Impacts of alkaline dust pollution on biodiversity of plants and lichens: from communities to genetic diversity

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PhD commencement

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Publications

I. Paal, J., **Degtjarenko, P.**, Suija, A. & Liira, J. (2013) Vegetation responses to long-term alkaline cement dust pollution in *Pinus sylvestris*-dominated boreal forests – niche breadth along the soil pH gradient. *Applied Vegetation Science* **16**: 248–259.

II. Marmor, L. & **Degtjarenko, P.** (2014) *Trentepohlia umbrina* on Scots pine as a bioindicator of alkaline dust pollution. *Ecological Indicators* **45**: 717–720.

III. Degtjarenko, P., Marmor, L. & Randlane, T. (2016) Changes in bryophyte and lichen communities on Scots pines along an alkaline dust pollution gradient. *Environmental Science and Pollution Research* **23**: 17413–17425.

IV. Degtjarenko, P., Marmor, L., Tõrra, T., Lerch, M., Saag, A., Randlane, T. & Scheidegger, C. (2016) Impact of alkaline dust pollution on genetic variation of *Usnea subfloridana* populations. *Fungal Biology* **120**: 1165–1174.

Introduction: air pollution

- Particulate matter (PM)
- Heterogenous mixture of solid particles (ca. 0.1–10μm)
- Coarse PM or large dust particles (hereafter dust pollution)
- Rock quarrying, combustion processes, kiln grinding, directly from surfaces of unpaved roads

Introduction: dust pollution

- Rock quarrying, combustion processes, kiln grinding, directly from surfaces of unpaved roads
- $CaCO_3$, MgO, K_2O ➔ extremely alkaline
- Important environmental issue

Introduction: dust pollution

Direct

Indirect

- Visible acute **injury** & necrotic **damage**
- **Physiology** (e.g. stomatal function, chlorophyll degradation, reduction of transpiration etc.)
- **Biochemistry** (level of carbohydrates, element concetration in tissues)

Introduction: dust pollution

Direct

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- **Physiology** (e.g. stomatal function, chlorophyll degradation, reduction of transpiration etc.)
- **Biochemistry** (level of carbohydrates, element concetration in tissues)

