2	5.5	2.30	0.0010
Group III				
Trichophorum alpinum	93.8	13.2	2.81	0.0010
Oxycoccus palustris	73.5	17.3	4.07	0.0010
Andromeda polifolia	38.1	10.4	2.62	0.0010
Equisetum fluviatile	35.4	5.7	2.29	0.0010
Carex limosa	32.8	9.8	3.60	0.0010
Group IV				
Schoenus ferrugineus	95.7	9.3	2.76	0.0010
Campylium stellatum	50.1	20.3	2.93	0.0010
Drepanocladus revolvens	41	19.2	3.14	0.0010
Parnassia palustris	39.1	6	2.24	0.0010
Eriophorum latifolium	37.3	6.2	2.25	0.0010
Ctenidium molluscum	30.8	4.3	2.15	0.0010
Potentilla erecta	29.5	10.1	2.61	0.0010
Primula farinosa	29.3	4.6	1.90	0.0010
Equisetum variegatum	28.3	4.5	2.11	0.0010
Group V				
Carex lasiocarpa	88.2	14	2.88	0.0010
Menyanthes trifoliata	33.9	12.7	2.65	0.0010
Salix rosmarinifolia	33.6	7.2	2.37	0.0010
Calliergon giganteum	33.3	5.1	2.18	0.0010
Peucedanum palustre	32.4	12.6	2.7	0.0010
Hamatocaulis vernicosus	27.8	5.1	2.35	0.0010
Cinclydium stygium	26.5	11.2	3.04	0.0020

Table 2

Synoptic table of studied plant communities

	1	2	3	4	5
Number of relevés	26	26	47	48	28
Ch1 Eleocharis quinqueflora	V (43	II (1)	r (1)	+ (2)	r (1)
Ch1 Drosera anglica	III (11)	.	.	II (2)	III (1)
Ch1 Scorpidium scorpioides	V (60	III (5)	II (29	II (32	III (21
Ch1 Calliergon trifarium	II (4)	.	.	I (1)	r (1)
Ch1 Carex bergotii	II (1)	.	.	r (1)	.
Ch2 Schoenus ferrugineus	.	V (9)	II (1)	.	I (1)
Ch2 Drepanocladus revolvens	IV (4)	V (32	III (4)	III (18	III (50
Ch2 Campylium stellatum	V (5)	V (23	V (10	III (7)	II (16
Ch2 Primula farinosa	.	II (1)	r (1)	r (1)	.
Ch2 Parnassia palustris	.	III (1)	.	I (1)	r (1)
Ch2 Ctenidium molluscum	.	II (3)	.	.	.
Ch2 Potentilla erecta	.	IV (1)	II (1)	II (2)	+ (1)
Ch2 Eriophorum latifolia	I (1)	III (1)	r (1)	.	.
Ch2 Equisetum variegatum	+ (1)	II (1)	.	.	.
Ch3 Carex buxbaumii	.	II (2)	V (17	.	I (2)
Ch3 Calliergonella cuspidata	.	I (2)	III(8)	I (18	I (2)
Ch4 Trichophorum alpinum	III (2)	.	.	V (25	II (3)
Ch4 Oxycoccus palustris	IV (2)	.	.	V (8)	III (3)
Ch4 Carex limosa	+ (1)	.	.	III (3)	II (1)
Ch4 Andromeda polifolia	II (1)	.	.	IV (1)	II (1)
Ch4 Equisetum fluviatile	.	.	.	II (1)	.
Ch5 Carex lasiocarpa	II (1)	.	II (1)	III (1)	V (10
Ch5 Cinclydium stygium	IV (10	.	.	II (31	III (41
Ch5 Menyanthes trifoliata	III (3)	.	.	IV (4)	IV (6)
Ch5 Calliergon giganteum	.	.	r (5)	r (1)	II (2)
Ch5 Peucedanum palustre	I (1)	I (1)	III (1)	II (2)	IV (1)
Ch5 Hamatocaulis vernicosus	.	.	.	+ (24	II (39
Ch5 Salix rosmarinifolia	r (1)	I (1)	+ (1)	I (1)	III (2)
Ch. Order *Caricetalia davalianae*					
Carex lepidocarpa	I (1)	.	II (1)	III (1)	II (2)
Carex panicea	II (1)	IV (1)	IV (1)	II (4)	II (1)

