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The role of local lichen biota in zonal ecosystems formation in Western Siberia

V.V. KONEVA*

Institute of Biology, National Research Tomsk State University, 36 Lenin av., Tomsk 634050, Russia

This paper describes the data on lichen biota of the major forest and wetland ecosystems in northern, central and southern taiga and sub-taiga in Western Siberia. It shows the results of floristic and comparative analysis of certain lichen biota basing on family and genus composition, cluster analysis (Sorensen-Chekanovsky, Simpson indices), a taxon's presence or absence on the species list or the weight characteristics of species.

Keywords: Lichen biota; Taiga subzones; Western Siberia

Introduction

The territory of Western Siberia attracts not only geo-botanists [1–4], but also lichenologists. There are many works devoted to lichenoflora of specially protected natural areas [5,6], communities of tundra [1–7], central taiga [12–14] and Nether-Polar Urals [15–17]. Nevertheless, from the point of view of lichenology, Siberian territories, especially the northern part of Western Siberia have been explored unevenly. There is a well-established idea of poor specificity and relative lack of boreal lichen biota on the plains of Siberia, owing to the difficulty of access to these areas, the severe climate and the lack of roads [18].

This study is aimed at the identification and comparative analysis of local lichen biotas and their role in the formation of main zonal ecosystems on the meridional transect of Western Siberia.

Research methods and materials

The research was conducted upon herbarium lichen specimens collected using the transect method during fieldwork in 1998–2013, when samples of soil, rotting timber, tree trunks and branches were collected. In the course of the fieldwork, we studied the communities of the right bank of the Ob river in the small-leaved aspen-birch forest subzone (Tomsk oblast); we conducted the field studies in the area of Yamalo-Nenets Autonomous Okrug (referred to below as YNAO) in the north taiga subzone, as well as the lichenological research in the northern part of Siberian Ridges. We also studied certain previously discovered communities, where Cladonia oxneri Rass. – the species earlier found only in tundra zone on the sandy soil of Yamal peninsula, at least 350 km northward from the explored

*Email: collema@mail.ru

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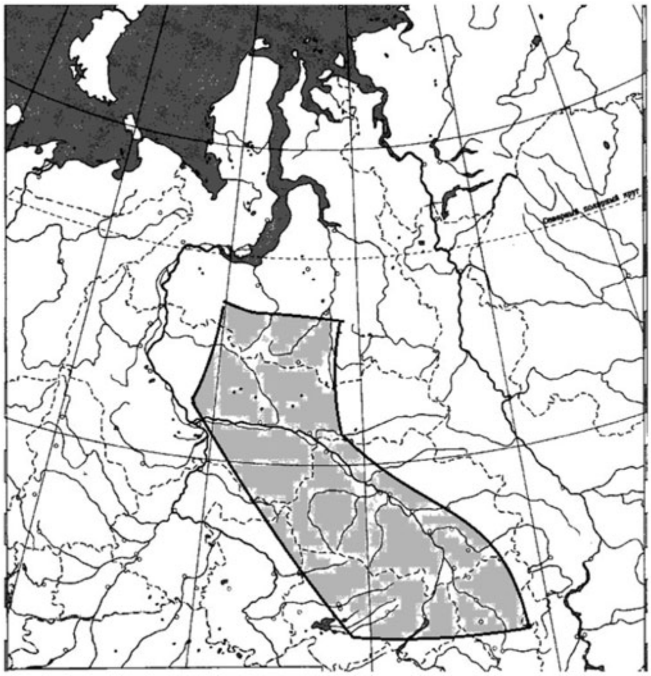

Figure 1. West Siberian Plain index map. Grey colour indicates the exploration area.

territory [19,20] – appears to be the dominant and practically the only former of lichenous storey. On the whole, 11.5 thousand specimens were processed and identified. Some relevant accessible literature data concerning the exploration area [5,7,21–24 etc.] were also used in this research.