Indirect

- Increase of pH
- Change of chemical properties
- Damage of soil biota

Changes in ecosystems

↓

- Composition
- Function
- Structure

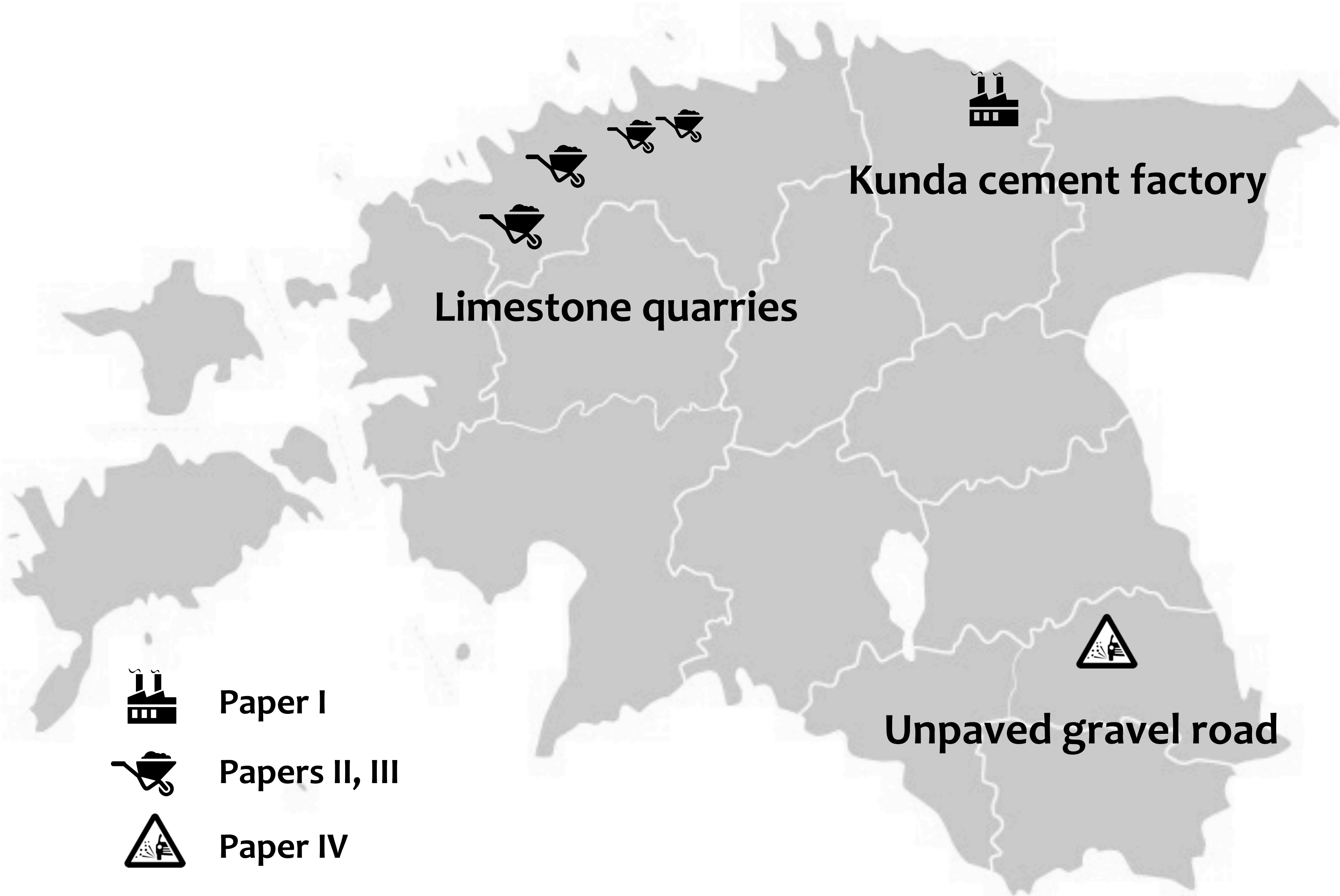
Introduction: multiple tasks

- Estimation of pollution impact
- Detection of pollution extent
- Indicators of dust pollution

Aims of the thesis

- Successional response of Scots pine forest communities to long-term dust pollution (**I**)
- Response of two epiphytic cryptogamic groups (lichens, bryophytes) to dust pollution (**III**)
- Potential bioindicators of dust pollution (**I**, **II**, **III**)
- Effects of dust pollution on genetic diversity of *Usnea subfloridana* (**IV**)

