KnE Life Sciences

Ecology and Geography of Plants and Plant Communities
The fourth International Scientific Conference on
Ecology and Geography of Plants and Plant Communities
Volume 2018

Conference Paper

Comparative Analysis of Soil Algal Flora of the Tundra, Mountain and Boreal Ecosystems of the European Northeast

E. N. Patova and I. V. Novakovskaya

Institute of Biology of the Komi Scientific Centre, Ural Branch of the Russian Academy of Sciences, 167982 Syktyvkar, Russia

Abstract

Soil algae is a group of photoautotrophic organisms able to live on the soil surface and in the soil profile. Algae participate in the accumulation of organic compounds and the main biogenic exchange cycles in terrestrial ecosystems. Their importance increases in northern and mountain ecosystems with extreme environments. The aim of our research was to summarize the results of studies into soil algae in tundra, mountain-tundra and boreal ecosystems in the Russian Northeast Europe based on literature and original data. We created a list of soil algae including 695 species from five divisions, 12 classes, 40 orders, 107 families and 245 genera. In tundra ecosystems, 348 species were found, 272 in mountain-tundra and 104 in boreal ecosystems. Taxonomical and eco-geographical analysis of the algal flora was also performed. We revealed the species with high frequencies of occurrence and the prevalent algal complexes in the different nature zones. Cosmopolite species widespread in typical soil or edaphophilic species indifferent to soil acidity were prevalent.

Keywords: soil algae, tundra, mountain and boreal ecosystems

Corresponding Author:
E. N. Patova
patova@ib.komisc.ru

Received: 12 September 2018
Accepted: 15 October 2018
Published: 29 October 2018

Publishing services provided by Knowledge E

© E. N. Patova and I. V. Novakovskaya. This article is distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use and redistribution provided that the original author and source are credited.

Selection and Peer-review under the responsibility of the Ecology and Geography of Plants and Plant Communities Conference Committee.

OPEN ACCESS

1. Introduction

Soil algae is a group of photoautotrophic organisms with unicellular, colonial or multicellular organizations of the thallus that are able to live on the surface of soil, forming accretions in the form of crusts and films, and in the soil profile. In plant communities, especially in such climatically severe regions as Russian Northeast Europe, these organisms play important role in creating organic soil matter and the main biogenic exchange cycles [1]. The area under study has a sharp continental climate with cold winters, short and cool summers and much precipitation. This territory includes northern part of the Urals and the northeast of the East European Plain. Tundra, forest tundra and taiga vegetation occurs here. The first investigations of soil algae in Northeast

Russian Europe were conducted in 1962 [2] and continue to the present day. Huge amounts of data have been accumulated during this time about species diversity and the distribution of soil algae in different zonal communities of tundra and taiga ecosystems [3–16]. The aim of our research is to summarize the results of studies into soil algae in the tundra, mountain-tundra and boreal ecosystems of Russian Northeast Europe.

2. Methods

In order to summarize data on the algal diversity of terrestrial ecosystems, we analyzed literature sources and the results of our long-term research in the Bolshezemelskaya tundra, the northern part of the Urals and the northeast of the Russian Plain. Cyanoprokaryota and algae were studied using standard soil-algological methods and algological pure strains in liquid and agar media. Russian and foreign guides were used to identify algae species [17–20]. The eco-geographical characteristics of species are given according to Barinova et al. [21].

3. Results

The algal flora of the studied area has a high level of diversity. The taxonomical list of algae includes 695 species from five divisions (*Chlorophyta* – 275, *Cyanoprokaryota* – 184, *Bacillariophyta* – 145, *Ochrophyta* – 65, *Streptophyta* – 25 and *Euglenophyta* – 1), 12 classes, 40 orders, 107 families and 245 species [16]. This is about 20% of world soil algal flora (about 3,500 taxa). The Bolshezemelskaya tundra (251 taxa) [4], Pechora lowland (Vozeyskoe deposit – 208) [5] and mountain tundra of the Subpolar Urals (the river Kozhym basin – 206) [14] are well-studied areas (Figure 1).

There are less algological data from the other areas of the European northeast. Algae from the divisions Chlorophyta and Cyanoprokaryota were prevalent in most studied soil algal flora. The proportion of the other divisions varied in different areas. An exception was the algal flora of the northeast Russian Plain, where green algae prevailed in the acid soils of forests due to their resistance to acidity.

