



Dramatic diversity losses in epiphytic lichens in temperate broad-leaved forests during the last 150 years

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ABSTRACT

Comparing data of epiphytic lichen diversity in semi-natural broad-leaved forests in north-western Germany from the 19th to early 20th centuries with recent inventories revealed strong changes, even though forest structure and tree species composition had changed only little. In three study areas, between 55% and 70% of the species became rarer during the 100–150-year long observation period. In the spatially extended study areas Weser-Ems Lowlands and Solling Mountains, 36% or 39% of the species, respectively, could not be rediscovered in the recent survey. Considering that species might have been overlooked during revisitation, the extinction rate was estimated to be 28% in the Weser-Ems Lowlands and 30% in the Solling Mountains based on a estimated probability for recovering the species of 75% in crustose lichens and 90% in foliose and fruticose lichens. The main causes of the species decline are thought to be forest management (especially the reduction of overmature and decaying trees), the reduction of soil moisture and, with it, air humidity due to drainage as well as the deposition of acidifying and fertilizing substances from the atmosphere. Lichens specialized on rain-sheltered bark furrows and cavities of old trees or smooth, shady bark or moist thick-stemmed deadwood in the forest interior have suffered the strongest declines, including the epiphyte flora of *Fagus sylvatica*, Central Europe's most abundant native forest tree species. Only few lichens which benefit from nitrogen deposition, global warming or the acidification of bark due to sulphur dioxide pollution have spread.

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1. Introduction

Industrialization has caused considerable changes in the biodiversity of Central Europe. These changes are not confined to urban areas and the immediate vicinity of factories, but even concern rural areas due to the mechanization of agriculture, the demand for wood and the pollution of air and water from industry, traffic and industrialized agriculture. Long lists of threatened species witness the detrimental human impact on biodiversity. Approximately one third of Germany is forested (Ellenberg and Leuschner, 2010). Though forests are principally the natural vegetation of most of Central Europe's land surface, they are subject to considerable human disturbance. The most direct human impact is via logging and the conversion of semi-natural forest ecosystems into plantations of tree species which are not part of the regional natural vegetation. Furthermore, forests are disturbed by transportation routes, drainage, air pollution and global warming.

Lichens make a substantial contribution to forest biodiversity. In Germany, about one third (i.e. more than 800 species) of the li-

chen flora regularly occurs in forests (Wirth et al., 2009). Most of them (more than 500 species) are epiphytes of bark and deadwood. Epiphytes respond more directly to timber harvesting than most vascular plants, because logging means that they are removed from the forest together with their substratum. Moreover, epiphytes are particularly susceptible to air pollutants, as the deposition of substances from the atmosphere is a major source of nutrients for them and as bark and wood surfaces are chemically poorly buffered (Conti and Cecchetti, 2008; Hauck et al., 2009). In addition epiphytic lichens respond very sensitively to global warming (Aptroot and van Herk, 2007).

Losses of lichen diversity, which are caused by the replacement of semi-natural broad-leaved forests by plantations of conifers, are well documented for Central Europe (Wirth, 1978). Epiphytic lichens are strongly dependent on the pH of their substratum and the bark of most coniferous trees is much more acidic than the bark of most broad-leaved trees (Hauck, 2011). Therefore, most epiphytes of beech, oak and other Central European broad-leaved trees cannot grow on spruce, pine or larch. On the other hand, many epiphytes specialized on the chemical conditions on conifer bark need a moist-cool mountain climate and cannot grow at low elevations with low precipitation and rare fog events. Moreover, the interior of many conifer plantations, especially those stocked

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with spruce, is considerably darker than natural conifer forests or broad-leaved forests. This excludes many epiphytic lichen species, a fact recognized early in lichenological studies by Lotsy (1890). Plantations of locust (*Robinia pseudacacia*) or poplar are also much less diverse in epiphytic lichens than semi-natural forests, though such stands are quantitatively less important than conifer plantations in Central Europe (Nascimbene and Marini, 2010).

While the effect of tree species composition on epiphytic lichen vegetation is quite obvious, changes in epiphytic lichen diversity due to land use, air pollutants and global warming, which occur even in semi-natural forests of Central Europe, demand more detailed study. Therefore, we analyzed changes in epiphytic lichen diversity in broad-leaved forests of north-western Germany comparing surveys which originate from the mid 19th to early 20th century with the present vegetation. Since historical data are only available for limited areas of north-western Germany, our study focuses on three study regions (Fig. 1) from where historical records are published by Beckhaus (1855, 1856, 1857, 1859), Lahm (1885), Sandstede (1889, 1893, 1896, 1898, 1903, 1912) and Rüggeberg

(1911). The historical data allow for the assessment of the former frequency of species in rough classes. These data are compared with the present situation in order to test the hypotheses that (1) the total species diversity of epiphytic lichens has decreased during the past 100–150 years and (2) this decline particularly concerns species susceptible to logging, sulphur dioxide and eutrophication.

