

Rapid changes in the epiphytic macrolichen flora on sites in southern Sweden

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Abstract: A relatively quick and simple method is presented for monitoring changes in distribution and in site and substratum preferences of epiphytic macrolichens; the method also records the natural turnover of common species. Changes in the epiphytic lichen flora in southern Sweden were recorded at 64 sites in 1986 and again in 2003. In total 1990 observations of lichens were recorded on 15 tree species, mainly on trunks but also on branches up to 2 m above the ground. Almost all species showed a high turnover with regard to substratum, including very abundant species such as *Hypogymnia physodes*. Many of the species had changed substratum within their sites, possibly reflecting a general change in the ecological quality of sites. Canonical Correspondence Analysis was used to extract the variation in species composition over time, using 1685 records of 55 lichen species on 8 different substrata. Some species such as *Hypogymnia tubulosa* had increased in abundance whilst others such as *Vulpicida pinastri* had decreased.

Key words: bark, biodiversity, lichens, tree trunks, temporal change, monitoring

Introduction

The epiphytic lichen flora of southern Sweden has changed substantially during the last 100 years as manifested both through changes in geographical distribution and a change in ecological preferences (Mattsson 1988; Arup *et al.* 1989, 1997; Kärnefelt & Mattsson 1989; Seaward & Letrouit-Galinou 1991; Wirth *et al.* 2001). Proposed explanations for these changes relate mainly to forestry, new methods in agriculture, and air pollution. Although some of these changes affect lichens mainly locally by reducing their available substrata, there are also indications of general, large-scale changes in the geographic distribution of species. Southern and thermophilic lichens seem to be expanding northwards

whilst the southern border for northerly distributed lichens is moving northwards (van Herk *et al.* 2002). The explanation proposed for this large-scale drift is a change in climate, in particular an increase in temperature (van Herk *et al.* 2002).

For conservation purposes, it is important to be able to detect changes in species distribution and community composition over fairly short periods of time. Such changes are, however, difficult to detect and finding an appropriate combination of spatial scale and data details is a challenge. Detailed studies of populations of lichens are manageable only on a relatively small number of selected sites; this makes data subject to site-specific changes (e.g. forestry, management change) and renders transferability to regional scales or a wider range of habitats of dubious worth. In order to draw sound regional conclusions, less detailed data from more sites representing a range of different environments are preferable.

One way of achieving this is to use common species, preferably easily determined, with low substratum specificity and,

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preferably, with different ecological dispersal strategies. In our survey work in southern Sweden we recorded the occurrence of all epiphytic macrolichens found at sites instead of making an *a priori* list of species. Although some 500 species of macrolichens are known from southern Sweden, only some dozen appear regularly on randomly selected sites and only a handful may be found on a majority of these. The number of species used in the current study is therefore quite low.

By using common species it will also be possible to detect the ordinary turnover of the lichen thalli if the number of observations is high. Such information is also important in conservation issues. Death and reestablishment are natural events in lichen life cycles and do not necessarily indicate changes in ecological factors but the higher the turnover of thalli, the higher the potential rate of changes in community structure.

Thus, the main objective here is to present a relatively quick and simple method for monitoring changes in an epiphytic lichen flora concerning shifts in distribution, site and substratum preferences, and also to cover the natural turnover for common species. The study also aims to present the actual changes in distribution and substratum preferences in the epiphytic macrolichen flora in southern Sweden based on observations on 64 sites in 1986 and 2003 respectively.

Methods

Field survey

In 1986 and again in 2003, 64 sites in southern Sweden were visited (Fig. 1). The sites were originally selected and visited by JEM for a study on the extent to which *Vulpicida juniperinus* (L.) J.-E. Mattsson & M. J. Lai and *V. pinastri* (Scop.) J.-E. Mattsson & M. J. Lai were still present at former localities (Mattsson 1988). In that study, the identification and selection of the sites were based on herbarium specimens of these species collected during a period of about one hundred years. Hence, the sites are not a random selection but follow the (previous) ecological distribution of these species. Nevertheless, the sites span a wide range of ecological situations with no apparent bias towards a particular tree diameter (succession stage). Therefore, we believe they are a representative sample for detecting large-scale changes over time. The sites were of different

sizes, often delimited by natural boundaries such as creeks or ridges, or by man-made ones such as fences, or differences in land use. The investigated area at most sites was about a quarter of a hectare, in some cases up to one hectare. The sites represented different habitats common in southern Sweden; coniferous, deciduous and mixed forests, grazing land, parks, and also, sometimes even single trees in towns, villages and farms.

