Understorey Vegetation of Scots Pine Stands along a Pollution Gradient Near the Nitrogen Fertilizer Plant

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Abstract

Species composition of the understorey of Scots pine (*Pinus sylvestris* L.) forests was studied along a 9 km transect running east from a nitrogen fertilizers producer plant J/V "Achema", situated in central Lithuania. Long-term accumulation of nitrogen and sulphur in the forest ecosystems has changed plant communities. Species typical of *Vaccinio-myrtillosa* site type (e.g., *Vaccinium myrtillus*, *V.vitis-idaea*) were those that increased in cover with the distance from "Achema". Many non-typical species (*Calamagrostis epigejos*, *Chameriom angustifolium*, *Galeopsis tetrahit*, *Rubus idaeus*, *Stellaria graminea*) preferring nutrient-rich sites increased in frequency in the vicinity of "Achema". The cover of species which were indifferent to low soil pH (*Deschampsia cespitosa*, *Chelidonium majus*, *Rumex acetosella*, *Athyrium filix-femina*) was negatively correlated with the distance from "Achema". According to the comparison of average Ellenberg indicator values between the sample plots and reference level, the sample plots had become more acid and nitrogen rich.

Key words: Ellenberg indicator values, forest vegetation, nitrogen deposition, Scots pine stands, species abundance

Introduction

During recent decades, the atmospheric deposition of acidifying substances had a large impact on the environment. There are many areas where the long-term exposure of deposition, often associated with sulphur and nitrogen oxides, has damaged forest ecosystems. Most research has focused on forest stands and on the effects on tree vitality what is considered as the most prominent effect of atmospheric deposition in terrestrial ecosystems (*e.g.* Pearson and Stewart 1993, Rennenberg *et al*. 1998). Besides, atmospheric deposition also induces changes in the composition of ground vegetation (Binkley and Högberg 1997, Bobbink *et al.* 1998). Studies have related changes in forest plant species composition to the impact of air pollution and deposition of pollutants (Falkengren-Grerup 1986; Falkengren-Grerup and Eriksson 1990, Nieppola 1992, Rosén *et al.* 1992, Kellner and Redbo-Torstensson 1995, Brunet *et al.* 1997, Nygaard and ¨degaard 1999, Armolaitis and Stakenas 2001). Increased levels of acidifying substances and increasing soil acidity can lead to alterations in species composition and abundance. In addition, in some areas several species favoured by nitrogen (N) have shown an increase in frequency, while species sensitive to low pH have been negatively affected (*e.g.* Ellenberg 1988, Binkley and Högberg 1997).

In Lithuania forests are severely damaged only in the vicinities of the largest pollution sources. Local damage areas are close to the nitrogen fertilizers producer plant J/V "Achema" where many exposed and declined forests were re-planted, particularly in the intense impact zone – downwind of the plant (Armolaitis *et al.* 1999). Damaged coniferous forest zone expanded into the 20-25 km distance north-east of the plant. Dead and damaged stands composed close to 4000 ha. These forests usually grow on naturally nitrogen poor soil and are characterized by species and processes adapted to low nitrogen availability (Karazija 1988). One of the most pronounced effects of increased nitrogen deposition in such ecosystems is the change in plant community structure it induces (Bobbink *et al.* 1998). The slow-growing species (*e.g.* dwarf shrubs) were replaced by fast-growing species in the areas with high N deposition (Ellenberg 1988, Falkengren-Grerup 1995, Strengbom *et al.* 2003) or after N additions (Mäkipää 1994; Strengbom *et al.* 2001).

There is a relatively large number of pine stands in the surroundings of "Achema" and the effect of air pollution on trees is well studied (Armolaitis 1998, Armolaitis *et al.* 1999, Juknys *et al.* 2003) but corresponding changes in the ground layer are less frequently studied (Stakenas and Armolaitis 2000, Armolaitis and Stakenas 2001).

