THE LICHENOINDICATIVE EVALUATION OF PINE NATURAL WOODLAND HABITATS

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Abstract

The main pine natural woodland habitats (woodland key habitats – WKH) and the importance of their management and monitoring have been described in this paper. The ecological importance of lichen epiphytes in forest ecosystem has been analysed. The lichenoflora and its percental cover features have been described. The exposition of lichen species depending on the cardinal points have been analysed. The paper presents the characteristics of ecological indicators of lichen in the landscape features. The lichenoindicative evaluation and comparison of pine WKH have been carried out.
Key words: lichens epiphytes, pine woodland key habitats, management of woodland habitats.

Introduction

As a result of the inventory of woodland key habitats (WKH) carried out in Latvia's state owned forests over the period of 1997-2002, 39,655 ha of WKH and 12,025 ha of potential woodland key habitats (PWKH) had been distinguished (Bērmanis, Ek, 2003). In order to preserve adequate conditions for special woodland habitat species, 6 % of WKH and 51% of PWKH require special management. In 2002, the joint–stock company 'Latvia's State Forests', State Forest Service and Östra Götland regional forest administration (Sweden) started the project 'Management of woodland key habitats in Latvia', whose main goals are to elaborate the most appropriate management types in WKH to preserve biological values and provide their effective protection in future. Simultaneously, monitoring has started in these areas, which reflects the condition of the environment concerning the living organisms there. The results of the monitoring make up a system of observation, control, analysis and forecasting, which gives information about the present environmental condition and possible changes in the future, as a result of the management (Donis et al., 2004; Bērmanis, 2006).

The pine WKH is a naturally regenerated stand, formed after storms and forest fires as well as a result of forest stand's gap disturbance processes. The most essential structure elements with a high potential of biological diversity in such forests are biologically old trees, decaying trees, naturally formed snags and also logs. The different ages, sizes, decomposition and degrees of moisture of the dead wood testify about the sustainability of the forest. It should be noted that the amount of biologically old trees and dead wood essentially depends on the previous management of the forest. In most cases the lack of dead wood in pine stands is attributed to the sanitary cuttings (Ek et al., 2002).

Because of natural peculiarities, a lot fewer WKH specialist and indicator species can be found in dry pine forests, compared to spruce forests. The main special woodland habitat species in pine ecosystems are insects (beetles) and those species which need light. On such occasions an important feature of pines is a rough, thick bark ('crocodile skin' bark) and thick branches, which are inhabited by rare and endangered beetle species (Johansson, 2005).

Nowadays in pine forests on dry soils and soils with a normal amount of moisture, a comparatively large number of spruces grow. Quite often the reason for that is the successful extinguishing of fire over a longer period of time. As a result of that, the spruces which are not so fire resistant, occupy more and more forest areas, where under natural conditions, pines would grow. Pines demand light and they are relatively fire resistant. In the forests, where most of biological diversity is connected with pine, and where the amount of the spread of spruce threatens the values of the biological diversity, the best management would be a partial cutting of spruce or imitation of a forest fire (prescribed fire). Only those spruces are to be preserved, which already sustain or will maintain certain biological values. The reduction of spruce admixture to the pine WKH is considered to be an experiment, the results of which will be possible to evaluate in a few years (Donis et al., 2004; Johansson, 2005).

Lichens are found in almost all terrestrial ecosystems, forming a significant biomas also in boreal coniferous forests. In forest ecosystems, lichen epiphyte communities have been studied comparatively little. These communities carry out nitrogen fixation and nutrient circulation functions (Pike, 1978; Will-Wolf et al., 2002). The lichen epiphytes make up microhabitats and nutrient basis for invertebrates. They also serve as nest building materials for birds and small animals (Will-Wolf et al., 2002). Lichen is a slow growing organism, having particular nutrition way and metabolism, which to a great extent depends on phytocenotic and ecological conditions in the stand (Somermaa, 1972). Lichens intercept and absorb precipitation