The highest algal diversity was found in the tundra ecosystems and the lowest in the forests (Table 1). A significant increase in the species diversity of soil algae in tundra and mountain tundra ecosystems was due to various forms of cryogenic relief created by permafrost thawing, frost fracturing, cryoturbation and solifluction. There is low competition from the highest plants in habitats without closed vegetation.

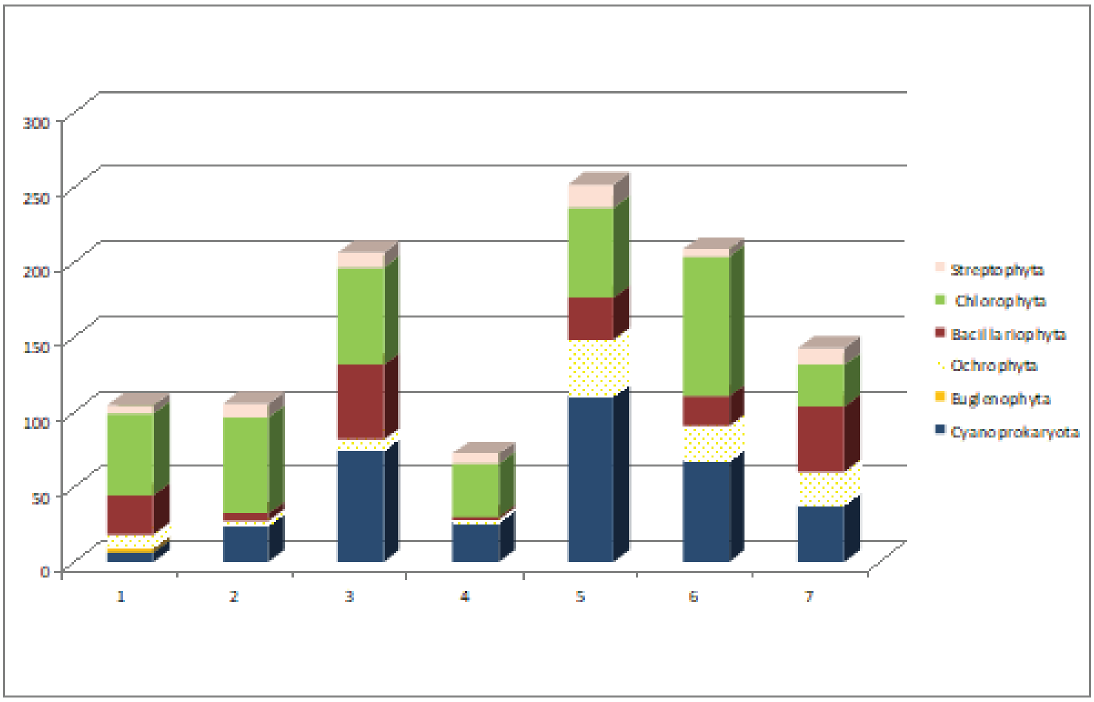

Figure 1: Taxonomical structure (divisions) of soil algae in the study area: 1 – northeast of the Russian Plain (middle taiga), 2 – Polar Urals, 3 – Subpolar Urals, 4 – Northern Urals, 5 – Bolshezemelskaya tundra, 6 – Pechora lowland, 7 – Vorkuta tundra. **Source:** Authors' own work.

Here, the main dominants are spore organisms, including algae that form biological soil crusts [14, 15]. The algal flora of forest ecosystems was not so rich due to the closed vegetation, ash structure, overlogging of soils, high acidity and the low level of nutrient elements in the soils [13].

Table 1: Distribution of algae by systematic groups in soils of the northeast of European Russia.

Ecosystem	Number of algae	Number of species in the divisions					
		Cyanopro-karyota	Chloro-phyta	Bacillario-phyta	Ochro-phyta	Strepto-phyta	Eugleno-phyta
Mountain tundra	272	89	110	51	9	13	–
Tundra	348	110	157	28	38	15	–
Forest	104	6	55	26	8	5	4
Source: Authors' own work.							
Note: – No data.							

Taxonomical analysis revealed that the basis of algal flora in the studied area is formed by species from the orders: *Chlamydomonadales*, *Oscillatoriales*, *Nostocales*, *Naviculales* and *Sphaeropleales*. The leading families are: *Chlamydomonadaceae*, *Chlorococcaceae*, *Oscillatoriaceae*, *Eunotiaceae*, *Pinnulariaceae* and *Nostocaceae*. The highest species number was found in the genera: *Chlamydomonas*, *Pinnularia*, *Eunotia*, *Phormidium*, *Leptolyngbya*, *Tetracystis*, *Nitzschia*, *Nostoc* and *Chlorococcum*.