In this study, we analyse how the structure of understorey vegetation changes along acidifying pollutants gradient near “Achema” in central Lithuania. Our aims were: (1) to compare the abundance of plant species in the stands with data from reference, (2) to evaluate site condition differences according to the relative occurrence of nitrogen indicators and species indicating acid soil conditions in the impact zone.

Material and methods

Study area

The sample plots were located in Scots pine (*Pinus sylvestris* L.) stands at five distances (2, 4, 5, 8 and 9 km) east of nitrogen fertilizers producer plant J/V “Achema”, situated in the central part of Lithuania (55˚05’ N, 24˚20’ E). Vegetation data collected from the sample plots at 8 km distance west of the plant were used as the reference level (control).

We assumed that according to the changes in soil chemistry and stands condition (Armolaitis *et al.* 1999) this was a deposition gradient where the impact of “Achema” pollution decreased with increasing distance from it. The sample plots have been exposed to the relatively highest amount of deposition in the vicinity of “Achema” because they are located under the predominant south-westerly winds in Lithuania. Apart from the pollution level, the tree stands and site type at the individual plots were originally relatively similar (Table 1). All stands were mature and growing on sandy and poor soil sites of the *Vaccinio-myrtillosa* site type (Karazija 1988). The soils are classified as Arenosols. The climate is continental with an annual precipitation of 586-625 mm and the mean annual temperature of 6.2ºC.

Table 1. General characteristics of the study plots of *Vaccinio-myrtillosa* forest type stands (according to the forest inventory in 2002)

	Distance from the plant (east, km)					
	2	4	5	8	9	reference*
Stand age, years	90	80	85	100	100	90
Mean pine height (m)	27	27	28	25	28	26
Mean pine diameter (cm)	30	32	30	28	30	27
Stocking level	0.7	0.7	0.6	0.7	0.7	0.7
Stem volume (m^3/ha)	330	330	300	300	310	300

* 8 km west of “Achema”.

Air pollutant emissions

J/V “Achema” is one of the largest point sources of emissions in Lithuania and the largest fertilizer plant in the Baltic region. The plant has been operating since 1965. Its main products were ammonia water, methanol, urea, polyvinyl acetate, ammonia nitrate, urea, formaldehyde resin and nitrophoska. Emissions of dusts, sulphur, nitrogen and carbon oxides as a result of burning fossil fuel (annually about 40, 000 t), were emitted into the atmosphere, causing severe damage to the surrounding coniferous forests. During 1989-1991, the average annual emissions of CO were 9,874 t, SO_2 4,630 t, NO_x 4 thousand t, ammonia 3734 t and mineral fertilizer dust 14 thousand t (Armolaitis *et al.* 1999). During the last 15 years, the emissions have been considerably reduced: in 1999, SO_2 83 t, NO_x 380 t, NH_4 196 t and dust 300 t and annual emissions now have attained to 5,000-7,000 tons.

Air pollution is considered to be the main cause of a massive forest dieback that peaked in the second half of the 1980s when the total annual sulphur flux was 28 kg ha^{-1} at 10 km, 63 kg ha^{-1} at 5 km and 151 kg ha^{-1} at 0.2 km from the plant (Armolaitis *et al.* 1999). The corresponding values for nitrogen were 93, 119 and 121 kg ha^{-1}. In 1996, sulphur deposition decreased to 9-16 and nitrogen - 17-48 kg ha^{-1}. The stands in the surroundings were affected at 20-25 km distance from the emission source; meanwhile acidification of the soil was determined up to 4-8 km in 1989 (Armolaitis *et al*. 1999). The recovery of damaged trees was observed, but soil acidification still continues – the average of pH value of the upper soil layer (20 cm) was lower in 1996 (pH_{KCl} 3.38) than it was in 1989 (pH_{KCl} 3.55) (Armolaitis 1998). The decline in pH levels led to increased content of toxic Al^{3+} and leaching of K^+, Ca^{2+} and Mg^{2+} ions.

