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Effects of forest continuity and tree age on epiphytic lichen biota in coniferous forests in Estonia

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ABSTRACT

Epiphytic lichen biota on *Picea abies* and *Pinus sylvestris* in Estonia was studied. Twenty-one spruce and 21 pine sample plots were located in old forests with long forest continuity, and 12 spruce and 12 pine sample plots in young first-generation forests (<100 years). Altogether 103 lichen species were recorded on the 330 sampled trees. Lichen species richness per plot was significantly higher in old forests in case of both tree species; 31 lichen species, including red-listed and protected species, were found only in old forests. Tree age had a positive effect on lichen species richness on tree stem in old and young spruce forests and in young pine forests. Tree age also had an effect on the presence of several species. Both tree age and forest continuity affected lichen species composition. *Arthonia leucopellaea*, *Chrysothrix* spp. and *Lecanactis abietina* were found in at least every third old spruce or pine forest and in no young forests, and can be regarded as good indicators of old coniferous forests with long continuity in Estonia.

1. Introduction

Several lichen species are restricted to old-growth forests with long ecological continuity and have been used as indicators of good ecological condition and high conservation value of forests. Epiphytic lichen biota is known to be responsive to forest management (Kuusinen, 1996; Dettki and Esseen, 1998, 2003), and also to forest history and continuity (Tibell, 1992; Josefsson et al., 2005; Ellis and Coppins, 2007; Fritz et al., 2008). Lichen diversity is generally higher in old-growth forests compared to young managed forests (Kuusinen and Siitonen, 1998; Nascimbene et al., 2010). Many species, including species with high conservation value, prefer to grow in forests with high ecological continuity (e.g. Tibell, 1992; Fritz et al., 2008). Tree age is also known to affect epiphytic lichen composition as several rare species are associated with older trees (Rolstad et al., 2001; Ranius et al., 2008; Fritz et al., 2009).

Studies have revealed that restricted dispersal ability is important in explaining species scarcity in younger stands (Sillett et al., 2000; Hilmo and Såstad, 2001; Lõhmus and Lõhmus, 2008). In addition, many species can be associated with specific substrate qualities of older trees as bark qualities change when trees grow older (Ranius et al., 2008; Fritz et al., 2009). Often it is difficult to distinguish between the effects of various factors on lichen biota. Still, it is crucial to understand the relative importance of different factors on the occurrence of indicator species in order to distinguish the species which actually indicate long forest continuity (Norden and Appelqvist, 2001). For the development of conservation strategies it is also important to know whether rare epiphytic lichen species connected with old forests are primarily sensitive to forest continuity, or to tree age and related microhabitats.

The aim of our study is to contribute to the knowledge of how tree age and forest continuity influence epiphytic lichens in boreal forests, using the example of coniferous forests in Estonia. Lichen species richness and species composition have been compared in old forests with long continuity and in first-generation forests on mixed aged trees. The study may also provide useful information about potential additional indicators of old forests with high conservation value in the area. The main objective of this study is to assess (1) how forest continuity affects lichen species richness in the forest stands, (2) how tree age affects lichen species richness on the trees, and (3) which are the most suitable indicator species of old coniferous forests in Estonia. We hypothesise that species richness and frequency of species with conservation value are higher in old forests.

2. Materials and methods

2.1. Study area

Estonia is located in Northern Europe on the eastern shores of the Baltic Sea. The climate is temperate. According to the Estonian Meteorological and Hydrological Institute, the mean tempera-

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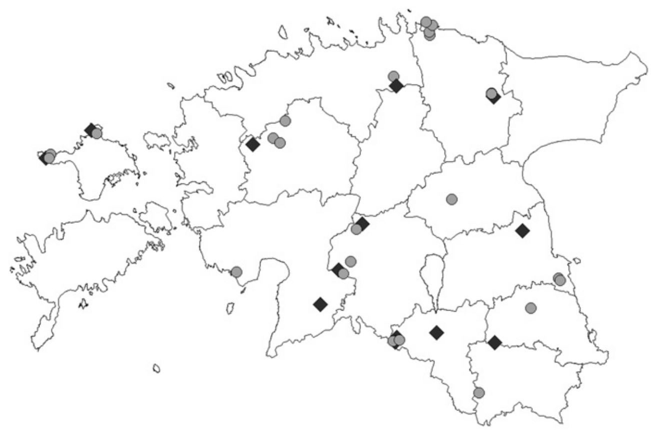

Fig. 1. Location of sample plots (diamonds – young forests; circles – old forests).