During fieldwork in the north taiga, attention was paid to collection and description of epiphytic lichen abundance in the main zonal spruce–larch, larch–spruce–cedar lichen–moss–suffruticose, larch forests and sparse forests (in the northern area of the subzone). Within the described area, we investigated the species composition of lichens at a height of 2 m on spruces and larches within two levels: (1) stem-adjacent level – from the soil surface to 0.3 m high; (2) trunk level – 0.3–2 m high. Both lichen descriptions and definitions were arranged into the integrated botanical information system IBISS 6.2 [25] database, with the help of which verified taxa lists were obtained and the analysis was done. The tables represent the results, which are discussed below.

Field data processing and species determination were performed by the author with the help of standard lichenological methods using various 'Determinators', 'Florae', monographs and both local and foreign authors' summary reports [26–30].

After we had established verified taxa lists using IBISS 6.2 [25], we constructed primary and secondary matrices for use in cluster analysis (Sorensen-Chekanovsky, Simpson indices) [31–34]. Binary similarity metrics according to the Sorensen–Chekanovsky method were calculated according to the following formula:

$$S = \frac{2a}{2a + b + c},$$

where:

a – the number of species mentioned in both lists;
b – the number of species mentioned only in the first list (specific species 1);
c – the number of species mentioned only in the second list (specific species 2).

Chekanovsky–Sorensen quantitative similarity metrics were calculated according to the following formula:

$$S = \frac{2\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i{}^2 + \sum_{i=1}^{n} y_i{}^2},$$

where:

x – percentage occurrence of i-species in the first biota;
y – percentage occurrence of i-species in the second biota.

Based on given indices, we conducted an agglomerate hierarchic cluster analysis according to the Unweighted Pair-Group Mean Averaging (UPGMA) method, the graphical results of which are given below.

Results and discussion

The exploration area is located in the boreal forest zone, the peculiar feature of which is a wide dissemination of dark coniferous forest, represented by such species as *Picea obovata*, *Abies sibirica* and *Pinus sibirica*, with a widespread significant birch and aspen addition. Dark coniferous forests occupy well-drained interfluvial territories. The size of these territories tends to increase from north to south. Pine forests, which appear on sandy soil or form bog moss pine forest on the bogged soil [35], are widely spread as well.

Regular dissemination of zonal vegetation in latitudinal direction is significantly affected by the extensive development of the bog formation process, especially on plain watersheds, where the dark coniferous species are found in the form of small islands on elevated terrain elements, whereas the main taiga forest massifs belong to river valleys. The Western Siberia boreal forest zone, in turn, is divided into north, central and south taiga subzones and a birch–aspen forests subzone [36].

During our work, we built a boreal zone east-west line (transect) of the Western Siberia flatland part, in the framework of which we studied the lichen biota consisting of separate (local) species of four different subzones. While studying vegetation communities, we paid particular attention to zonal forest communities and various types of bog phytocoenoses.

In consequence, a general list of lichens belonging to forest and bog phytocoenoses of the Western Siberia boreal zone comprises 430 taxa of 102 genera and 42 families. The general list of lichens belonging to the West Siberian Plain boreal zone was compiled using both our own data and data from [22,23,37,38]. These results do not claim to cover the entire range of issues, as they include the data exclusively on zonal communities (forest) and azonal (bogs) that are widely spread around the study area. We excluded the data obtained on rock substrates in the southern part of study area from the analysis for the sake of data's equivalence. Rock habitats were explored in south taiga and sub-taiga zones;

the total number of epilithic species exceeds 100. In other subzones such substrates were not found [23,39].

Order and family sizes in taxonomic analysis are used in accordance with the paper by Lumbsh and Huhndorf [40]. Table 1 presents taxonomic structure of lichen biota (general taxonomic characteristics).

As shown in the table, the total number of species, genera and families decreases in latitudinal direction from the subzone of northern taiga to sub-taiga. The exception is the southern taiga which has the greatest number of species. This is, first of all, connected with the wide diversity of habitats.