While sulphur deposition slightly exceeded the Lithuanian background level close to the plant, the total annual nitrogen flux at the distance of 8-10 km from the emission source was 2-4 times greater than that in non-industrial areas of Lithuania (Armolaitis 1998). The nitrogen deposition levels still exceeded the calculated critical loads for coniferous forests - 20 kg ha^{-1} per year (Rosén *et al.* 1992) at the 8-10 km distance from the plant (Armolaitis *et al.* 1999).

Sampling design and vegetation assessment

The understorey vegetation was studied at different distances from “Achema” in July 2003. The vegetation assessment was carried out on three sample plots at each distance. In each sample plot sampling was performed on 16 vegetation quadrates (1 m^2) laying out in fours quadrates in the direction of 0˚, 90˚, 180˚ and 270˚ azimuths from the chosen central tree.

The percentage cover of vascular plants (<1.5 m height) and mosses was visually estimated in each sample quadrate, then the mean value of each species cover was calculated for each sample plot (value per distance). The mosses and vascular plant species data set used for further analysis only included non-woody plants, except for *Rubus* sp., *Vaccinium* sp., *Calluna vulgaris*. The nomenclature of species follows that of Tutin *et al.* (1980).

Data analysis

Values of species cover were transformed into a 1-9 ordinal scale (van der Maarel 1979) for use in ordination analysis. The relationship of species composition to distance from the emission source was evaluated by Canonical Correspondence Analysis (CCA) using the program CANOCO for Windows (ter Braak and Šmilauer 2002). The "down weighing of rare species" option was applied in ordination in order to reduce noise.

Kruskal-Wallis non-parametric analysis of variance was used in comparing species abundance and cover at 9 km distance (east) and in the reference data (control, 8 km west).

The values of the environmental variables in the plots were assessed by species analysis using indicator values for soil acidity (pH) and soil nitrogen according to Ellenberg *et al.* (1991). Weighted averages of indicator values (E_R and E_N, respectively) were calculated using the equation:

$$WA= (x_1y_1 + x_2y_2 +...+x_ny_n) / (x_1 + x_2 +...+ x_n) \quad (1)$$

where x_1, x_2, ... x_n are the cover of those species present in the plots, while y_1, y_2, ... y_n are the species indicator values (Diekmann 1995). The comparisons of indicator values between plots from different distances were calculated using Kruskal-Wallis non-parametric analysis.

Results

Species frequency and cover

The total cover of vascular plants was significantly lower at 9 km than that in the reference (H=24.06, $P<0.01$, Table 2). There was no significant difference in the cover of mosses (H=0.07, $P>0.05$) although the typical mosses (*Hylocomium splendens*, *Ptilium crista-castrensis*) frequency was still lower in the sample plot located 9 km from the plant.

Many species non-typical of *Vaccinio-myrtillosa* forest type, such as *Moehringia trinervia*, *Poa nemoralis*, *Rubus idaeus* and *Rumex acetosella*, were numerous near the plant (2-5 km) – their distribution comprised about 33% (Table 2). Other non-typical species, *Calamagrostis arundinacea*, *Festuca ovina* and *Galeopsis tetrahit*, were less spread but quite common. Their occurence constituted about 10%. But a decrease in frequency near the plant was found for most common species of vascular plants and mosses: at greater distances (8-9 km) their frequencies increased (*e. g. Vaccinium* sp., *Hylocomium splendens*, *Ptilium crista-castrensis*). These species are characteristic of *Vaccinio-myrtillosa* forest type (Karazija 1988).