Material & Methods: study areas

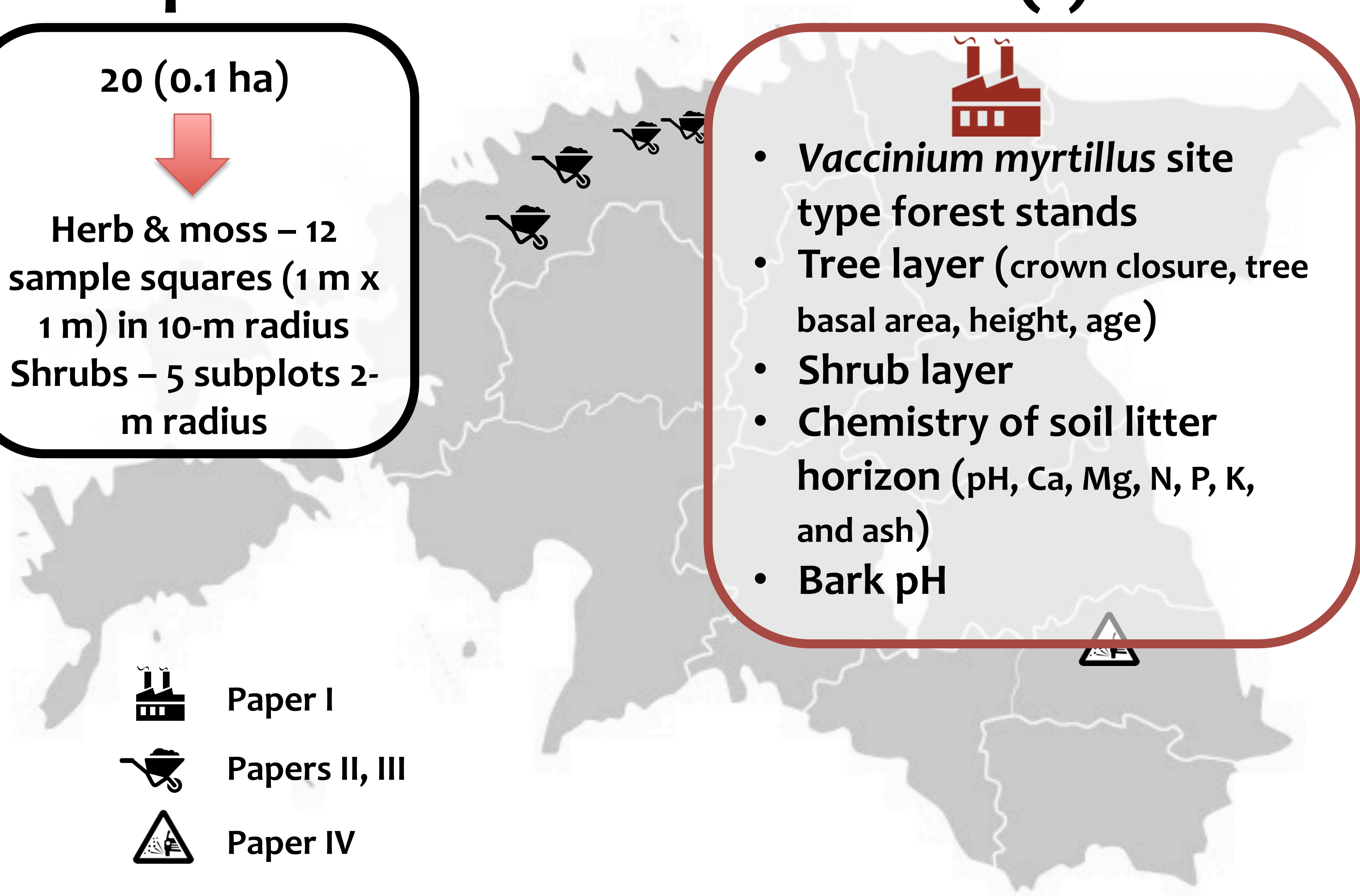


M & M: Successional response of Scots pine forest communities (I)

20 (0.1 ha)

Herb & moss – 12 sample squares (1 m x 1 m) in 10-m radius
Shrubs – 5 subplots 2-m radius

- *Vaccinium myrtillus* site type forest stands
- Tree layer (crown closure, tree basal area, height, age)
- Shrub layer
- Chemistry of soil litter horizon (pH, Ca, Mg, N, P, K, and ash)
- Bark pH



M & M: Response of epiphytic lichens, bryophytes and alga *Trentepohlia umbrina* (II, III)

T. umbrina

- 5 Scots pine trees in 32 sample plots (up to ca. 3 km)
- Cover (line cover method) & occurrence of lichens, bryophytes, green alga *Trentepohlia umbrina* (0.5-2 m)
- Bark pH

Paper I

Papers II, III

Paper IV

M & M: The effect on genetic diversity of lichen-forming fungi (IV)

Usnea subfloridana

- Genetic diversity of *U. subfloridana*
- 8 populations (4 <u>polluted</u> VS 4 <u>unpolluted</u>) using 9 fungus-specific microsatellite loci
- 310 *Usnea* thalli up to 6 m from spruces
- Bark pH

Paper I

Papers II, III

Paper IV

M & M: data analyses (I-IV)

• Principal component analyses (PCA)	**I**
• ANOVA, Tukey post hoc test, t-test	**I, III, IV**
• Multiple response permutation procedure (MRPP)	**I**
• Indicator species analyses (ISA)	**I**
• Model analyses (GRM, CLZ, Logistic regression)	**I–IV**
• Spearman's rank correlation analysis	**II, III, IV**
• Kruskal-Wallis test	**II, III**
• AMOVA	**IV**
• Wilcoxon signed-rank test, mode-shift test	**IV**
• Genetic diversity – GenAlEx, Microsatellite Analyzer (MSA), script in R software	**IV**

Results: changes of environmental variables (I-IV)

- Neutralizing effect on natural substrates
- Increase in polluted habitats
  – pH of pines (I, II, III) and spruces (IV)
  – pH of soil litter horizon (I)
  – Ca, Mg and K content (I)

