Mapping aerial hypertrophication with epiphytic lichens as biomonitors in North Rhine-Westphalia (NRW, Germany)

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Summary

In North Rhine-Westphalia (Germany) the effects of hypertrophicating air pollutants were mapped with epiphytes as biomonitors. Spatial patterns of hypertrophication were obtained based on abundance and frequency of nitrophytic lichen species.

Introduction

Due to a strong decline of atmospheric sulphur dioxide concentrations, epiphytic lichen and bryophyte species diversity has, during the past decade, increased in formerly highly polluted regions of North Rhine-Westphalia (NRW). Immission levels of nitrogen oxides and ammonia have, however, remained largely unchanged. Nitrophytic species have recovered more frequently than others: About 60% of the epiphytic lichens that have recolonized the Ruhr District are dependent on mineral enrichment of the bark or tolerate hypertrophication to a certain extent (Stapper *et al.,* 2000; Franzen, 2001). To provide information on the regional distribution of epiphytic bryophytes and lichens, in particular, lichens indicating hypertrophication or acidification, epiphytic flora on 1815 trees uniformly distributed within NRW was investigated. This project was funded by the NRW Ministry of the Environment (grant to J-P Frahm, Univ. Bonn).

Methods

We have applied two standardized methods based on lichen frequencies within grids that allow to differentiate regions with statistically different *Air Quality Values* ("AQV"; German VDI guideline; VDI, 1995) or *Lichen Diversity Values* ("LDV", proposed EU protocol; Asta *et al.,* 2002). Ash (*Fraxinus excelsior*) and maple (*Acer platanoides* and *A. pseudoplatanus*) meeting the criteria of both guidelines were selected as the major phorophytes. Sampling units (SU) are based on the 1:25,000 Ordnance map grid. Each of the 234 SU consists of 8 trees placed in the north western quadrant of either map. Relevés were carried out at the face with highest cover and species diversity (20cm x 50cm, 10 quadrates; VDI, 1995) and at the four cardinal points (10cm x 50cm, 5 quadrates; Asta *et al*., 2002). The LDV of an SU is the mean sum of the frequencies of all lichen species occurring within the grid. Furthermore, all bryophytes and lichens above 50cm up to 200cm, and the cover of filamentous green algae were recorded. The nitrophytic species index (NIW) was estimated according to van Herk (1999).

Results and Discussion

Ninety-one lichen and 43 bryophyte species were recorded, 31 of which are red-listed in NRW, *e.g. Parmotrema stuppeum* (TAYLOR) HALE and *Orthotrichum pulchellum* SW. (cat. 1; Heibel *et al.,* 1999; Schmidt & Heinrichs, 1999). Species diversity was highest (49 per SU) in the southern highlands, where acidophytic species are dominant, and lower in the agricultural northern lowlands, where nitrophytic lichens, or bryophytes and lichens normally growing on basic rock are very common on bark. Highest mean numbers of nitrophytic lichen species per tree (≤10) were recorded north of a line between Krefeld, Duisburg, Münster, and Osnabrück up to the Dutch boarder. In this area, exceeded critical loads of eutrophicating nitrogen in forest ecosystems have been estimated (>25kg/ha/a; Gehrmann & Becker, 2000), and livestock is very dense, suggesting that in NRW, like in The Netherlands (van Herk, 1999), epiphytic flora is effected by livestock derived ammonia emissions. Both frequency-based