A high occurrence frequency (more than 60% from all sites under study) was found for (alphabetical order): *Botrydiopsis eriensis*, *Bracteacoccus aggregatus, B. minor*, *Bumilleriopsis terricola*, *Chlamydocapsa lobata*, *Chlorella vulgaris* var. *vulgaris*, *Chlorococcum infusionum*, *C. lobatum*, *Coenochloris signiensis*, *Cylindrocystis brebissonii, Elliptochloris bilobata*, *Eunotia fallax, Eustigmatos magnus*, *Hantzschia amphioxys*, *Klebsormidium flaccidum*, *Leptolyngbya foveolara*, *Leptosira terricola*, *Macrochloris dissecta, Microcoleus autumnalis*, *Mychonastes homosphaera*, *Myrmecia bisecta*, *M. incisa*, *Nitzschia palea, Nostoc commune* f. *ulvaceum*, *N. punctiforme*, *Parietochloris alveolaris*, *Phormidium ambiguum*, *P. corium*, *Pinnularia borealis*, *P. subcapitata*, *Pseudococcomyxa simplex*, *Scenedesmus rubescens*, *Scotiellopsis levicostata*, *S. terrestris*, *Stichococcus bacillaris*, *S. minor*, *Spongiochloris excentric, Stenomitos frigidus*, *Stigonema minutum*, *S. ocellatum*, *Tetracystis aeria*, *Tolypothrix tenuis*, *Ulothrix variabilis* and *Vischeria helvetica*.

The dominant complex of species was different in tundra, mountain and boreal ecosystems. In tundra, the most prevalent species were: *Nostoc commune, Stigonema minutum, S. ocellatum, Gloeocapsopsis magma, Scytonema hofmannii, Leptolyngbya foveolarum, Pseudococcomyxa simplex, Sporotetras polydermatica, Palmellopsis gelatinosa, Myrmecia bisecta, M. incisa, Klebsormidium flaccidum*, *Chlamydomonas debaryana* var. *atactogama*, *Nostoc punctiforme, Chlorella vulgaris, Microcoleus autumnalis, Tolypothrix tenuis, Phormidium ambiguum, Scotiellopsis levicostata, Desmonostoc muscorum, Mychonastes homosphaera* and *Pseudophormidium edaphicum*. In mountain tundra ecosystems, the most prevalent species were: *Stigonema minutum, S. ocellatum, Nostoc commune, Tolypothrix tenuis, Elliptochloris bilobata, Pseudococcomyxa simplex, Sporotetras polydermatica, Eustigmatos magnus, Gloeocapsopsis magma*, *Leptolyngbya foveolara, Microcoleus autumnalis, Myrmecia bisecta, Chlamydocapsa lobata, Phormidium corium* and *Stenomitos frigidus*. In forests, the dominant species were: *Bracteacoccus minor, Chlamydomonas elliptica, C. gloeogama, Chlorella vulgaris, Chlorococcum infusionum, C. lobatum, Eustigmatos magnus, Myrmecia incisa, Stichococcus bacillaris, Klebsormidium flaccidum* and *K. nitens* [13].

Eco-geographic analysis of soil algal flora by type of habitat revealed the prevalence of edaphophilic and typical soil species. The proportions of amphibian (water–air) and hydrophilic (water) species were about the same (Figure 2). Most species were indifferent to acidity (Figure 3) [16].