Trunks and branches of all tree species present were searched, up to a height of 2 m above ground, for epiphytic macrolichens. The number of tree species (with lichens) per site varied from one to eight with an average of four; and if possible about 50 trees were studied. Only records from trees carrying lichens were included as trees without lichens were not registered. Lichen-free trees were (relatively) rare and their omission does not affect the internal validity of the data. In 2003, two observers (JEM & HL) used approximately 20 minutes each per site to record all species present while only one person (JEM) conducted the field work in 1986. The working time spent per site was of similar magnitude and the search method was identical on the two occasions. In cases where the identity of species was uncertain, samples were taken to the laboratory for identification. The nomenclature follows Santesson *et al.* (2004).

Analyses

Data set

A total of 15 tree species and 1990 records of 59 lichen species were registered during the two field seasons. Several of the tree species were rare, and therefore only the eight most common were included in the current analysis. In total, 1685 records of 55 lichen species on 453 trees of eight tree species from two field seasons were used.

Multivariate analysis

As we were primarily interested in temporal differences, a direct gradient analysis technique was preferable as it highlights the part of the total variation in species composition of sites that distinguishes the two points in time. Furthermore, such an analysis can be combined with a test to evaluate the probability of observing the data under the null hypothesis of “no differences” (Leps & Smilauer 2003). As beta-diversity was relatively high in the data, we chose Canonical Correspondence Analysis (CCA). The data set was not completely balanced; for example, not all tree species were present at all sites, and a tree species may have been present at a site in 1986 but not in 2003. Therefore, to reduce the influence of tree species identity and geographic region, we used 20 categorical co-variables (eight tree species and twelve geographical regions). Hence, we conducted a partial CCA evaluating the time effect after eliminating most of the effects of substratum and location. We used the software CANOCO (ter Braak & Smilauer 2002) with default options, except that we down-weighted rare species. The explanatory power of the solution was evaluated in a permutation test with 9999 permutations with permutation blocks identified by tree species.

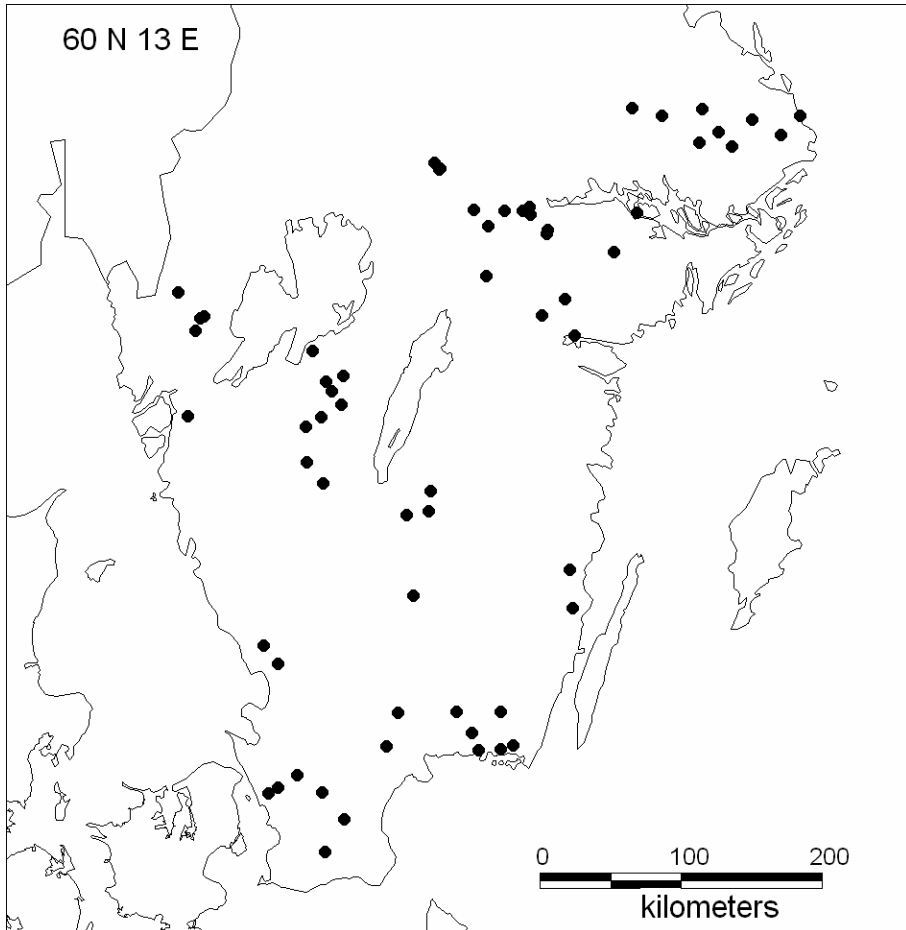


FIG. 1. Position of 64 sites in southern Sweden visited in 1986 and 2003.