which contains different nutrients and pollution substances. Their development and growth depend on precipitation, air moisture, light, and potential evaporation (Will-Wolf et al., 2002). In the inventory of WKH, lichen is one of the groups of organisms, which is used to evaluate the biological diversity and forest continuity (Ek et al., 2002; Znotiņa, 2003). If over the last hundred year period mainly the correlation regularities of lichen and air pollution have been studied, then in the last decades considerable attention has been paid to the research of interdependence of lichen diversity and forest management (Nash et al., 1988). As a result of forest management, with the changes in the forest canopy, the changes take place also in the microclimate of the stand which has a direct influence on the lichen epiphyte communities and their development (McCune, 2000).

The aim of the research is to describe and evaluate the pine WKH from the lichoindicative point of view. In order to reach the goal, the following objectives have been set:

1) the epiphytic lichenflora and the analysis of its cover in percentage in pine WKH;

2) the description and analysis of dependence of lichen exposition on cardinal points;

3) the description of lichen ecological indicators.

Materials and Methods

In order to carry out the lichenoindicative analysis in pine stands, in 2005 four research sites were chosen with important proportion of spruce. One or two sample plot sections were made depending on the size or configuration of the sites, each section consisting of four 500 m^2 area circular sample plots. One sample plot section is envisaged for the woodland key habitat control part in the future, while the other is to be used for experimental or management part. Different management types are envisaged in the selected pine stands – the decrease of spruces and burning. Sample plots are arranged according to a definite scheme, which, if necessary, gives the opportunity to supplement the scheme up to 9 sample plots per section, which are located interdependently in a network of 30 m*30 m (Donis et al., 2004). The general description of the sites is shown in Table 1.

In all the sites the inventory of epiphytic lichens is made, using the line intercept method. In each sample plot, 3-4 pines and one spruce are selected randomly. In total, 76 pines and and 18 spruces have been measured. The lichen record for the selected trees has been done at two heights – 0.5 m and 1.5 m above the root collar. Both marks of height are fixed with screws on the northen side, which has been identified by a Suunto compass, in order to repeat the measurements at certain times and compare the changes. The trunks of the trees are girdled by bands on which all the lichen species, which touch the band and the distances in cm occupied by lichens, are marked. The precision is 0.1 cm in circumference. The record is made clockwise (N – E – S – W). In order to define more accurately the species of lichens, samples were collected to identify them under laboratory conditions. The conspectus of lichens in Latvia is used for the classification of lichen species (Piterāns, 2001). The bands with the field data information on lichen were measured and the data obtained were summarized in the tables. When summarizing the line occuppied by each lichen species in cm and dividing that by the perimeter of the trunk and then multiplying it by 100, the projective coverage of each species is obtained. After that, summarizing the data obtained on the sample trees, and dividing this figure by the number of studied trees, the average projective coverage for each lichen species in sample plot is obtained.

Table 1

The description of the research sites

Site code	State Head Forestry (SHF)	State Forestry (SF)	Compartment / subcompartment	Forest type	Stand composition	Average pine age in years	The number of measured trees (pine/ spruce)
13	Aizkraukle	Taurkalne	24./1.	Myrtillosa	7P2 E1B	162	12/4
16	Jēkabpils	Viesīte	360./ 2.,12.	Hylocomiosa	6P4E	156	16/8
17	Ventspils	Usma	58./ 27., 28.	Myrtillosa	8P2E	147	23/4
19	Jelgava	Garoza	40./ 6., 14.	Myrtillosa mel., Hylocomiosa	7P2E1B, 8P2E	143 163	25/2