ture varies from −6 °C (in February) to 16 °C (in July); the mean annual precipitation is 630 mm; southern and western winds prevail. Estonian forests belong to the hemiboreal subzone of the boreal forest zone, i.e. the country is lying in the transitional area where the southern taiga forest subzone changes into the spruce-hardwood subzone (Ahti et al., 1968; Laasimer and Masing, 1995). About half of Estonian territory is covered with forests, *Pinus sylvestris* L., *Picea abies* (L.) H. Karst. and *Betula pendula* Roth being the most abundant tree species. As the present study concentrates on coniferous forests, *P. abies* (hereafter 'spruce') and *P. sylvestris* (hereafter 'pine') were chosen as phorophyte species; these two are also among the most common tree species in (hemi)boreal forests in Europe. The most abundant forest type group in studied forest stands was dry boreal forest; spruce or pine being the main tree species, and *Vaccinium myrtillus* L. and *V. vitis-idaea* L. dominating the undergrowth. However, other forest types, such as alvar forests and boreal heath forests, were also included if they had suitable tree species. In some young forest stands forest site type was not yet completely developed.

2.2. Forest history

The present study was carried out in Estonia mainland and island Hiiumaa (Fig. 1). Sample plots were divided into two groups according to the forest continuity which was studied using the historical maps from 17th century and from the end of 19th/beginning of 20th century. (1) All old forest sample plots were located in areas which were marked as forest on ca 100 year old maps. The oldest maps were unavailable for Hiiumaa island and one sample plot in the mainland; all other old forest plots were marked as forest also on maps from the 17th century, and thus are known to be used as forest land for at least 350 years. Most old forest sample plots were located in nature protection areas or woodland key habitats (WKH). (2) Young forest sample plots were located in forest stands which were marked as arable field or grassland on ca 100 year old maps; these are first-generation forests which have colonised above habitats after their abandonment. Only young forests that seemed to be naturally regenerated were chosen for the study. In both forest groups unmanaged stands with heterogenic tree species composition and age were preferred in order to exclude the effect of management; although old forests may have been managed historically. The number of studied young forest plots was lower compared to old forest plots because of the relative infrequency of young forests that would meet the above requirements.

2.3. Field methods

Fieldwork was carried out in 2008–2009 by the two first authors. Altogether 33 spruce and 33 pine sample plots were studied; 21 plots of both tree species were located in old and 12 plots in young forests. In most cases spruce and pine sample plots were located in the same forest stand. Each sample plot contained five trees of the same species i.e. altogether 330 trees were sampled. All trees were selected randomly within 50 m radius from plot center; only trees with >50 cm circumference were included. The age of all selected trees was determined with an increment borer; core samples were taken at the height of 1.3 m.

Presence of all lichen species growing on tree stem, branches and twigs on the first 2 m from the ground was recorded on every selected tree. Presence or absence of species found only on branches and twigs was recorded separately. The max length of sampled branches was measured for every tree. Some specimens were collected for later identification with microscope and spot tests. Thin layer chromatography with solvent A (Orange et al., 2001) was used for identifying secondary compounds in crustose lichens. All lichen species, including *Usnea* species and sterile crustose taxa, have been included in the study at species level in order to estimate the effects of forest continuity on the total species richness and composition of epiphytic lichens.

2.4. Statistical analysis

Data were analysed separately according to the two tree species. Software application STATISTICA 7 was used for the statistical analysis. Analysis of covariance (ANCOVA, type III) was used for estimating the effect of forest continuity on lichen species richness and species composition at the sample plot scale; as tree age was higher in older forests, max tree age in the sample plots was added as covariate in the analyses. All lichen species growing on tree stem, branches and twigs were included in ANCOVA; for that reason, max branch length in the sample plot was an additional covariate as several lichen species were mainly found on branches. In addition, Kruskal–Wallis test was carried out for verifying the effect of forest age group on the number of lichen species growing on tree stem. Principal component analysis (PCA) was used for describing the species composition in sample plots; PCA Factor 1 coordinates of sample plots were used as measures of species composition in ANCOVA for analysing the effect of forest continuity on lichen species composition.

In order to control the effect of tree age on lichen species richness, analyses were carried out at the tree scale separately in young and old forest sample plots to exclude the effect of forest continuity. Pearson's correlation coefficient was calculated for describing the correlation between lichen species richness on tree stem and tree age. Logistic regression analysis was used for describing the effect of tree age on the presence of lichen species on tree stem. Only old forest sample plots were included in logistic regression analyses in order to exclude the effect of forest continuity. Species which were recorded only on branches and twigs were excluded in these analyses because younger trees tended to have more branches at the reachable height and that could affect the results. As it was impossible to count tree rings of two pines and one spruce, these trees were left out of Pearson's and logistic regression analyses. The proportion of sample plots where every species was found was calculated as percentage of occurrence in 12 young and 21 old forest sample plots, separately for the tree species.