Bryum pseudotriquetrum	II (1)	II (1)	I (1)	II (1)	III (1)
Aneura pinguis	III (1)	.	r (1)	II (1)	II (1)
Liparis loeselii	+ (1)	r (1)	.	r (1)	I (1)
Epipactis palustris	r (1)	I (1)	I (1)	II (2)	+ (2)
Juncus alpino-articulatus	r (1)	I (1)	II (1)	r (1)	r (1)
Dactylorhiza incarnata	.	+ (1)	I (1)	r (1)	II (1)
Triglochin palustre	I (1)	r (1)	+ (1)	.	r (1)
Fissidens adianthoides	I (1)	III (1)	II (3)	I (3)	.
Ch. Class *Scheuchzerio-Caricetea nigrae*,					
Order *Scheuchzerietalia palustris*, Alliance *Caricion lasiocarpae*					
Comarum palustre	r (2)	.	I (1)	II (1)	II (2)
Eriophorum angustifolium	+ (1)	II (1)	III (1)	II (1)	III (1)
Carex diandra	.	.	.	+ (1)	II (1)
Ch. Alliance *Magnocaricion elatae*					
Carex rostrata	II (1)	.	I (1)	I (1)	r (1)
Carex elata	II (3)	I (1)	r (1)	.	+ (1)
Lycopus europaeus	r (1)	.	r (1)	r (1)	r (1)
Galium palustre	I (1)	I (1)	I (1)	.	I (1)
Ch. Class *Phragmitetea, Alliance Phragmition*					
Scutelaria galericulata	I (1)	.	+ (1)	r (1)	r (1)
Phragmites australis	IV (4)	IV (1)	III (1)	I (6)	r (1)
Cladium mariscus	r (2)	r (1)	.	.	.
Ch. Class *Utricularietea intermedio-minoris*					
Utricularia minor	IV (3)	.	.	II (1)	r (1)
Utricularia intermedia	IV (5)	I (1)	.	II (2)	r (1)
Sphagnum contortum	.	.	.	r (31	r (6)
Sphagnum warnstorfii	.	.	.	II (69	.
Drepanocladus aduncus	.	I (2)	I (7)	.	II (3)

1 – *Eleocharitetum quinqueflorae*
2 – *Schoenetum ferruginei*
3 – *Caricetum buxbaumii*
4 – *Chrysohypno-Trichophoretum alpini*
5 – *Caricetum lasiocarpae*

Ch – characteristic species of associations, alliances, orders and classes
Only the most common species are included. For full species lists see Appendices.

Syntaxonomy

According to the Central European vegetation classification system, associations Eleocharitetum quinqueflorae Lüdi 21, Caricetum buxbaumii Issl. 32, Schoenetum ferruginei Du Rietz 1925, and Chrysohypno-Trichophoretum alpini Hadač 1967 were included in the Class Scheuchzerio-Caricetea fuscae (Nordhagen 1936; R. Tx. 1937), Order Caricetalia davallianae Br.-Bl. 49, Alliance Caricion davallianae Klika 34, but the association Caricetum lasiocarpae Osvald 23 was included in the Class Scheuchzerio-Caricetea fuscae (Nordhagen 1936) R. Tx. 1937), Order Caricetalia nigrae (Koch 26) Nordh. 36 emend. Br.-Bl. 49, Alliance Caricion lasiocarpae van den Berghen ap. Lebrun *et al*. 49 (Dierssen 1982). Three variants based on bryophyte synusiae, namely *Scorpidium scorpioides*, *Hamatocaulis vernicosus – Cinclydium stygius*, and *Drepanocladus revolvens* could be distinguished, but in my opinion more data should be analysed for objectivity. Associations Caricetum buxbaumii and Eleocharitetum quinqueflorae clearly showed their affinity to the alliance Caricion davallianae in studied limnogenous mires due to significant presence of many calcicolous species characteristic for this alliance, but Chrysohypno-Trichophoretum alpini had also many species of alliance Caricion lasiocarpae besides species of Caricion davallianae (Table 2), thus showing an intermediate syntaxonomical position. Nevertheless, I followed Steiner and Dierssen (Steiner 1993; Dierssen 1996) and assigned Chrysohypno-Trichophoretum alpini to Caricion davallianae.