The 10 leading families with a number of species exceeding the average figure (table 2) comprise three-quarters of all lichen species composition (311 species or 76.62%); 14 families on the general list are represented by one species and 24 families by one genus. *Parmeliaceae* and *Physciaceae* families are the ones with the largest number of genera, especially among the families within this classification.

Parmeliaceae and *Cladoniaceae* families occupy leading positions by the number of species; they are followed by *Physciaceae, Ramalinaceae* and *Lecanoraceae* families. This

Table 1. General taxonomic characteristics of lichen biota.

№ Field of analysis	1 General list	2 Northern taiga	3 Central taiga	4 Southern taiga	5 Sub-boreal forest
The total number of species	430	151	228	244	236
The total number of genera	102	54	66	73	75
The total number of families	41	18	27	32	34
Mean number of species in a genus	4.24	2.80	3.47	3.34	3.147
Mean number of species in a family	10.29	7.95	8.18	7.63	6.941
Mean number of genera in a family	2.43	2.84	2.36	2.28	2.206
The number of one-species genus	49	32	32	36	39
The proportion of one-species genera (%)	48.04	59.26	48.48	49.32	52.00
The number of one-species families	14	4	9	12	14
The proportion of one-species families (%)	33.33	21.05	32.14	37.50	41.18
The number of one-genus families	24	8	18	20	21
The proportion of one-genus families (%)	57.14	42.11	64.29	62.50	61.76
Max. number of species in one genus	66	40	57	29	43
Max. number of species in one family	86	41	56	45	52
Max. number of genera in one family	22	18	15	17	16
The proportion of species in 10 leading genera (%)	46.06	60.93	56.77	47.54	55.93
The proportion of species in 20 leading genera (%)	64.58	76.16	72.49	68.44	69.92
The proportion of species in 10 leading families (%)	76.62	90.73	85.59	81.15	81.78
The proportion of species in 20 leading families (%)	92.59	100.00	96.07	95.08	94.07
The proportion of species in 25 leading families (%)	94.91	100.00	98.25	97.13	96.19

Table 2. Inclusion matrix.

	Northern taiga	Central taiga	Southern taiga	Sub-boreal forest
Northern taiga	1.00000	0.42105	0.32377	0.33475
Central taiga	0.63576	1.00000	0.58197	0.58898
Southern taiga	0.52318	0.62281	1.00000	0.64831
Sub-boreal forest	0.52318	0.60965	0.62705	1.00000

can be seen while both looking at the general list and studying separate subzones. In the central taiga, the *Cladoniaceae* family takes first place because of wide dissemination of high-moor bogs, where the lichens of this family play a major role in composition of the raised bog communities ground cover along with sphagnum moss. In the southern taiga, the second place is occupied by *Physciaceae* family with a large number of mesophytes requiring considerable air humidity and warmth.

The composition of leading lichen biota families shows that they are typical for lichen biota of the Holarctic forest zone. Thus, the leadership of *Cladoniaceae, Parmeliaceae* and *Lecanoraceae* families for the central and southern taiga subzones and sub-taiga highlights lichen biota boreality in this area. The specific feature of the forest region lichen biotas in the moderate Holarctic is the prominence of families that include a considerable amount of epiphytic lichens (e.g. *Parmeliaceae*, *Lecanoraceae* families), and also the families whose species play an important role in the forest and bog vegetation communities ground cover: *Cladoniaceae, Peltigeraceae* families. The high position of *Physciaceae* and *Ramalinaceae* families (with the *Bacidiaceae* family included to the latter*)* adds to lichen biota certain nemoral traits. Among tertiary relicts of nemoral lichen biota are also some species of *Lecanora* genus*: L. allophana, L. chlarotera, L. intumescens,* whose habitats are characterised by gaps, and the species themselves are characterised by differentiated general dissemination. Makarevich [41] accentuated tropical traits of *Lecanora* genus. Sidelnikova [42] also mentions them, attributing the ecological traits interchange to the influence of adaptation towards the new environmental conditions; mainly, the worsening of thermal conditions.