Table 2. Frequency (%) and cover of the plant species at different distances from "Achema"

Species	Distance from the plant (km east)					Reference (8 km west)
	2	4	5	8	9	
Vascular plants						
Athyrium filix-femina (L.) Roth	12.5		4.2			
Calamagrostis arundinacea (L.) Roth	8.3	4.2		4.2		
Calamagrostis epigejos (L.) Roth	25.0	22.9				22.9
Calluna vulgaris (L.) Hull	14.6	10.4	25.0		8.3	64.6
Deschampsia cespitosa (L.) Beauv.	4.2		10.4			
Dryopteris filix-mas (L.) Schott		2.1		8.3	2.1	
Festuca ovina L.	70.8	64.6	93.7	47.9	75.0	12.5
Galeopsis tetrahit L.	2.1	12.5	2.1			
Luzula pilosa (L.) Willd.		6.2	6.2	33.3	4.2	
Melampyrum pratense L.	83.3	79.2	72.9	70.8	89.6	6.2
Moehringia trinervia (L.) Clairv.	33.3	4.2	4.2			
Poa nemoralis L.	10.4	8.3	33.3	2.1	6.1	
Rubus idaeus L.	41.7	33.3	20.8	4.2		
Rumex acetosella L.	27.1	27.1	18.7			
Stellaria graminea L.		2.1	6.2			
Trientalis europaea L.	12.5	6.2	6.2		6.1	
Vaccinium myrtillus L.	6.2	2.1	14.6	79.2	72.9	87.5 n.s.
Vaccinium vitis-idaea L.	27.1	6.2	39.6	41.6	95.8	100.0**
Veronica officinalis L.		4.2	2.1			
Total cover per plot	16.2	7.1	16.3	24.2	37.3	56.4**
Number of species per plot	3.8	3.0	3.8	2.9	4.0	3.2
Total number of species per distance	15	20	19	10	13	9
Mosses						
Dicranum undulatum	42.9	85.4	37.5	85.4	95.8	66.6
Eurhynchium striatum	20.8	20.8	22.9			
Hylocomium splendens	35.0	20.8	60.4	33.3	50.0	85.4
Pleurozium schreberi	76.1	90.4	100.0	95.8	89.6	73.0
Ptilium crista-castrensis	22.1	18.7	20.8	6.1	27.1	54.2
Total cover per plot	56.9	86.9	73.1	75.1	89.9	94.3 n.s.
Number of species per plot	2.6	2.5	2.4	2.2	2.8	2.8
Total number of species per distance	6	7	5	4	6	5
All species						
Total cover per plot	93.3	93.9	89.5	99.4	127.2	150.7**
Number of species per plot	6.7	5.5	6.2	5.2	6.8	6.1
Total number of species per distance	24	27	24	14	19	14

Frequency and cover of the most abundant species are compared between 9 km and the reference data using Kruskal-Wallis test (**= $P < 0.01$, n.s. = not significant ($P>0.05$)).

The frequency of main forest dwarf shrubs typical of the studied forest type – *Vaccinium vitis-idaea* and *V.myrtillus* – increased with increasing distance from the plant (Fig. 1). Close to the plant (up to 5 km distance) the mean frequency of *V.myrtillus* was significantly lower in comparison with the reference (Kruskal-Wallis 1-way ANOVA: F=42.0, $P<0.001$). The cover was even 21 times lower at the closest sample plot than that in the reference. The differences between the plots farther from the plant (8-9 km) were not significant ($P>0.05$). This trend was similar for abundance of *V. vitis-idaea* but differences between the sample plots and reference were significantly higher than for *V. myrtillus* (*P*<0.001). The cover of *V.vitis-idaea* was even 28 times lower in the closest sample plot (2 km) in comparison with the reference (F=72.9, *P*<0.001) (Fig. 1).

A reverse tendency was found for some nitrophilous and acidophilous species (Fig. 1). The frequency of *Rubus idaeus* significantly decreased with the distance from the plant (*P*<0.05) – at 8 km distance it decreased 10 times as compared with at 2 km distance and did not appear at 9 km distance. The significant decrease in frequency also was pronounced for acidophilous *Rumex acetosella* (*P*<0.05) - the mean frequency was 19-27% in the sample plots exposed to the heaviest pollution (up to 5 km distance) while it did not occur farther (8-9 km).