In the preliminary processing of data, to determine the exposition of lichen species depending on the cardinal points and height, MS Excel 2003 program was used, calculating how many times in the course of 2 degrees (0 – 2; 2 – 4; etc.) the respective lichen species was found out in distribution by species (pine P, spruce E) and heights (0.5 and 1.5 m) in each site. If certain species in the classification group in total (site x tree species x measurement height) has been stated in more than 1000 stages, its number is reduced 2 or 3 times, choosing every second or third measurement from the range if number of observations exceeded 1000 and 2000 respectively. For further processing of the data, the circular data statistical analysis computer programme AXIS 1.1. (PISCES Conservation Ltd.) has been used. The mean direction has been calculated for each classification group and its 95% confidence interval, the mean resultant length and other statistical indicators (Fisher, 1993). The correspondence of the niche direction carried out by the species to the randomness has been verified, using The Rayleigh test for unspecified mean direction. The mutual comparison of objects has been done by means of GLM Univariate analysis (SPSS 12.01 GLM) method, using the total projective coverage and 'site *tree species* height' as classification group (Field, 2005). For the decrease of heterogenity of data variability, arcsin transformation has been used (Liepa, 1974; Krebs, 1999). The projective coverage of separate species is compared, using TWINSPAN and DECORANA analysis in computer programme CAP 3.1. (PISCES Conservation Ltd.) (Kent, Coker, 1999).

In all the research sites, using lichen species and their coverage in percentage on tree trunks in two heights, the ecological evaluation has been performed, using the following six indicators: light, temperature, continentality, moisture, reaction, and amount of nutrients (Wirth, 1992).

Results and Discussion

The analysis of epiphytic lichenflora and its percentile coverage in pine WKH.

A total of 13 lichen species, belonging to 12 genera were found in the research sites (Piterāns, 2001) (Table 2).

In all the sites the crustose lichen species *Lepraria incana* (L.) Ach. is present, constituting a significant proportion of coverage in percentage (Table 3).

Only on one tree and with small percentage of coverage proportion, there were found the lichen species *Parmeliopsis ambigua* (Wulfen) Nyl., *Pertusaria albescens* (Huds.) M.Choisy & Werner, *Ramalina farinacea* (L.) Ach. un *Scoliciosporum chlorococcum* (Grewe ex Stenh.) Vezda. Only in one site – 17 stand – there was found the WKH's indicator species *Lecanactis abietina* (Ach.) Körb. which can be found on spruces and which indicates high moisture content of the air and long-time continuity of the trees. Only in this site two other species are found on pines: *Cladonia squamosa* Hoffm. and *Hypocenomyce scalaris* (Ach.) M.Choisy.

The number of species on the trunk is shown in Table 4. The composition of lichens on the trunk is more homogenious than on the basis of the trunk: overall on the

Table 2

The lichen species found in pine woodland key habitats

No.	The lichen species	Morphological group	On pine	On spruce
1.	*Chaenotheca ferruginea* (Turner & Borrer) Mig.	K	*	*
2.	*Cladonia coniocraea* (Flörke) Spreng.	Kr	*	*
3.	*Cladonia squamosa* Hoffm.	Kr	*	–
4.	*Hypocenomyce scalaris* (Ach.) M.Choisy	K	*	–
5.	*Hypogymnia physodes* (L.) Nyl.	L	*	*
6.	*Lecanactis abietina* (Ach.) Körb.	K	–	*
7.	*Lepraria incana* (L.) Ach.	K	*	*
8.	*Micarea melaena* (Nyl.) Hedl.	K	*	*
9.	*Parmeliopsis ambigua* (Wulfen) Nyl.	L	*	–
10.	*Pertusaria albescens* (Huds.) M.Choisy & Werner	K	*	–
11.	*Platismatia glauca* (L.) W.L.Culb.&C.F.Culb.	L	*	*
12.	*Ramalina farinacea* (L.) Ach.	Kr	–	*
13.	*Scoliciosporum chlorococcum* (Grewe ex Stenh.) Vezda	K	*	–

Designations: K – crustose, L – foliose, Kr – fruticose lichens.