Indicates the impact of alkaline dust pollution

Aims of the thesis

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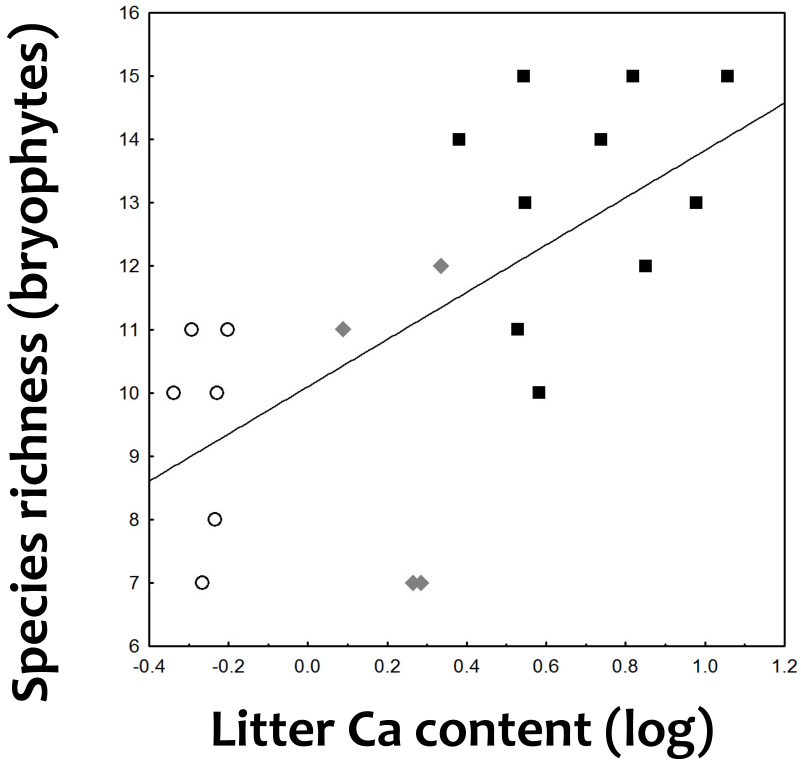
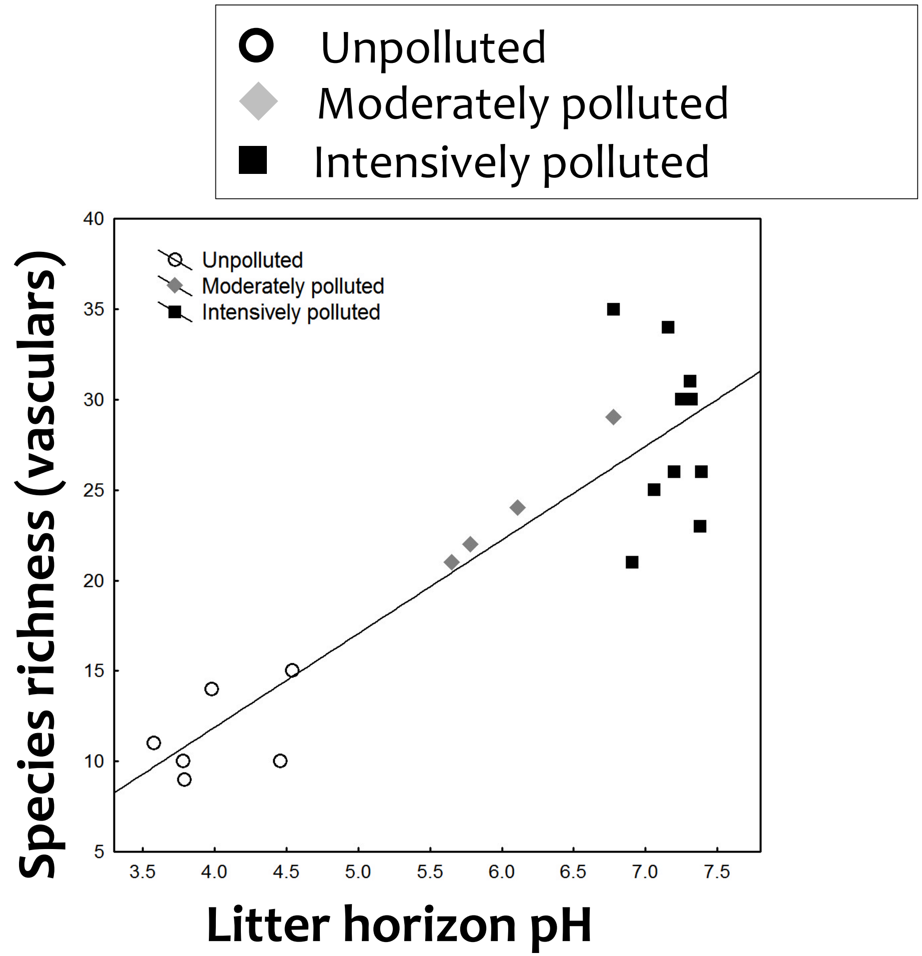
- Response of two epiphytic cryptogamic groups (lichens, bryophytes) to dust pollution (III)
- Potential bioindicators of dust pollution (**I**, **II**, **III**)
- Effects of dust pollution on genetic diversity of *Usnea subfloridana* (**IV**)