Composition of leading genera from the lichen biota boreal zone list shows wide dissemination of epigeic and epiphytic lichens on this territory. Thus, the first place belongs to *Cladonia* genus both in the general list and in all the four subzones. Representatives of this genus form a separate lichen storey in forests and sparse forests of the northern taiga and in raised bog communities of the central and southern taiga. When moving southward, participation of the species of this genus in the composition of forest communities decreases; they go up to the feet of trees or fallen trunks covered in moss. The exception is pine forests which, within the territory under study, grow on sandy river terraces and sand deposits in the hollows of the ancient river runoffs. In the driest parts of the ground cover, there are solid lichen mats, consisting of various species of Cladonia and less often Cetraria genera.

Both on the general list and in the central and southern taiga subzones and in the sub-taiga, the second to fourth places are occupied by representatives of Lecanora, Usnea, Bryoria genera. These are typical epiphytes, connected with forest communities in their dissemination and playing an important role in biodiversity of z-storey phytocoenoses. In the course of spectra analysis for the northern taiga, we can see a completely different ranging. The second place also belongs to ground cover lichens of *Peltigera* genus. Among epiphytic lichens only representatives of *Bryoria* genus can be found, both by the number of species and their phytocoenotic role.

In addition, many authors accentuate the leading positions of the species belonging to *Usnea* genus in the process of epiphytic communities' composition in boreal taiga forests and sparse forests [5,14,17,22,23,38,43]. For boreal forests of the central taiga and hemiboreal forests of the southern taiga, this statement is fair enough. But, in the case of the northern taiga and sparse forests, the species of this genus (*Usnea hirta*, *Usnea subfloridana*) were found only in a third part of the relevés, their quantitative participation not exceeding 5%, and often only single small-sized (2–3 cm) blastema being registered. The dominant epiphytic communities, especially the branches, are *Bryoria, Hypogymnia physodes, Melanohalea olivacea* species with permanent participation of *Evernia mesomorpha, Parmelia sulcata* and *Cetraria sepincola*. The common lichen *Parmelia sulcata,* which plays an important role in boreal forests of the central and southern taiga, is simply present in northern taiga communities, mainly on spruce trees [44].

Another peculiarity is that crustose lichens show little participation in epiphytic communities' formation on the second altitudinal level: trunks and branches. Sometimes separate caliciaceae lichens granules can be found on trunks, rarely: *Scoliciosporum* sp*., Lecanora symmicta* or *Lecanora filamentosa* (definition by V. Faltinovich). In most cases, crustose lichens were found on branches, but with a small number of species, infrequent occurrence and insignificant abundance. This might be connected with climatic factors: strong insolation, big values of positive and negative temperatures, strong winds.

In the process of comparative analysis among lichen biotas of four subzones, we have built inclusion and crossing matrices.

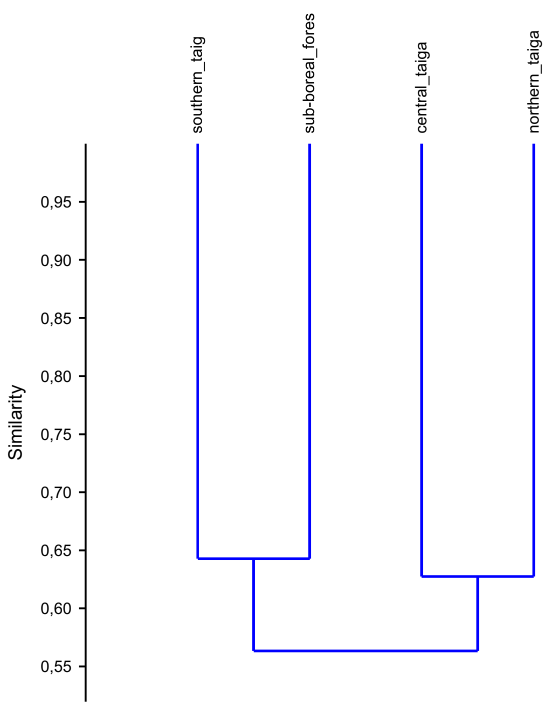

Figure 2. Similarity dendrogram of lichenoflorae in four subzones: similarity aspect – symmetrised similarity metric according to Simpson's method. UPGMA (Unweighted Pair-Group Mean Averaging).