Table 3

The coverage of lichen species *Lepraria incana* (L.) Ach. in objects in percentage

Site code	State Head Forestry (SHF)	State Forestry (SF)	The coverage in percentage at the trunk height 0.5 m	The coverage in percentage at the trunk height 1.5 m
13	Aizkraukle	Taurkalne	42	25
16	Jēkabpils	Viesīte	49	35
17	Ventspils	Usma	31	22
19	Jelgava	Garoza	40	24
Average			40.5	26.5

pine and spruce trunks at the height of 0.5 cm, 13 lichen species have been found, but at the height of 1.5 m – 9 species.

There are controversial facts in literature about the connection between the lichen species and the tree species. Some authors consider that with the age the physical properties of the bark become more significant and similar (water absorbtion capacity and texture), while the specifics of the substratum correspond to certain ecological conditions (Somermaa, 1972; Uliczka et al., 1999; Lohmus, 2005). Thus, approximately in 60% of cases the lichen community is determined by the substratum factor and in 40% of cases by microclimate. Some authors have an opposite view – they hold that the lichen species and their amount are related to a definite species of trees. There are researches that indicate that lichen species are connected with definite forest growth types (Somermaa, 1972).

The mean numbers of lichen species by heights are the following: 6.75 species at 0.5 m and 4,5 species at 1.5 m height. The largest number of species on the trunk at the height of 0.5 m – 8 species – are found in site 16; whereas at the height of 1.5 m 7 species – are found in site 17. The fewest number of species on the trunk at the height of 0.5 m (5 species) and at the height of 1.5 m (3 species) are found in site 19, as well as at the height of 1.5 m – 3 species in site 13.

The coverage with lichen species on the trunk in percentage is shown in Table 4, too. Totally the lichens coverage in percentage is about twice higher at the spruce trunk height of 0.5 m and about three times higher at the spruce trunk height of 1.5 m than at the pine trunk. The average of the lichens coverage in percentage at the pine trunk height of 0.5 m is 44.3% but at the height of 1.5 m – lower – 24%; at the spruce trunk height of 0.5 m – 84.4%, but at the height of 1.5 m – slightly lower – 71.9%. The highest lichens coverage in percentage at the pine trunk height of 0.5 m is in site 16, on the spruce trunk – in site 19, but at the height 1.5 m respectively both on pine and on spruce trunk – in site 17. The lowest lichens coverage in percentage at the pine trunk height of 0.5 m is in site 19, at the spruce trunk height of 1.5 m – in site 16; at the height of 1.5 m respectively both on pine and on spruce trunk – in site 13.

Pine bark is flaky and peels off, therefore there are not much lichens on the upper part of the trunk (Znotiņa, 2003). On old pine trunks, lichen is usually found in the cracks between the flakes of the bark, which can be valued as

Table 4

The number of lichen species and coverage with lichens in percentage

Site code	The number of species at the trunk height 0.5 m	The number of species at the trunk height 1.5 m	The coverage in percentage at the pine trunk height 0.5 m	The coverage in percentage at the spruce trunk height 0.5 m	The coverage in percentage at the pine trunk height 1.5 m	The coverage in percentage at the spruce trunk height 1.5 m
13	7	3	44.8	89.5	21.9	65.7
16	8	5	46.1	74.6	24.2	72.6
17	7	7	45.1	83.2	27.7	76.3
19	5	3	41.2	90.2	22.2	72.9
Average	6.75	4.5	44.3	84.4	24.0	71.9