monitoring approaches indicate low immission loads in the southern and south-eastern highlands, and high loads in (formerly) highly industrialized regions like the Ruhr District. The agriculturally formed north-western lowlands, however, show high LDV indicating low immission loads due to high frequencies of nitrophytic lichen species often covering the whole surface of the trunks. Thus frequency-based biodiversity values do not indicate "real" immission loads unless the species specific behaviour of either lichen is respected. By analogy with the LDV we estimated the diversity value of only nitrophytic lichen species (van Herk, 1999) that may be regarded as an indicator of hypertrophication. High values were calculated for the agricultural regions in the north of the country, whereas low values indicate no or only slight hypertrophication in the south. This approach yields essentially the same result as van Herk's (1999) method based on the *occurrence* and *number* of nitrophytes on the whole trunk instead of their *frequency* within the *grid* area.
To study the influence of "traffic" or "agriculture" on the frequency of epiphytes, we estimated whether the respective influence was low, moderate or high. Influence was "low" outside of villages, far away from traffic or farming, "high" along major roads, downtown or near (>100m) farms. Basically, epiphytic species diversity declines with increasing impact of either influence, some species react, however, contrarily and may therefore be regarded as indicators for one or both influences (Table 1). All lichen species reacting positively to increasing "traffic" or "agriculture", are nitrophytes according to van Herk (1999) or are considered as nitrophytes in the United Kingdom (Wolseley & James, 2002). Most of the lichens responding negatively to either influence are acidophytes. *Physcia tenella* was found on 94% of all phorophytes and normally yielded high frequencies. Therefore, only negative changes at high traffic stations became visible. All species positively influenced by traffic are not limited to bark, but also may occur on rock and therefore may be regarded as indicators for (alkaline) dust immissions, *e.g. Physcia dubia* or the moss *Grimmia pulvinata*. Among the epiphytes positively influenced by traffic are the filamentous green algae of the genus *Klebsormidium* (*e. g. K. crenulatum* (KÜTZING) LOKHORST) which have become very common on trees in NRW (Frahm, 1999). They were recorded at two thirds of all sampling units. Even fast growing foliose lichens like *Parmelia sulcata* or *Physcia tenella* may become overgrown rapidly. Sometimes 50% and more of a trunk's surface is covered by dense mats of algal filaments, in particular in highly populated regions at stations with strong traffic influence. It is unclear whether nitrogen containing immissions or mineral enrichment of the bark by dust are responsible for the positive reaction of some lichens, bryophytes and filamentous green algae to increased traffic influence. Traffic influence chemically means a complex mixture of different gaseous or particulate components with different physiological effects on lichens and other sensitive organisms. The proposed EU protocol for lichen biomonitoring stands for a high degree of objectivity and standardization in the sampling procedure. Epiphytic lichen biodiversity on its own, however, is no longer a suitable indicator of immission loads. Future mapping projects should be used to identify indicator species, lichens and bryophytes, and their tolerance range.

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Figures and Tables

Table 1: Epiphytes responding to increasing influence of "traffic" or "agriculture" with decreasing or increasing frequencies ($p \leq 0.05$ between categories "low" and "high"). Only sampling units below 160m above sea level are included. N, A: species identified by van Herk (1999) as nitrophytes and acidophytes, respectively. *, Species considered as nitrophytes in the UK (Wolseley & James, 2002).

N*	*Amandinea punctata*	Frequency decreases with increasing impact of **traffic**
	Dicranoweisia cirrata	
	Hypnum cupressiforme	
N*	*Lecanora expallens*	
A	*Lepraria incana*	
A	*Parmelia saxatilis*	
N	*Physcia tenella*	
	Ramalina farinacea	
	Filamentous green algae	Frequency increases with increasing impact of **traffic**
	Grimmia pulvinata	
	Orthotrichum diaphanum	
N	*Phaeophyscia nigricans*	
N	*Phaeophyscia orbicularis*	
N	*Physcia dubia*	
N	*Xanthoria parietina*	
A	*Evernia prunastri*	Frequency decreases with increasing impact of **agriculture**
A	*Hypogymnia physodes*	
A	*Lecanora conizaeoides*	
A	*Lepraria incana*	
	Orthotrichum diaphanum	
	Melanelia subaurifera	
	Parmelia sulcata	
N	*Phaeophyscia orbicularis*	
N	*Physcia caesia*	
N*	*Amandinea punctata*	Frequency increases with increasing impact of **agriculture**
N	*Caloplaca holocarpa*	
N*	*Lecidella elaeochroma*	
N*	*Physconia grisea*	
N	*Xanthoria parietina*	