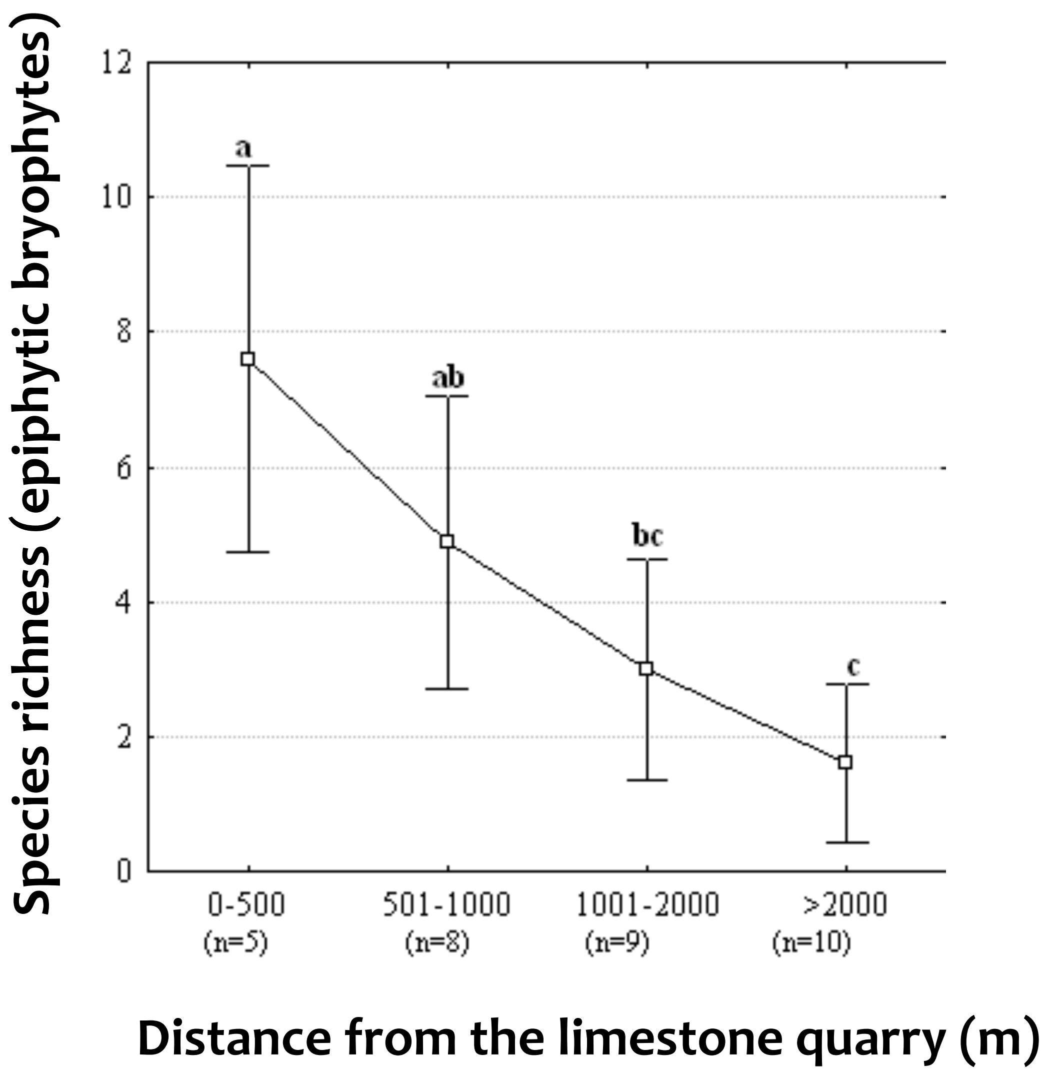
Results: species richness (I)