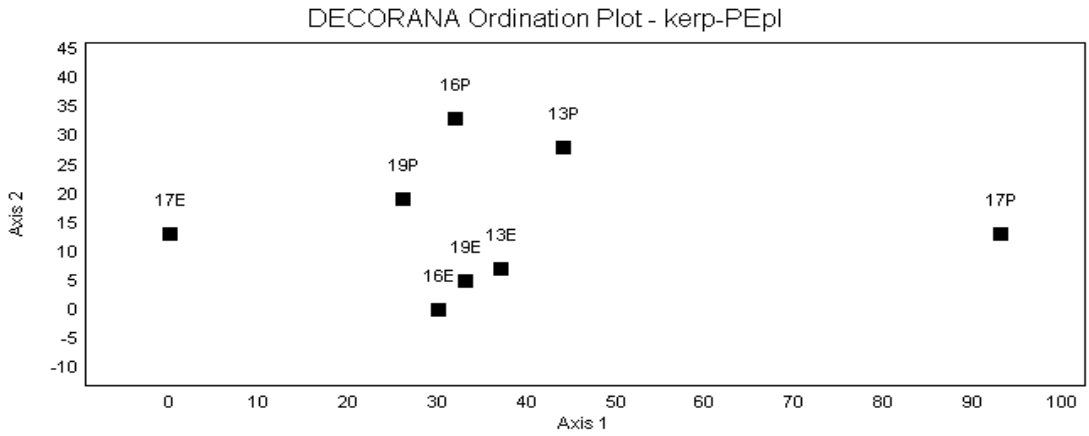

Figure. 1. The comparison of sites using DECORANA analysis.
Designations: 13, 16, 17, 19 – research site codes; P – pine, E – spruce.

important microbiotopes for their propogation and development processes (Hyvarinen et al., 1999). It explains the differences in lichen coverage in percentage of the basis of the trunk and on the trunk.

The species which are found on the basis of the trunk are found with a higher frequency and higher coverage in percentage. Thus, for example, *Cladonia coniocraea* (Flörke) Spreng. forms big groupings on the trunk in favourable conditions. At the same time, one can observe a strong competition between lichen and moss. The species *Lepraria incana* often is a parasite on it. On the trunk at the height of 1.5 m more often crustose lichens are found, less often foliose lichens and their coverage on the stem is lower in percentage. At the same time on the trunk the lichens composition is more homogeneous than on the base of the trunk (Somermaa, 1972). It is thought that wind also influences the lichen communities: on the one hand, the lichen which are in the cracks are protected against evaporation, but, on the other hand, under the influence of prevailing winds they get additional moisture. Higher moisture content determines higher location of epiphytes on the trunk (Znotiņa, 2003).

The sites are compared using TWINSPAN and DECORANA analysis (Fig. 1).

When comparing the sites by the species, the differences appear in site 17 (respectively 17E un 17P), besides, separately distinguished are both pines and spruces. Whereas the other sites are grouped according to tree species (respectively 19P, 16P, 13P and 16E, 19E, 13E). The amount of data is not sufficient for describing results because respectively 26.4% and 5.3% of data dispersion are explained by the axes 1 and 2.

TWINSPAN analysis shows a similar situation, where sites are grouped according to lichen species – *Cladonia coniocraea, Cladonia squamosa*, and *Lecanactis abietina*, from which the last two have been found only in site 17 on different tree species as a result of that they have been distinguished (17E and 17 P). Similar are also pines in site 13 and 16 (the group has been distinguished – according to the lichen species *Parmeliopsis ambigua* and spruces in site 13 and 16, as well as pines and spruces in site 19.

In order to compare the research sites according to the coverage of lichen species in percentage, a three factor analysis of variance has been used (site* tree species* height). The results prove that at the 95% confidence level limit there are significant differences between tree species – pine and spruce – and heights – $F_{0.05}=196.6 > F_{0.05} = 27.6$ respectively ($n_{total}=188$).

Description and analysis of the dependence of lichen exposition on the cardinal points.