Results

Species turnover

The presence of the 18 most common macrolichens on the most common tree species at the sites is presented in Table 1. There was a relatively high turnover for all lichen species on all eight tree species. In general, there was a substantial turnover, including common species. For example, *Hypogymnia physodes* (L.) Nyl. had a turnover index (T) of 0.21 [$T=(A+B)/(A+B+C)$; where A=number of substrata on all sites unique for 1986, B=unique for 2003, C=substrata on sites with occurrence in both years]. For decreasing, (*Pseudevernia*

furfuracea (L.) Zopf, -14%, $T=0.66$ and *Vulpicida pinastri*, -62%, $T=0.77$) and increasing species (*Evernia prunastri* (L.) Ach., +20%, $T=0.54$) the index was higher.

Only three species were found on all the eight substrata, *Evernia prunastri*, *Hypogymnia physodes*, and *Parmelia sulcata* Taylor, but nevertheless these species changed substrata within many of the sites. This tendency was even more pronounced for less common species. For example, *Bryoria capillaris* (Ach.) Brodo & D. Hawksw. was observed on nine occasions in 1986 and seven occasions in 2003, but only at one of these was it found on the same substratum and at the same site in both 1986 and 2003. Further,

TABLE 1. Number of sites with lichen species occurrence on *Acer platanoides*, *Betula pendula*, *Fraxinus excelsior*, *Juniperus communis*, *Picea abies*, *Pinus sylvestris*, *Populus tremula*, and *Quercus robur* exclusively in 1986, both in 1986 and 2003, and exclusively in 2003

Lichen species	<i>Acer platanoides</i>			<i>Betula pendula</i>			<i>Fraxinus excelsior</i>			<i>Juniperus communis</i>			<i>Picea abies</i>			<i>Pinus sylvestris</i>			<i>Populus tremula</i>			<i>Quercus robur</i>			Sum over all tree spp				
	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003	1986	1986 & 2003	2003		
<i>Bryoria capillaris</i>	1	0	0	1	1	1	0	0	0	3	0	1	1	0	4	2	0	0	0	0	0	0	0	0	0	0	8	1	6
<i>Cetraria sepincola</i>	0	0	0	3	2	4	0	0	1	3	0	2	0	0	2	0	0	1	0	0	0	0	0	0	0	9	2	7	
<i>Evernia prunastri</i>	1	4	10	7	5	10	0	3	6	4	1	7	2	1	5	1	1	5	1	4	3	9	8	23	25	51			
<i>Hypocomyce scalaris</i>	0	0	0	9	6	9	0	0	0	0	1	0	0	4	6	10	14	0	0	0	0	0	2	15	16	30			
<i>Hypogymnia physodes</i>	3	2	10	8	36	14	3	2	4	15	22	6	10	28	3	8	31	3	10	3	10	7	10	6	64	134	56		
<i>H. tubulosa</i>	0	0	0	0	15	2	0	1	2	1	10	0	1	15	1	0	4	0	0	3	1	0	6	6	2	54			
<i>Melanelia glabratala</i>	0	0	7	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	3	0	1	4	0	3	19			
<i>Parmelia saxatilis</i>	3	0	2	0	0	10	2	1	0	0	0	1	0	0	1	0	0	1	0	0	2	0	0	8	5	1	25		
<i>P. sulcata</i>	4	4	8	7	1	14	0	2	7	6	1	4	0	2	5	0	0	1	5	2	8	5	6	3	27	18	50		
<i>Parmeliopsis ambigua</i>	0	0	0	5	3	19	0	0	0	11	1	5	7	1	3	3	6	16	4	0	0	0	0	1	30	11	44		
<i>Platismatia glauca</i>	0	0	0	10	7	9	0	0	2	8	2	4	8	6	12	6	3	6	2	0	0	1	2	4	35	20	37		
<i>Pseudevernia furfuracea</i>	1	0	0	16	6	12	0	0	7	4	5	9	9	12	8	9	9	3	0	1	0	1	5	44	29	44			
<i>Ramalina farinacea</i>	0	4	4	0	0	3	1	0	6	1	0	0	0	0	1	0	0	0	0	2	0	1	4	2	5	20			
<i>Tuckermanopsis chlorophylla</i>	1	0	0	5	2	6	0	0	0	5	0	0	6	1	7	0	1	3	1	0	0	1	0	1	19	4	17		
<i>Usnea hirta</i>	1	0	0	7	1	1	0	0	0	5	2	0	5	1	0	8	2	2	1	0	0	0	0	0	27	6	3		
<i>U. subfloridana</i>	2	0	0	8	0	1	0	0	0	4	0	0	3	0	1	2	0	1	0	0	0	1	0	0	20	0	3		
<i>Vulpicida pinastri</i>	0	0	0	9	3	3	0	0	0	14	5	3	13	0	1	8	3	2	2	0	1	0	0	0	46	11	10		
<i>Xanthoria parietina</i>	1	2	2	2	0	2	0	0	6	0	0	0	0	0	0	0	0	1	2	8	0	0	1	4	4	19			
Σ Column.	18	16	43	97	73	133	8	10	38	88	39	49	64	50	74	55	66	63	35	8	42	19	30	53	384	292	495		
Σ tree species	77			303			56			176			188			184			85			102			1171				