- Species richness ➔ correlation with pollution intensity





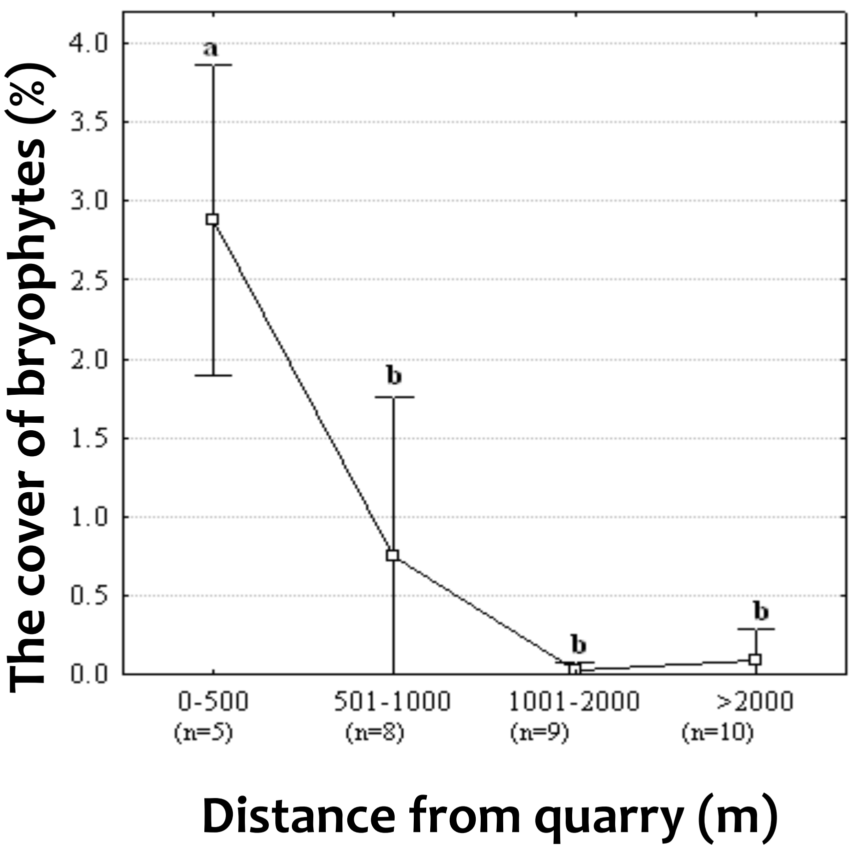
Results: species richness (III)