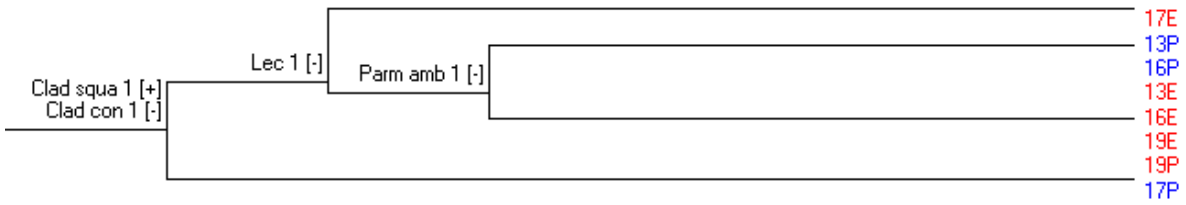

Figure. 2. The comparison of sites using TWINSPAN analysis.
Designations: Lichen species Clad squa – *Cladonia squamosa,* Clad con – *Cladonia coniocraea,* Lec – *Lecanactis abietina,* Parm amb – *Parmeliopsis ambigua;* 13P – site code and tree species; tree species P – pine, E – spruce.

The vertical exposition of lichen on cardinal points is determined by the ecological situation (light, moisture) and physical-chemical properties (the age of the tree, the texture of the bark surface and the presence of nutrients) (Znotiņa, 2003). The age of the substratum is an influencial factor, since within one group the trunks are similar with regard to the composition of lichen species and coverage. The research shows that on average the largest number of species is found in the northern side, but on average the largest coverage in percentage is found in the western side. There are lichen species which have been found in different expositions, but with greater potential coverage found in certain exposition (Somermaa, 1972). The mean values of expositions of lichen species depending on the cardinal points are shown in Fig. 3.

Only those 6 lichen species have been analysed which are found in several objects and on both coniferous species. The Figure 3 shows that the lichen species utilize different exposition niches not only depending on the geographical point, but also on the tree species. Most widely represented species found on trunks *Lepraria incana* found in smaller amount is only on the NE side, but the total mean value is directed to the west; with regard to tree species there are sharp differences in exposition: on pines it is found on NW, but on spruces on the S side. The total mean value of exposition of the species *Chaenotheca ferruginea* (Turner & Borrer) Mig. is directed toward the West. Also on pines it is found in the W, whereas on spruces – on the NW side. The total mean value of the species *Cladonia coniocraea* is directed eastward. The total mean value of both species *Hypogymnia physodes* (L.) Nyl. and *Platismatia glauca* (L.) W.L.Culb.&C.F.Culb. is found in the NE, on pines in NE and in E, but on spruces in the N and NE side respectively. Ecological indicators of both species are similar. The moisture index was considerably different, which is higher for the species *Platismatia glauca*. The mean value of the species *Micarea melaena* (Nyl.) Hedl. is directed toward SE, also on pines, but on spruces it is found on the southern side.

The description of lichen ecological indicators

The research sites have been ecologically evaluated according to the proportion of the coverage of the lichen species in percentage, using the values of ecological indicators (Wirth, 1992). In the objects mainly shade-tolerant and half shade lichen species are found (relative lighting 5–10%), only in site 17 also half-shaded lichen species are found. The lichen species found belong to W and E European species, which grow in temperate temperature conditions. Dry place lichen species prevail in sites. Site 17 is an exception, where the composition of the lichen species corresponds to the conditions, where the precipitation reaches 700–1000 mm. That is explained by the location of the plot – it is situated between lake Usma and the river Engure. The reaction of substratum-bark is rather acid in all the objects (pH 4.1–4.8) and there is a medium amount of minerals on the bark. The indicator of bark's pH varies with the height: at the base of the trunk it is less acidic due to the influence of soil particles and also in the direction towards the top of the tree the acidity decreases. The pH value of