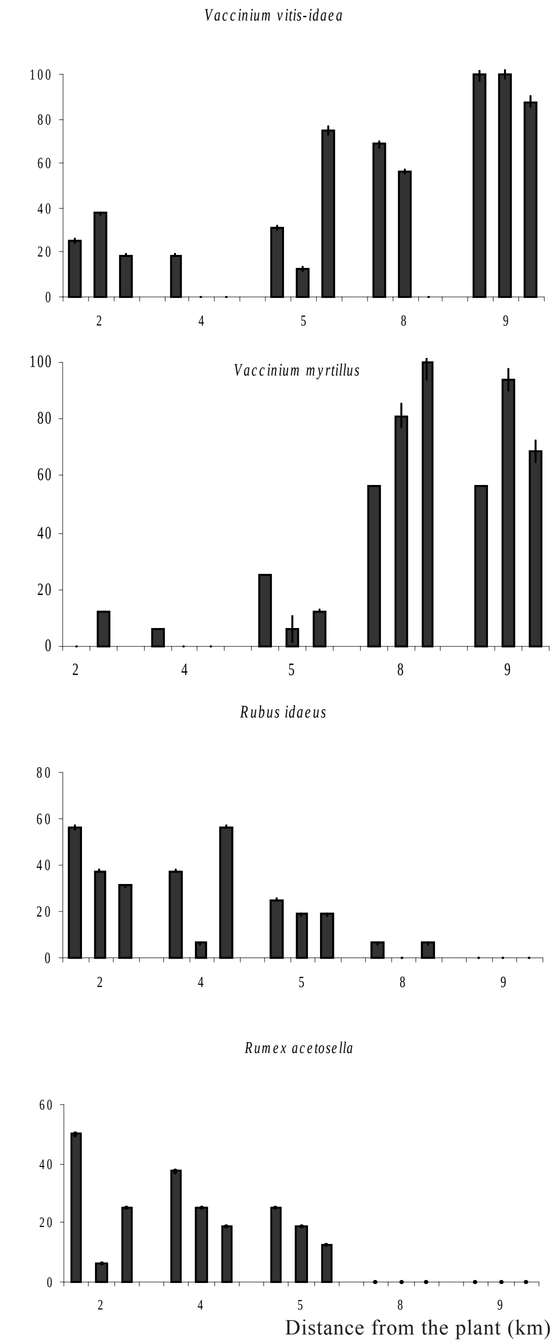

Figure 1. Changes in frequency (%) on the sample plots (columns) at the different distances from "Achema". The line indicates standard error of the mean value

Species composition

Ordination diagram showed that there were a common species such as *Rubus idaeus*, *Chelidonium majus*, *Chamerion angustifolium*, *Calamagrostis epigejos*, *Athyrium filix-femina*, *Moehringia trinervia*, *Galeopsis tetrahit* the cover of which was negatively related to the increase in distance from the plant (F=3.52, p<0.005, Fig. 2). There are relatively nitrogen-demanding species with indicator values for soil nitrogen ³6. Near the plant not only positively to nitrogen deposition responding species were found but also species tolerant to acid soil (low pH). Those were such species as *Calluna vulgaris*, *Stellaria graminea*, *Festuca ovina*, *Veronica officinalis*, *Rumex acetosella* with indicator values for soil acidity <4.