2. Material and methods

2.1. Study areas

The study areas are located in the lowlands and submontane (to montane) uplands of north-western Germany. The selection of areas for the investigation depended on the availability of historical data from the mid to late 19th or the early 20th century. Study areas are located in (1) the Weser-Ems Lowlands, (2) the Westphalian Bight, and (3) the Solling Mountains (Fig. 1).

The Weser-Ems Lowlands are delimited by the rivers Weser in the east and Ems in the west, the cities of Lingen and Cloppenburg

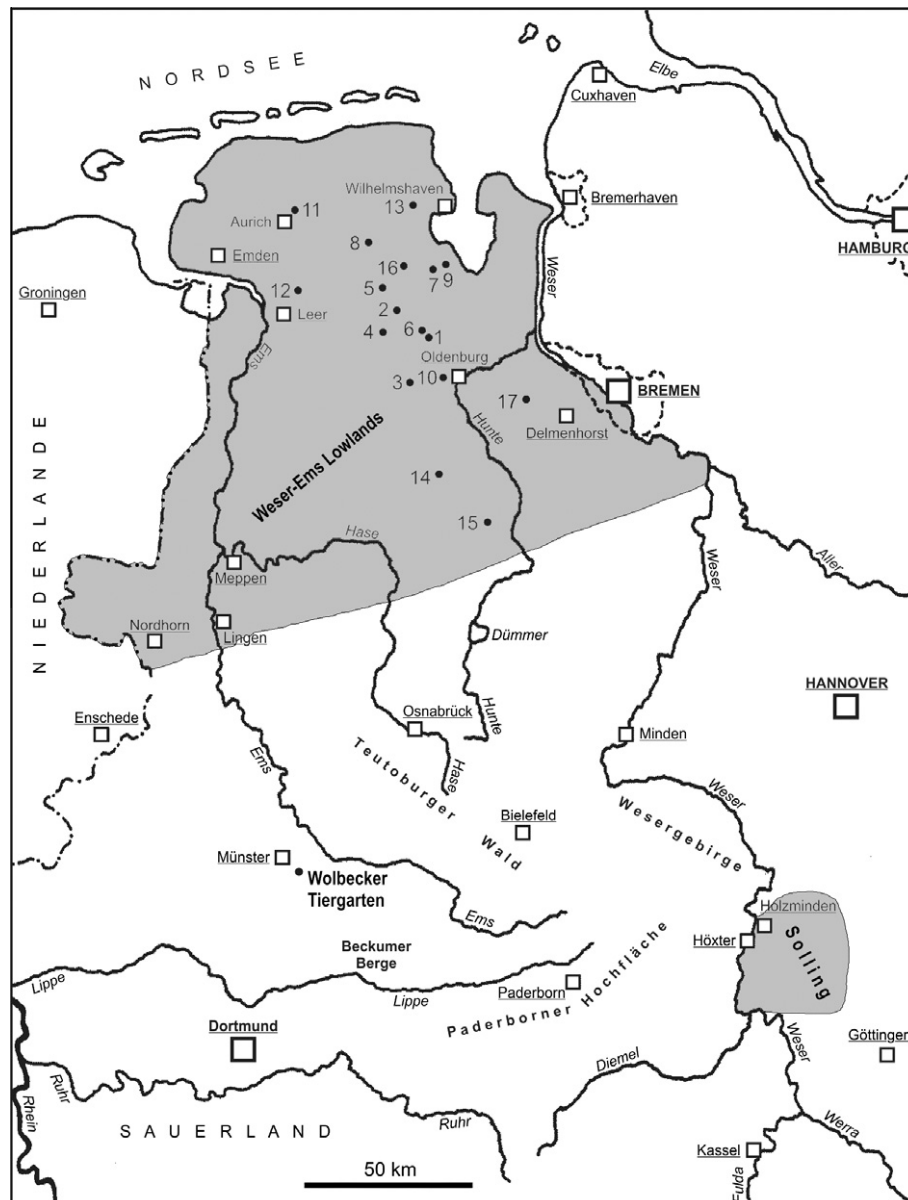


Fig. 1. Studied forest sites in north-western Germany. Numbers for study sites in the Weser-Ems Lowlands are defined in Table 1.

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