Correlation between plant community data and Ellenberg indicator values

The Monte Carlo test results indicated that the null hypothesis, no correlation between the matrices, is to be rejected ($p < 0.05$) (Table 3).

Table 3

Monte Carlo tests results for eigenvalues and species – environment correlations based on 99 runs with randomised data

Montekarlo testa rezultāti – korelācija starp sugām un vides faktoriem

Axis	Real data	Mean	Randomized data		
			Minimum	Maximum	*p*
Eigenvalue					
1	0.471	0.098	0.054	0.188	0.0100
2	0.458	0.063	0.038	0.103	
Spp-Envt Correlations					
1	0.797	0.431	0.347	0.672	0.0100
2	0.838	0.380	0.279	0.468	

The first two CCA axes were interpreted and the proportion of variances explained were 6.9 for Axis 1 and 6.7 for Axis 2. The first canonical axis was most strongly associated with soil reaction and nitrogen content (Table 4, Fig. 3.) and all the relevés of *Schoenus ferrugineus, Carex buxbaumii* and *Eleocharis quinqueflora* communities representing vegetation found in the most basic soils was placed at the left part of diagram, but *Trichophorum alpinum* community encompassing different *Sphagnum* species – at the furthest right part (Fig. 3).

Table 4

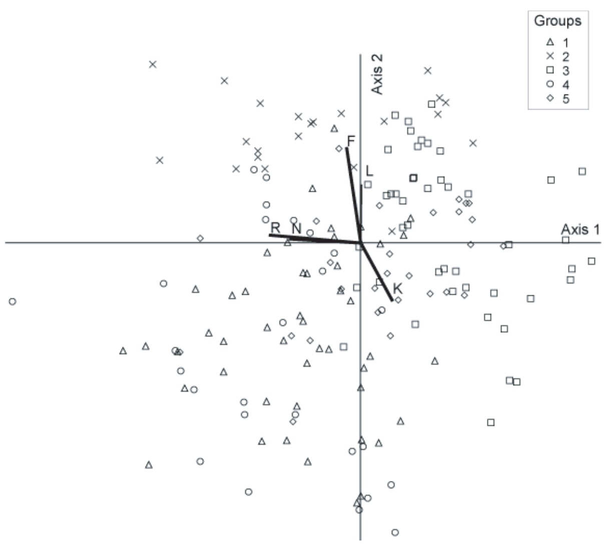
Intra-set correlations of six Ellenberg indicator values with canonical correspondence analysis (CCA) axes 1–2

Variable	Axis 1	Axis 2
L – light	0.010	**0.555**
T – temperature	0.242	– 0.016
K – continentality	0.300	**– 0.550**
F – moisture	– 0.135	**0.910**
R – soil reaction	**– 0.861**	0.076
N – nitrogen content	**– 0.666**	0.038

Intra-set correlations of Ellenberg indicator values with canonical correspondence analysis (CCA) axes 1 and 2.