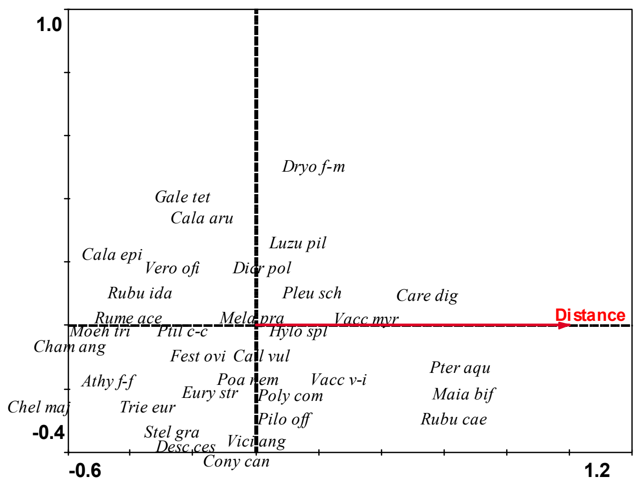

Figure 2. Plant species abundance dependence on the distance from "Achema" (km). Species abbreviations include the first four letters of the genus name and the first three letters of the species name (for full names, see Table 2)

Distribution of species in relation to distance from the plant showed that with increasing distance an increase in cover of such indicator species as *Vaccinium vitis-idaea*, *Vaccinium myrtillus*, *Maianthemum bifolium*, *Luzula pilosa* and *Pteridium aquilinum* (Fig. 2). The cover of the main forest mosses (*Pleurozium schreberi*, *Hylocomium splendens*) varied not markedly.

Assessment of environmental conditions

The weighted averages for soil acidity (E_R) along the study transect were significantly correlated with the distance from "Achema" (R^2=0.54, p>0.05, Fig. 3). The soil acidity according to species indicator values decreased more than 20% in comparison to the closest (2 km) and the farthest (9 km) from "Achema" sample plots (E_R =2.32 and 2.95, respectively). The average of the indicator values in the reference (E_R=3.11) were slightly and insignificantly higher than that in the sample plots (Kruskal-Wallis 1-way ANOVA: F=2.95, P>0.05).

The weighted averages for soil nitrogen along the study transect showed a decreasing trend with increasing distance from the plant (Fig. 3). They were significantly higher closer to the plant than those for the farther plots (R^2= 0.72, p<0.05). Significant lower averages for soil nitrogen in the reference (E_N=1.6) may also indicate a change in species composition under the intense influence of "Achema" (F=4.8, P<0.05). This means that there is relatively major part of nitrophilous species downwind of the plant, in comparison with the reference. Species indicating a nitrogen rich environment (indicator values for soil nitrogen E_N =6-8) constituted a more important part of the forest vegetation in the impact zone of "Achema".

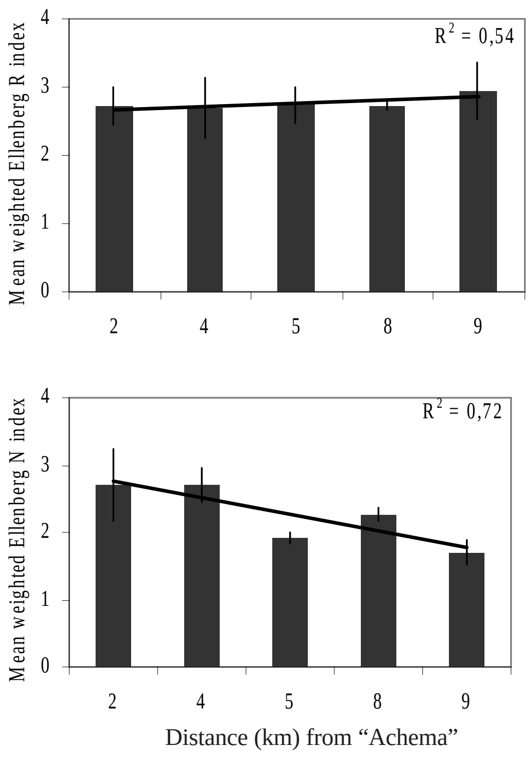

Figure 3. Weighted averages for soil acidity (E_R) and nitrogen (E_N) at the different distances from "Achema"