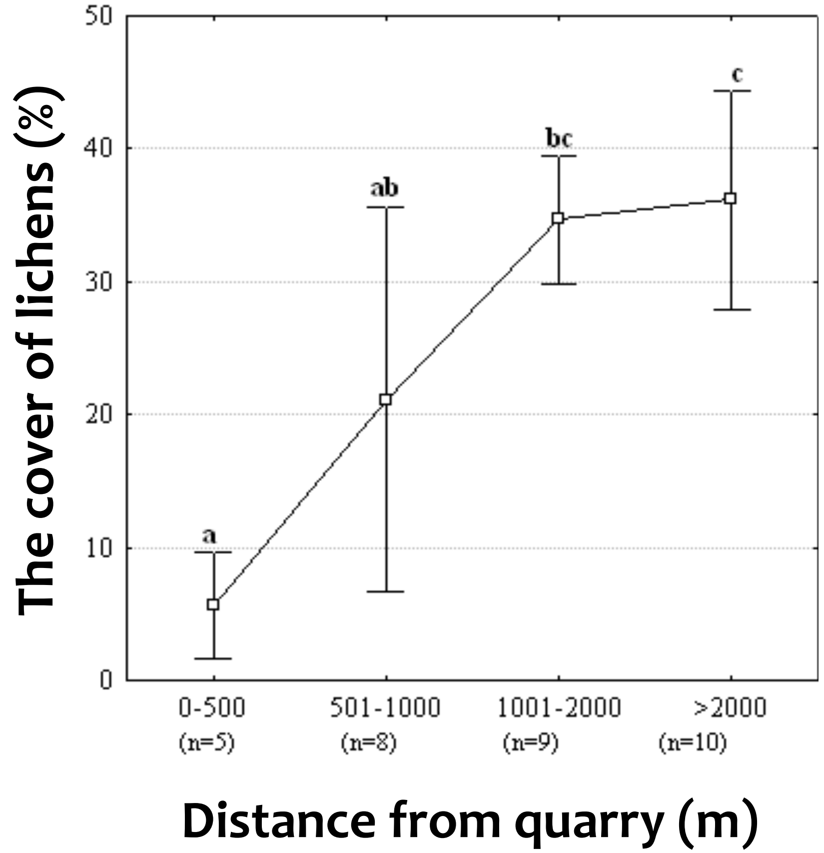


- Species richness of epiphytic bryophytes ➔ similar gradient

Results: species cover (III)

- Species cover ➔ correlation with pollution intensity





Results: changes of natural communities (I, III)

- 'Nemoralization' in the vegetation of the studied pine forests (**I**)
- Replacement of acidophilous by neutrophilous, and then by calcicolous species
- Shifts of cryptogamic communities along pollution gradient (**III**) ➔ typical for nutrient-rich bark or calcareous substrata

Results: changes of natural communities (I, III)

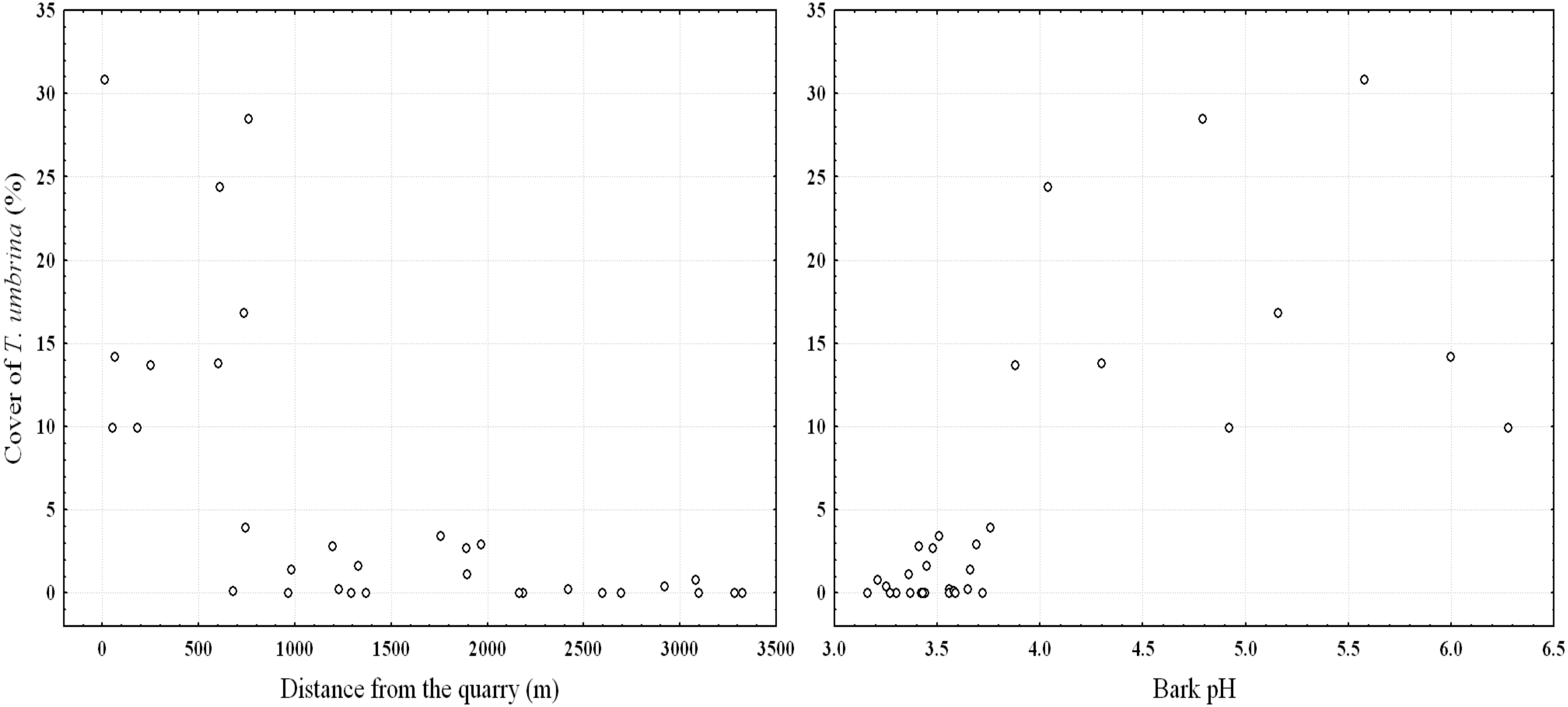
- ‘Parapositive’ effect on species diversity
- At the closest distance from the pollution source ➔ **locally rare, red-listed, protected** and **woodland key habitat** species (e.g. *Pseudoleskeella catenulata, Caloplaca ulcerosa, Neottia ovata, Ulota crispa*)
- Changed environmental conditions ➔ alternative habitat