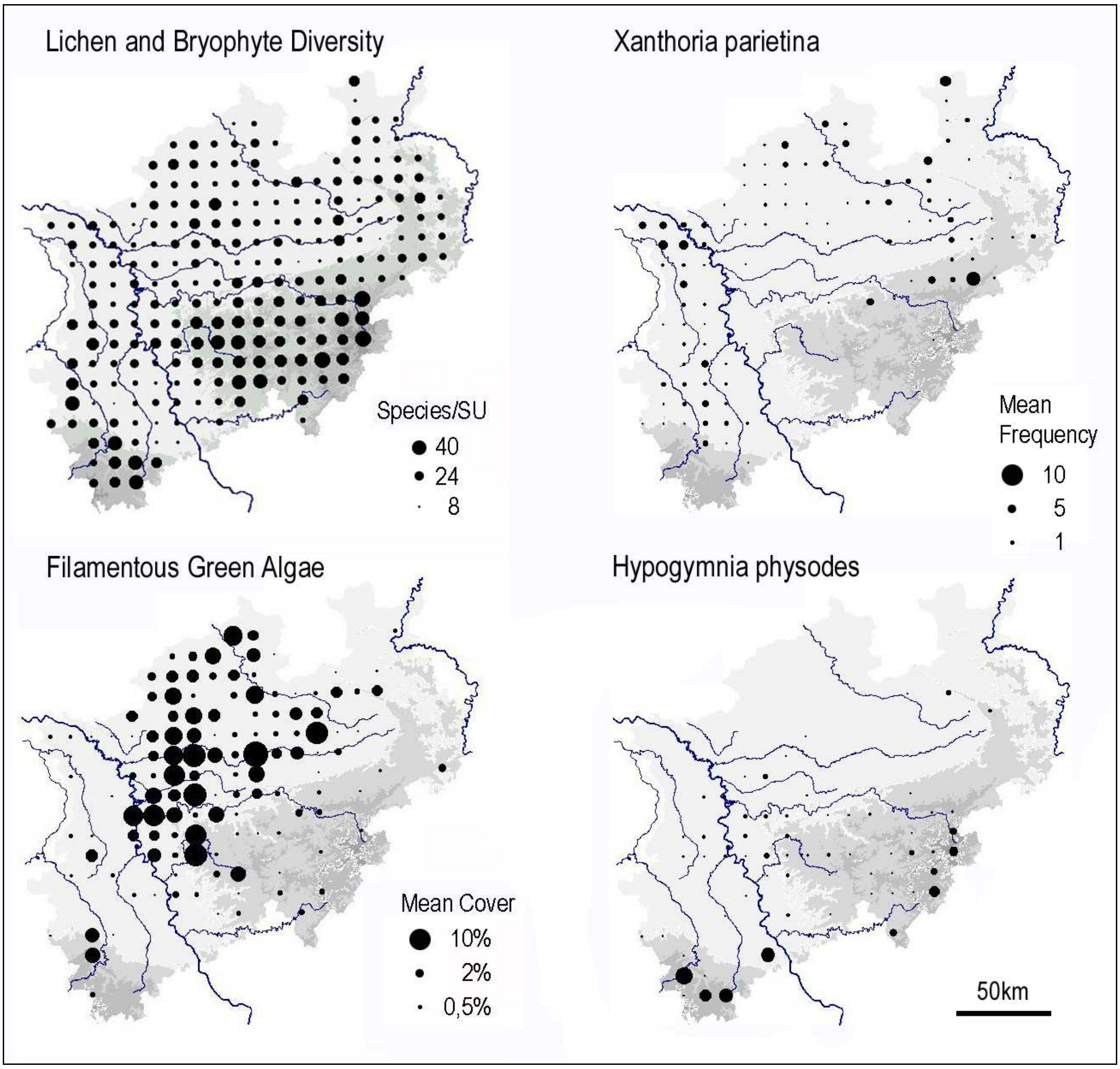

Figure 1: Epiphyte mapping in NRW: Lichen and bryophyte diversity per sampling unit, distribution and mean cover of filamentous green algae on bark, and distribution of nitrophytic lichen *Xanthoria parietina* and acidiophytic lichen *Hypogymnia physodes*. Background indicates height above sea level (15m to 840m).