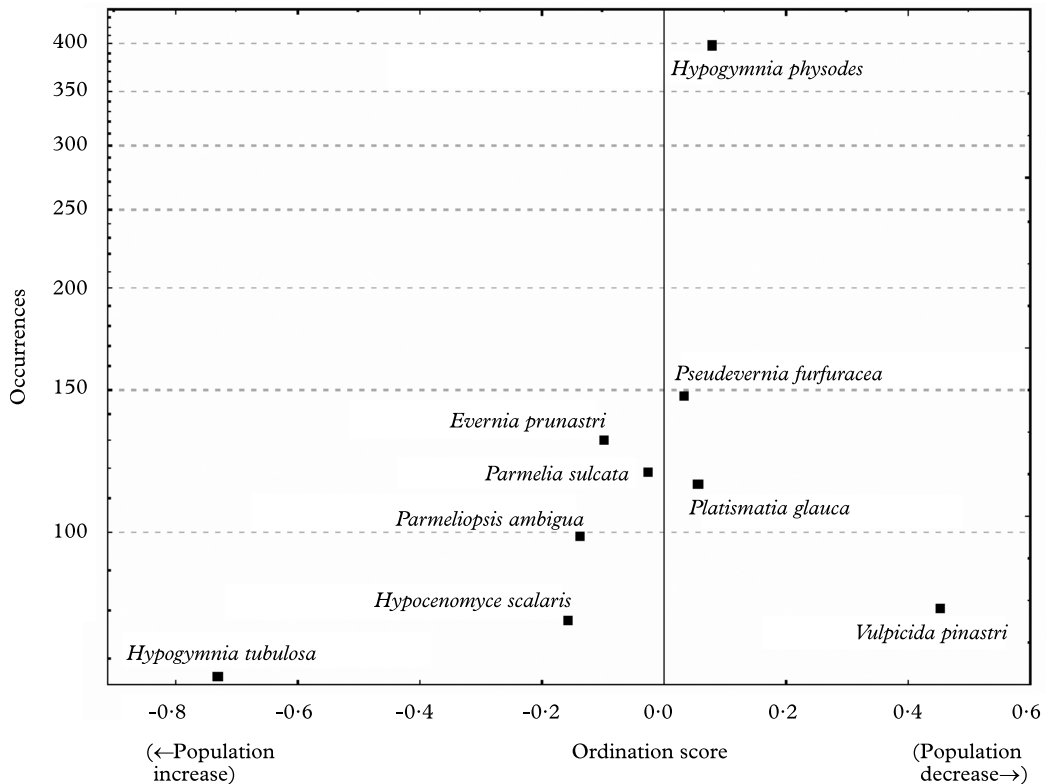


FIG. 2. Outcome of the partial CCA, contrasting the results from 1986 and 2003. The graph presents the results of the most frequent species only. Occurrences were summed over 453 trees investigated.

B. capillaris, where it changed substratum, was recorded on both occasions only at one further site.

Large-scale changes over time

The partial CCA, contrasting the two points in time after taking geographic region and tree species into account, yielded a highly significant solution (the time-constrained axis had an eigenvalue of 0.058; $P=0.0001$). Of the nine most frequent species in the data, *Vulpicida pinastri* had decreased in abundance while *Hypogymnia tubulosa* (Schaer.) Hav. had increased (Fig. 2). There were also other, less common, species exhibiting an overall increase or decrease in abundance (Table 1), or less drastic changes in common species [e.g. a small increase in *Hypocenomyce scalaris* (Ach.) M. Choisy, *Parmeliopsis ambigua*

(Wulfen) Nyl., and *Evernia prunastri*; a small decrease for *Hypogymnia physodes* and *Pseudevernia furfuracea* (Fig. 2)].