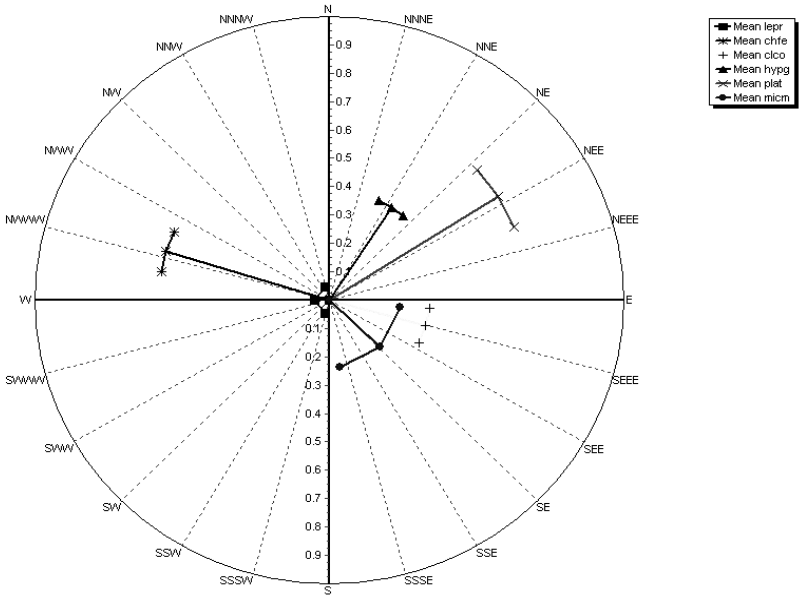

Figure. 3. The exposition of lichen species depending on the cardinal points.
Designations (abbreviations of lichen species): Lepr – *Lepraria incana*; Chfe – *Chaenotheca ferruginea*; Clco – *Cladonia coniocraea*; Hypg – *Hypogymnia physodes*; Plat – *Platismatia glauca*; Micm – *Micarea melaena*.

pine and spruce bark is lower than 4.0 (Kuusinen, 1996), and with the stand age increasing, it becomes more acidic (Hyvarinen et al., 1992). It is supposed that the value of the substratum-bark reaction is also influenced by the amount of minerals in that. When analysing the indicators of toxicotolerance it should be noted that they are different for different lichen species. These indicators reflect the sensitiveness of lichen species to air pollution. At the same time, in different ecological conditions one and the same species can develop different mechanisms of resistance, the relationships of which have not been studied much. When in a stressful situation, the indicators of toxicotolerance of the species decrease and they react to air pollution with higher sensitiveness (Wirth, 1992). For some species, like *Cladonia coniocraea, C.squamosa, Lecanactis abietina*, and *Micarea melaena* such indicators have not been measured. The highest indicators of toxicotolerance are typical of the following species: *Lepraria incana* (very high tolerance), as well as *Hypogymnia physodes, Hypocenomyce scalaris* and *Scoliciosporum chlorococcum* (high tolerance). The species with the lowest tolerance to pollution is *Chaenotheca ferruginea*. It is not found only in one research site – site 19, in other sites this species is recognized on the trunks of pines and spruces.

Conclusions

1. In research sites of pine woodland key habitats, 13 lichen species have been found: on pine trunks – 11, but on spruce trunks – 7 lichen species.

2. On the trunk the composition of lichens is more homogeneous than on the base of the trunk. The species, which are found on the base of the trunk, have a higher frequency and a higher coverage in percentage.

3. The difference in lichen coverage in percentage on the base of the trunk are explained by the characteristics of pine bark. Totally the lichens coverage in percentage is about twice higher at the spruce trunk height of 0.5 m and about three times higher at the spruce trunk height of 1.5 m than at the pine trunk.

4. The three factor analysis of variance (site*tree species*height) used for the comparison of the sites at the confidence level of 95% revealed that significant differences exist in coverage of lichen species in percentage between the tree species – pine and spruce and height of the trees.

5. Lichen species utilize different exposition niches not only depending on geographical points, but also on tree species.

6. Dry place, shade-tolerant and half-shade lichen species (relative lighting 5–10%) prevail in the objects. The species belong to W and E European species, which grow in temperate temperature conditions. The substratum- bark reaction in all the objects is rather acidic (pH 4.1–4.8), and on the bark there is a medium amount of minerals.

7. The highest indicators of toxicotolerance are typical of the following species: *Lepraria incana*, as well as *Hypogymnia physodes, Hypocenomyce scalaris*, and *Scoliciosporum chlorococcum*. The least resistance species to pollution is *Chaenotheca ferruginea.*

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