Figure 3

Canonical correspondence analysis (CCA) biplots of six Ellenberg indicator values in relation to five plant communities (axes 1 and 2)



F – moisture, R – soil reaction, N – nitrogen content, L – light, K – continentality

1 – *Caricetum buxbaumii*; 2 – *Eleocharitetum quinqueflorae*; 3 – *Chrysohypno-Trichophoretum alpini*; 4 – *Schoenetum ferruginei*; 5 – *Caricetum lasiocarpae*

Axis 2 was positively correlated with the moisture and light and negatively correlated with continentality (Table 4, Fig. 3). *Eleocharis quinqueflora* community had the highest positive scores and the *Schoenus ferrugineus* community and *Carex buxbaumii* community – the lowest negative scores on Axis 2 (Fig. 3). *Carex lasiocarpa* community encompassed the central part of the diagram.

Discussion

The study revealed two already known associations for Latvia and three new ones, namely Eleocharitetum quinqueflorae, Caricetum buxbaumii and Chrysohypno-Trichophoretum alpini. The presence of the associations Eleocharitetum quinqueflorae, Caricetum buxbaumii and Chrysohypno-Trichophoretum alpini in Latvia was not a surprise as they are distinguished in Estonia and Lithuania (Balaviciene 1991, Paal *et al.* 1998). Despite the fact that *Eleocharis quinqueflora* is quite common in Latvia (Tabaka *et al.* 1988), the plant community was distinguished only in three limnogenous mires and it can be considered as a rare plant community in Latvia. It is a rare plant community also in Lithuania (Balaviciene 1991). Dierssen (1982) distinguishes two variants of the Eleocharitetum quinqueflorae in northern Europe – one with *Scorpidium scorpioides* and another with *Drepanocladus revolvens* as a dominant species in moss layer. Latvia`s examples are similar to var. *Scorpidium scorpioides,* which represents the wettest variant of the association and to the Ass. Scorpidio-Eleocharitetum quinqueflorae Succ. 74 recorded in an overgrowing calcareous lake in Poland (Jasnowska, Jasnowski 1991). It differs from the association Carici dioicae-Eleocharitetum quinqueflorae from Scotland (Birse 1980) by lack of *Carex dioica* and absence of a number of oceanic species, e. g. *Erica tetralix* and *Narthecium ossifragum*.

The Carex buxbaumii community also is a rare fen community in Latvia (five localities). It is obvious, because the species itself has rather local and uncommon distribution in Latvia. A majority of its scattered localities are confined to the Coastal Lowland; in the rest of Latvia it is fairly rare (Baroniņa 2001). Caricetum buxbaumii is also considered to be rare in Estonia (Paal 1998). Similar to fens in northern Europe (Dierssen 1982) it was distinguished in drier parts of a fen in comparison with surrounding *Carex lasiocarpa, Carex elata* or *Schoenus ferrugineus* communities. However, seven relevés recorded in Lake Liepājas clearly were found in depressions characterised by significant cover of *Scorpidium scorpioides.* The species composition is similar to the wet variant of Caricetum buxbaumii mentioned by Dierssen (1982).

Concerning the *Trichophorum alpinum* community, it is seldom treated as an association elsewhere. Usually, it is considered to be a variant of an association, such as of Amblystegio stellati-Caricetum dioicae (Steiner 1993) or Drepanoclado-Trichophoretum (Dierssen 1992) or Chrysohypno-Caricetum lasiocarpae-trichophoretosum alpini (Klötzli 1969). Some authors still distinguish a separate association, such as Chrysohypno-Trichophoretum alpini (Hadač, Vane 1967) or Sphagno-Trichophoretum alpini (Paal *et al.* 1998). Ellenberg (1996) also refers to the association of Chrysohypno-Trichophoretum alpini as distinguished in Czechoslovakia by Rybniček (1964). This study proves that in Latvia the *Trichophorum alpinum* community clearly differs from the other communities (*Carex lasiocarpa, Rhynchospora alba,* and *Eleocharis quinqueflora* com-ies) regarding species composition and has its own characteristic species composition. Therefore, the association Chrysohypno-Trichophoretum alpini was distinguished. Still *Trichophorum alpinum* can be one of the main associates in *Carex lasiocarpa* community, but it never dominates. Two variants of Chrysohypno-Trichophoretum alpini were revealed by an cluster analysis (not presented here). The first one represented a lawn community characterised by