Discussion and conclusions

In the study tree canopy composition and cover were uniform throughout the study transect, and the distance at which understorey vegetation composition was adversely affected could be clearly detected from the frequency of the main species. In the vicinity of "Achema" some species (e.g., *Calamagrostis epigejos*, *Chameriom angustifolium*, *Galeopsis tetrahit*, *Rubus idaeus*, *Stellaria graminea*, *Moehringia trinervia*) preferring nutrient-rich sites increased in frequency. The expansion of these species, which were often mentioned as positively reacts to nitrogen deposition (Tyler 1987, Thimonier *et al.* 1992, Falkengren-Grerup 1995, Diekmann *et al.* 1999) showed that the ground vegetation in the impact zone (2-5 km) was affected due to increased nitrogen supply. The comparison of indicator averages for soil nitrogen pointed to an increase in comparatively nitrogen-demanding species in the impact zone. The previous ground vegetation monitoring studies (Armolaitis and Stakenas 2001) also showed that many of these species had decreased in abundance with the distance from "Achema", for example, the mean coverage of *Rubus idaeus* was significantly higher at 10-12 km in comparison with 20-22 km distance.

The cover of acidophilous species indifferent to low soil pH (*Deschampsia cespitosa*, *Chelidonium majus*, *Rumex acetosella*, *Galeopsis tetrahit*, *Athyrium filix-femina*, *Calamagrostis epigejos*) was negatively correlated with the distance from "Achema" and this showed that soil acidification increased on moving towards the plant. These floristic changes may also reveal acidification of the environment in the vicinity of "Achema". It is possible that abundance of such species close to "Achema" is a response to soil acidification rather than to increased nitrogen supply. Armolaitis *et al*. (1999) measured pH_{KCl} at a number of points downwinds of the plant and found that pH was relatively low at 4-8 km distance and showed a significant increase with distance from "Achema", being 3.3 at 0.2-0.5 km and 6.8 at 10-14 km. The Ellenberg indicator values for soil acidity showed a relationship with distance from the plant and indicated more acidic soil conditions close to the plant.

If soil acidity increases nitrophilous species may decrease if they are sensitive to high soil acidity. The repeated soil analysis has shown a significant decrease in NO -N over the last decade at the 10-12 km distance from "Achema" (Armolaitis and Stakenas 2001) and as a consequence such species (*e.g.*, *Rubus idaeus*, *Chameriom angustifolium*) also decreased. The reduced amounts of nitrate may explain a decrease in nitrophilic species decrease not over time but with the distance from the emission source.

Some vascular plants typical of nutrient-poor sites, *e.g. Vaccinium myrtillus* and *V. vitis-idaea*, decreased in abundance in the nearest sample plots while farther it approached the reference level that there was no significant difference. It is not known if these species are influenced by soil acidification to an extent that results in abundance decline. The results from both nitrogen fertilizer application experiments (Persson 1981, Kellner and Marshagen 1991, Mäkipää 1994, Prescott *et al.* 1995, Nordin *et al.* 1998, Thomas *et al.* 1999, Strengbom *et al.* 2001, Strengbom *et al.* 2002) and the field studies (Strengbom *et al.* 2003) showed that these shrubs were less frequent, less abundant and more susceptible to the leaf pathogen in areas with high nitrogen deposition but some found contrary to this estimation (Nohrstedt 1998, Vacek *et al.* 1999). The previous study also observed the increase in cover of these dwarf shrubs with the distance from "Achema" (Armolaitis and Stakenas 2001).