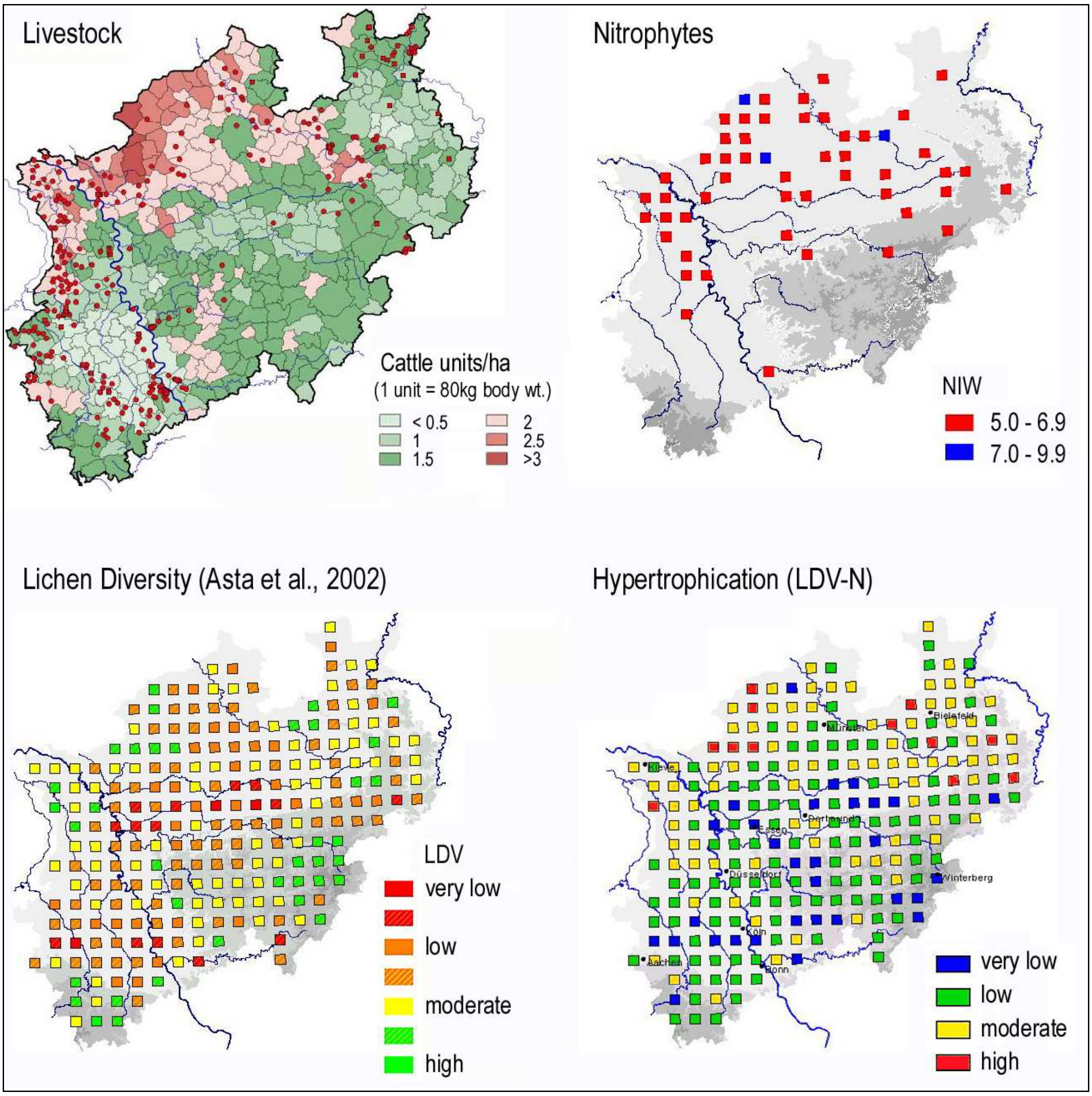

Figure 2: Mapping environmental stress: Livestock density (source: Grundwasserbericht Nordrhein-Westfalen 2000. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen. Düsseldorf, 269p.). Mean number of nitrophytic lichen species per tree (NIW) according to van Herk (1999), where only sampling units with NIW ≥ 5 are shown. Map of Lichen diversity (Asta *et al.* 2002) as indicator of environmental stress (5.6 < LDV < 65.5, class width = 9.4). Map of hypertrophication as determined by the frequencies of nitrophytic species only (LDV-N; class width = 12.5).