Scorpidium scorpioides, *Drepanocladus revolvens* and *Campylium stellatum* in a moss layer (Pūrics, Baltezers and Pelcene lakes), but the second represented a hummock community with basophilous *Sphagnum* species, such as *Sphagnum warnstorfii* and *Sphagnum teres* (Aizdumble Lake) (App. 3). The second variant could be similar to the association Sphagno-Trichophoretum alpini from Estonia (Paal et al. 1998). *Trichophorum alpinum* itself is considered to be a rich fen species in northern Europe and Canada (Singsaas 1989, Dale, Chee 1994, Dierssen 1996). However, it also grows well in intermediate mires (Sjörs 1983, Moen 1985). It prefers less calcareous habitats in Latvia and Lithuania and it is rarely found in calcareous fens with *Schoenus spp.* or *Carex davalliana* (Balaviciene 1991, Tabaka et al. 1988), and was absent from the studied *Schoenus ferrugineus* and *Carex buxbaumii* communities. Like Eleocharitetum quinqueflorae and Caricetum buxbaumii, also Chrysohypno-Trichophoretum alpini is a rare plant community in Latvia.

Caricetum lasiocarpae is one of the most diverse fen communities having many sub associations or variants ranging from poor fen to rich fen vegetation (Dierssen 1992, Steiner 1993) thanks to the wide ecological amplitude of the dominant species of association *Carex lasiocarpa* (Dierssen 1982). The main difference among association subunits lies in the species assemblages in the moss layer. Species composition of the studied *Carex lasiocarpa* community with *Scorpidium scorpioides* was similar to the var. *Scorpidium scorpioides* distinguished in the north-west European mires (Dierssen 1982). Rich fen vegetation with *Carex lasiocarpa* is common and characteristic for the Coastal Lowland (Pakalne 1994), but rare outside this region, but moderately rich fen and poor fen *Carex lasiocarpa* community occurs throughout Latvia. Besides limnogenous mires, it is also quite common in topogenous mires in Latvia, and the most nutrient-poor variants can be found even in laggs.

Three *Schoenus ferrugienus* communities are distinguished in northern Europe, *Vaccinium oxycoccos-Schoenus ferrugineus* community, Ass. Schoenetum ferruginei, and Ass. Trichophoro-Schoenetum ferruginei, and the last association is found only in the boreal zone (Dierssen 1992). In Latvia only association Schoenetum ferruginei is recorded (Pakalne 1994). Because of the fact that dominant species *Schoenus ferrugineus* is a species with oceanic distribution (Meusel et al. 1965), in Latvia Schoenetum ferruginei is found mainly in the Coastal Lowland (Pakalne 1994). All the studied localities (Dūnieris, Kaņieris and Liepāja lakes) are also in the Coastal Lowland. *Schoenus ferrugineus* communities are largely restricted to calcareous districts (Tyler 1981). Together with its oceanic distribution range and loss of habitat, these communities are in the category of rare plant communities throughout Europe (Dierssen 1982, 1983, Balaviciene 1991, Pakalne 1994, Paal 1998). In Latvia, this community occupies mainly topogenous and limnogenous mires, however, it is found in soligenous mires, namely spring fens as well, e. g., in Puzuru Ravine. Just the opposite is in the central Europe and Scotland, where *Schoenus ferrugineus* community prefers soligenous mires (spring fens and flushes) (Koch 1926 in Wheeler 1983, Wheeler 1983).