Aims of the thesis

- Successional response of Scots pine forest communities to long-term dust pollution (I)
- Response of two epiphytic cryptogamic groups (lichens, bryophytes) to dust pollution (III)
- **Potential bioindicators of dust pollution (I, II, III)**
- Effects of dust pollution on genetic diversity of *Usnea subfloridana* (IV)

Results: bioindication (II)

- ≥10% cover of *T. umbrina* on pines indicates considerable dust pollution



Results: bioindication (II)

- Green alga *Trentepohlia umbrina*, **if growing on pines**, could be used as an ecological indicator of dust pollution

Results: bioindication (I, III)

- **Among bryophytes: 3** indicators – *Orthotrichum pallens*, *O. speciosum*, *Schistidium apocarpum* on pines
- **Among lichens:** at least **5** indicators – *Caloplaca cerinelloides*, *Lecania cyrtella*, *Lecidella elaeochroma*, and *Alyxoria varia* on pines
- **Among vascular plants: 12** indicators for heavily polluted zone (among them two orchids – *Neottia ovata* and *Neottia nidus-avis*); **6** indicators for the moderately polluted zone

Results: bioindication (I, III)

- Increased bryophyte diversity and cover on pines (III)
- Cover of lichens on pines (III)
- Appearance of typical species for mesotrophic and meso-eutrophic habitats in oligotrophic habitats (I)
- Replacement of acidophilious by neutrophilous and calciphilous species (I, III)

Indication of environmental changes and monitoring the extent of dust pollution

Aims of the thesis

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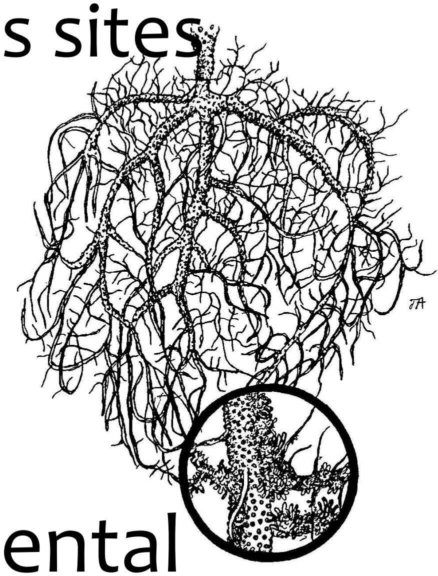
- Response of two epiphytic cryptogamic groups (lichens, bryophytes) to dust pollution (**III**)
- Potential bioindicators of dust pollution (**I**, **II**, **III**)
- **Effects of dust pollution on genetic diversity of *Usnea subfloridana* (IV)**

Results: genetic diversity

- For the first time – negative impact
- Allelic richness, Shannon's information index, gene diversity – **lower** in **polluted** forests sites than in **unpolluted** forest sites



- Decline of suitable habitats (environmental conditions: increased pH value of phorophyte)
- Increase of mortality – bottleneck effect

Conclusions

- **Neutralizing effect** of soil and bark
- **Destruction** of natural communities and **formation** of novel communities (‘nemoralization’ & shifts)
- New bioindicators of dust pollution among **algae, lichens, bryophytes**, and **vascular plants**

Conclusions

- Total community changes, species richness, cover of selected species groups ➔ **additional indicators** of dust pollution
- **‘Parapositive’ impact** of dust pollution on natural communities
- Dust pollution released from unpaved road ➔ **negative impact** on the **genetic diversity** of *Usnea subfloridana* populations

Thank you for your attention!

Photo by Tiiu Tõrra