The inclusion matrix was used to illustrate the correlation of community between different-sized lists; i.e. the proportion of the number of species found in both lists to the number of species in each of them. (table 2) [25].

After the process of inclusion matrix symmetrisation, we conducted a cluster analysis based on Simpson's index [25,33,34]. Figure 2 shows the results.

By analysing numerical and graphical data, we can see that lichen biota of the northern taiga is closest to that of the central taiga by its composition (at approximately 40%) and farthest from the southern taiga and sub-boreal forest. It is not only connected with the number of species but also with participation of other 'non-forest' species, especially arctic-alpine and *hypo*-arctic-montane ones, in the biota of the northern taiga.

During the agglomerative hierarchic cluster analysis by UPGMA method basing on the similarity metric quantitative variant of Chekanovsky-Sorensen (Figure 3), we obtained a different distribution. In the construction of this dendrogram not only the presence or absence of a taxon was taken into account, but also the weight characteristics of species, such as the occurrence of various species in percentage. Thus, the final result was different. In this dendrogram, we can see that the lichen biota of the northern subzone stand closer to the lichen biota of the southern taiga than to lichen biotas of any other subzones. The reason for such similarity is the important role the species of *Cladonia* and *Peltigera* genera play in both the lichen biota of the northern subzone and the lichen biota of the southern taiga.

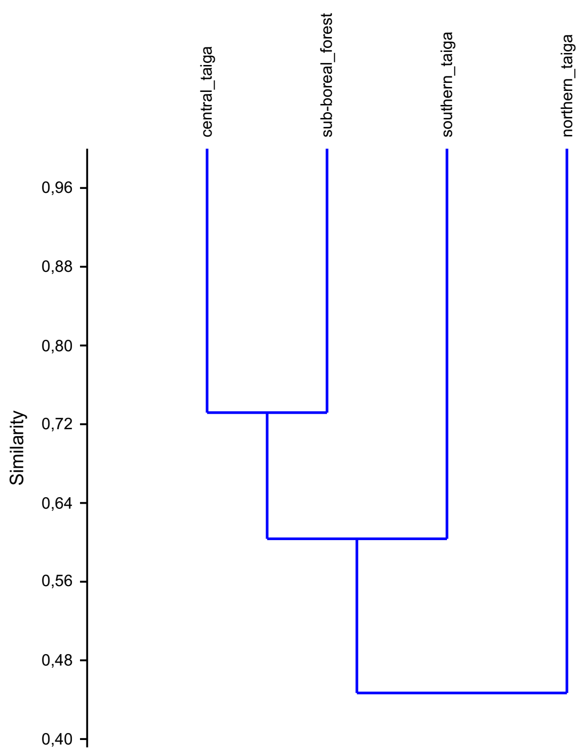

Figure 3. Similarity dendrogram of lichenoflorae in four subzones: similarity aspect – Chekanovsky-Sorensen quantitative variant. UPGMA (Unweighted Pair-Group Mean Averaging).

To sum up, the data obtained show that the lichen biota of the northern taiga stands apart from the other three groups and we can assume that the northern lichen biota are transitional between the central taiga subzone and tundra zone. The central taiga subzone comprises a number of 'northern' and 'southern' species from neighbouring subzones, but mainly consists of typical boreal species. The southern taiga subzone appears to be the richest in species of all four subzones and contains a large number of nemoral species, many of which are widely spread in broad-leaved forests of Europe and the South Siberian taiga. The sub-taiga zone also contains a large number of thermophilic species; but, when air humidity decreases, species diversity decreases as well along with the occurrence of species inside the communities. Moreover, we can assume that the sub-taiga zone is a transitional one between the forest vegetation type (boreal and hemiboreal) and foreststeppe and steppe.

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