The differences in floristic composition among the studied plant communities are also reflected in the ecological differences illustrated by CCA. Despite the fact, that the studied plant communities were often found together, they have different ecological requirements. The *Carex buxbaumii* community preferred mainly the driest conditions in a fen, while *Eleocharis quinqueflora* community – the wettest. These are habitat preferences mentioned also by Dierssen (1996). *Eleocharis quinqueflora* community is also the most light demanding community, as full-light or half-light plant species, such as *Scorpidium scorpioides, Drepanocladus revolvens, Campylium stellatum,* and the dominant vascular plant species in this plant community *Eleocharis quinqueflora* were abundantly found there. The *Trichophorum alpinum* community preferred the most acid and nitrogen-poor conditions, while the *Schoenus ferrugineus* community – the most basic, calcareous and nitrogen-rich (in context of this study) ones. However, the nitrogen content in mires in terms of the Ellenberg indicator values can be interpreted only regarding the nitrites, as total amount of nitrogen is found in rather equal concentrations in poor fens and rich fens (Ellenberg 1996). In most cases, soil reaction correlates positively with calcium content (Schaffers, Sykora 2000). The CCA ordination has also indicated that by placing typical calcareous plant communities at the left side of the diagram and others at the opposite side along the first axis. Geographically, *Carex lasiocarpa, Eleocharis quinqueflora*, and *Trichophorum alpinum* communities were found throughout Latvia, but *Carex buxbaumii* and *Schoenus ferrugineus* communities were concentrated in western Latvia, because they represent more oceanic plant communities.

To sum up, Caricetum buxbaumii can be considered as a typical rich fen community found mainly in the Coastal Lowland like Schoenetum ferruginei, while Eleocharitetum quinqueflorae and Chrysohypno-Trichophoretum alpini – as communities of moderately rich fens with wider distribution in Latvia. And what is more, while Caricetum buxbaumii, Eleocharitetum quinqueflorae and Chrysohypno-Trichophoretum alpini are typical limnogenous mire communities in Latvia, Schoenetum ferruginei and Caricetum lasiocarpae are not.

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Jaunas zāļu purvu sabiedrības Latvijā

Kopsavilkums

Pētīta bagāto zāļu purvu veģetācija limnogēnajos purvos Latvijā un analizēti vides faktori, kas nosaka atšķirības starp augu sabiedrībām. Veģetācijas datu klasifikācijai izmantota klāsteru analīze, kuras rezultātā tika izdalītas piecas augu sabiedrības. Tām veikta indikatorsugu analīze, lai noskaidrotu sugas, kas vislabāk raksturo katru augu sabiedrību. Augu sabiedrības pielīdzinātas šādām asociācijām – *Caricetum lasiocarpae*, *Schoenetum ferruginei*, *Caricetum buxbaumii*, *Eleocharitetum quenquiflorae* un *Chrysohypno-Trichophoretum alpini*. Pēdējās trīs asociācijas ir Latvijā izdalītas pirmo reizi. Lai noskaidrotu atšķirības augu sabiedrību ekoloģijā, tika izmantota kanoniskā korelācijas analīze (CCA), kur ekoloģiskos faktorus atspoguļoja Ellenberga indikatorvērtības. Datu analīze liecina, ka augsnes reakcija, slāpekļa daudzums, mitrums, gaisma un klimats nosaka atšķirības sugu sastāvā starp pētītajām augu sabiedrībām. Asociācija *Caricetum buxbaumii* ir tipiska kaļķaino zāļu purvu sabiedrība, kas sastopama galvenokārt Piejūras zemienē līdzīgi kā *Schoenetum ferruginei*, bet *Eleocharitetum quenquiflorae* un *Chrysohypno-Trichophoretum alpini* ir vidēji ar kaļķi bagātu zāļu purvu sabiedrības ar plašāku izplatību visā Latvijas teritorijā, savukārt *Caricetum lasiocarpae* ir augu sabiedrība ar plašu ekoloģisko amplitūdu un samērā bieži sastopama Latvijā, tomēr ir izplatības atšķirības attiecībā uz šīs asociācijas variantiem.

Atslēgvārdi: Ellenberga indikatorvērtības, zāļu purvu veģetācija.

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