Discussion

Field methods

There were some changes in the fieldwork as two people participated in the investigation in 2003 (JEM & HL) and only one in 1986 (JEM), but the working time spent on each site was of similar magnitude. One person (JEM) participated both times, which ensured that the search method was identical. The fieldworkers' experience may have influenced the results, but as the species included were mainly common and easily determined, such influences were probably small.

In hindsight, it would have been beneficial to have included tree species lacking lichens

recorded at each site to make it possible to describe the phenomenon in greater detail and to identify the reasons for change.

The selection of sites leads to some problems regarding generalizations of the results (external validity) and random or stratified selection would have been preferable from this perspective. We do believe, however, that the internal validity is high for two reasons. First, the original selection of the sites was based on *Vulpicida* occurrences and this taxon (especially *Vulpicida pinastri*) appears in a range of habitats which led to the inclusion of a wide range of sites differing in several ecological attributes. Second, a wide range of tree size classes was also included. Hence there is no reason to assume a bias due to the ageing of trees (succession), which would have been the case if only previously visited trees had been included. Consequently, we believe that data collected in this way can document the phenomenon of temporal change, although very little can be concluded regarding the mechanisms involved.

Turnover and variability over time at sites

When revisiting 64 sites spread across southern Sweden after 17 years, screening all available tree trunks and branches for epiphytic macrolichens, it is apparent that the constancy of species on the different substrata is surprisingly low (Table 1). Tree trunks and branches are growing substrata whose suitability is not constant (e.g., Hedenås & Ericsson 2000), but a time span of 17 years cannot be the only explanation for the high turnover of species. Another possible reason for the high turnover, or at least for the loss of species, is logging because this reduces or eliminates selectively among and within tree species. As individual trees were not recorded at sites, the magnitude of logging and the influence of other human activities on lichens cannot be evaluated from the current data set.

The actual turnover is probably much higher than indicated in Table 1, as movements between stems of the same tree

species, and changes due to dying and establishment of new thalli on the same trunk, were not recorded. On the other hand, the average number of tree species (with lichens) on the sites had increased from 3.35 to 4.85. This was partly due to changes in land use, transforming pastures and meadows to forested land. Many trees present in 1986 were too young to carry lichens and consequently were not recorded during the first survey. Hence, it is possible that the turnover is boosted by a general increase in the amount of substratum (number of suitable trees) as well as its quality (more shading) both driven by relaxed grazing.

The very common *Hypogymnia physodes*, which was found at all sites in both years, shows an unexpected turnover with regard to substratum. One possible explanation for the high turnover is a shorter life span than previously assumed. Other sorediate species with high turnover were *Parmelia sulcata*, *Parmeliopsis ambigua*, *Tuckermanopsis chlorophylla* (Willd.) Hale, *Usnea subfloridana* Stirt., and *Vulpicida pinastri*. The sexually dispersed species showed a similar pattern, although the numbers of observations were fewer and should only be used with caution.

The high turnover has implications for the design of more intensive monitoring of epiphytic lichens on trees, which is faced with a substantial variance in the data collected and potentially strong temporal trends. For example, it might be advantageous to keep time intervals relatively short and to sample a relatively large number of trees per sites.

Large-scale changes over time

Hypogymnia tubulosa, and to a lesser extent *Hypocenomyce scalaris*, *Parmeliopsis ambigua*, and *Evernia prunastri*, had increased (Fig. 2). This is, for some of the species, in contrast to the situation in the Netherlands (van Herk *et al.* 2002) where abundance of *Evernia prunastri* has decreased, that of *Hypogymnia tubulosa* and *Parmeliopsis ambigua* have remained relatively constant whereas *Hypocenomyce scalaris* has also increased. Abundance of *Hypogymnia tubulosa* and *Parmelia saxatilis* (L.) Ach. (Table 1) had also

increased on most substrata but the number of observations was very low.

The partial CCA, accounting for possible differences between tree species and among geographic regions, highlighted a marked population decrease for *Vulpicida pinastri* and a decrease also for *Hypogymnia physodes* and *Pseudevernia furfuracea* (Fig. 2). The decrease in abundance of the latter species is also reported by van Herk *et al.* (2002).

Data in Table 1 also indicate temporal changes for several other species over time but these are more uncertain as the number of observations was quite low. However, they highlight the need to investigate these apparently large changes and the processes that drive them.

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