Our results showed that impact of pollution was stronger for *V. vitis-idaea* than *V. myrtillus* although it is suggested that the *Vaccinium* species do not differ in nutrient requirements (Ingestad 1973, Mäkipää 1999). The occurrence of *V. vitis-idaea* was also stronger negatively correlated with high nitrogen deposition, in comparison with *V. myrtillus* (Strengbom *et al.* 2003). *Vaccinium* species often dominate on nitrogen poor soils with high organic matter and low pH and available nutrients (Ingestad 1973). Their biomass may decrease with increasing nitrogen concentrations (Mäkipää 1999). Some authors have ascribed this effect to increased shading from the fertilized tree crowns (Persson 1981). Prescott *et al.* (1995) found reduction of ericaceous cover to be correlated with the rate of nitrogen application and Strengbom *et al.* (2003) – with the rate of nitrogen deposition, not tree volume. It is proposed that a reduction in mycorrhizal colonization may be responsible for the decline in ericaceous shrubs. Hawkins and Henry (2004) have found little interaction of the effects of nitrogen supply and irradiance on survival and biomass but fertilization reduced allocation to roots and thus may have had a negative effect on mycorrhizae and plant water status. This indicates that dwarf shrubs lack or have low potentials for a positive response to addition of nitrogen, and that nitrogen is not a limiting resource for them. Another explanation may be that ericaceous species are known to have a poor capability to utilize nitrate (Högberg *et al.* 1990). Because these two dwarf shrubs can be regarded as keystone species in *Vaccinio-myrtillosa* site type (Karazija 1988), a reduced frequency of them is likely to affect a wide range of other associated organisms in forest ecosystems.

Ground vegetation recovery could be observed in terms of the changes in indicator figures as compared on time scale (Armolaitis and Stakenas 2001). The indicator values showed that soil acidification still continued near "Achema" (10-12 km), but decreased farther (20-22 km). A comparison of indicator values with our study results, showed that near the plant (2-8 km) soils were even more acid (E_R=2.67). According to the changes between 1988 and 1999 in the indicator values for nitrogen, its reduction from 4.81 to 2.61 (10 km) showed significant reduction of nitrophilous vegetation (Armolaitis and Stakenas 2001). Our study results showed that indicator averages for nitrogen still lowered over time but not so significantly and this could be as an indication of decreased rates of nitrogen deposition.

In summary, this study shows that the species composition of the plant communities has changed, typical of site type plant species have disappeared and competitive interactions between the species have been altered as a result of 40 years' activity of the mineral fertilizer plant "Achema" in Lithuania. According to their occurrence along the pollution gradient, sensitive and typical forest mosses and vascular plants species were changed by nitrophilous and acid tolerant plant species. The frequency of keystone understorey species in the affected Scots pine sites was positively correlated with the increasing distance. A changed abundance of these species will have consequences for a wide range of associated species including herbivores and microfungi. The decreased emissions will enable the vegetation to recover gradually, particularly at further distances.

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ЖИВОЙ НАДПОЧВЕННЫЙ ПОКРОВ СОСНОВЫХ НАСАЖДЕНИЙ ВДОЛЬ ГРАДИЕНТА ЗАГРЯЗНЕНИЯ В ОКРЕСТНОСТЯХ ЗАВОДА АЗОТНЫХ УДОБРЕНИЙ

Г. Суетовиене

Резюме

Видовой состав живого надпочвенного покрова бруснично-черничных древостоев сосны обыкновенной (*Pinus sylvestris* L.) исследовался вдоль 9-километровой трансекты в центральной части Литвы на восток от завода азотных удобрений “Ахема”. Многолетняя аккумуляция выбрасываемых азотных и серных соединений в лесных экосистемах, сильно изменила растительность сообщества. Проекционное покрытие доминирующих видов (*Vaccinium myrtillus*, *V.vitis-idaea*) увеличивается по мере удаления от источника загрязнения. Вблизи завода появляются нетипичные для бруснично-черничных сосняков виды растений, такие как *Calamagrostis epigejos*, *Chameriom angustifolium*, *Galeopsis tetrahit*, *Rubus idaeus*, *Stellaria graminea* и др. Оценка местопроизрастаний по средним взвешанным балам фитоиндикационной шкалы Элленберга показали, что по сравнению с контролем, на пробных площадях восточнее завода почвы более кислые и насыщенные азотом.

Ключевые слова: древостой сосны обыкновенной, загрязнение азотом, индикаторные балы Элленберга, обилие видов, живой надпочвенный покров