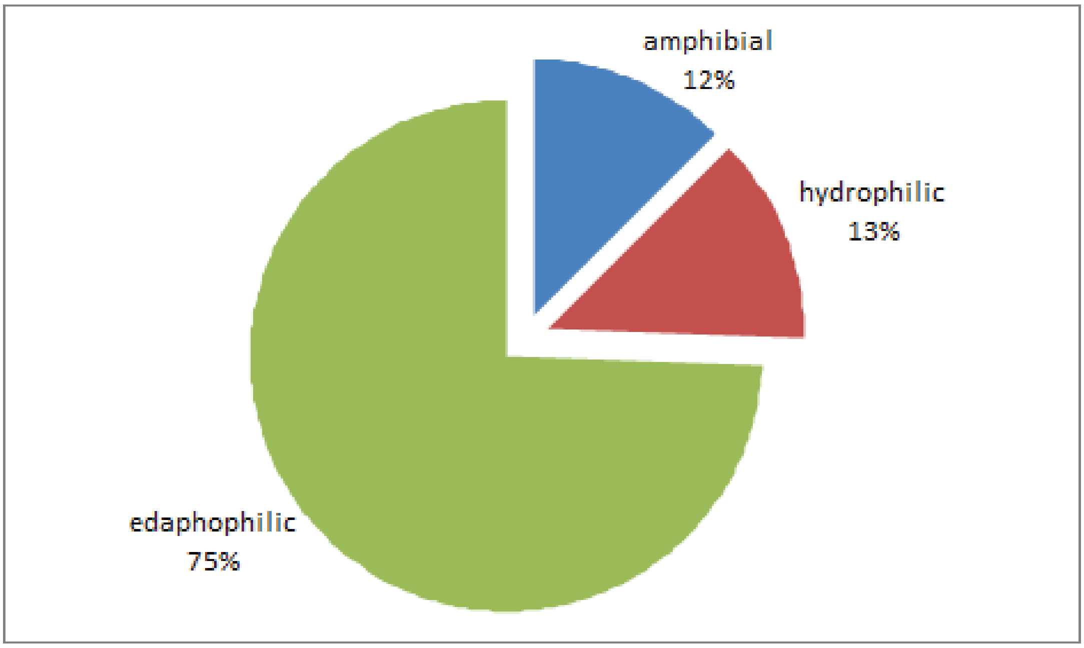

Figure 2: Distribution of soil algae of the northeast of European Russia according habitat. Source: Authors' own work.

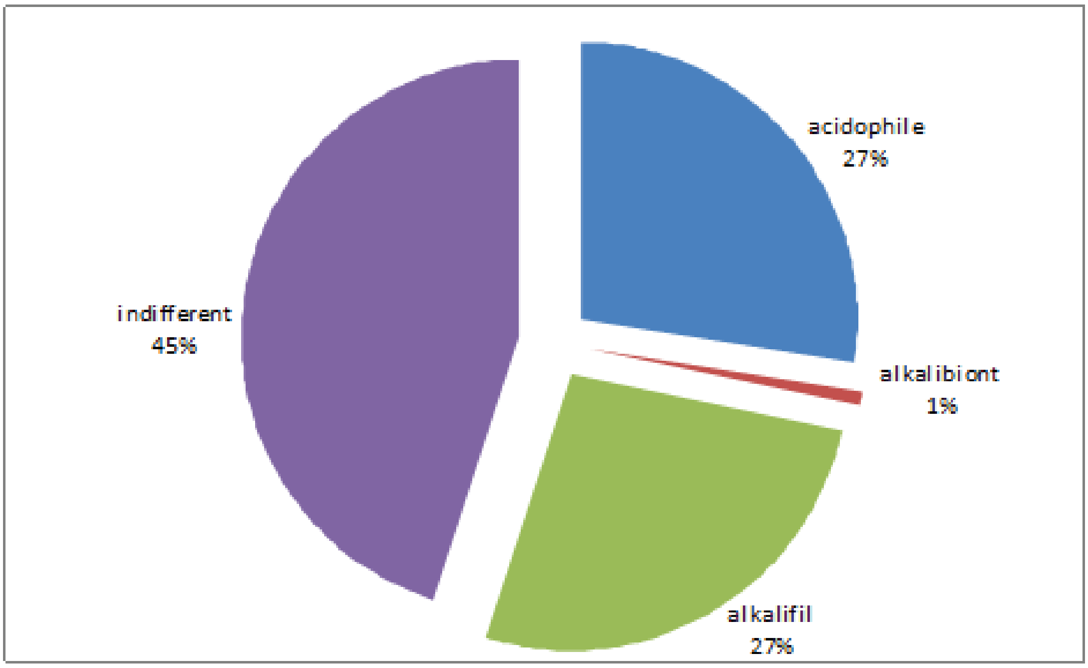

Figure 3: Distribution of soil algae of the northeast of European Russia according to pH. **Source:** Authors' own work.

Geographical analysis revealed the prevalence of cosmopolite species typical for the northern algal florae [3]. Species indicating the severe climate of the study area count for more than 20% of the flora: boreal, arcto-alpine and holarctic taxa (Figure 4).

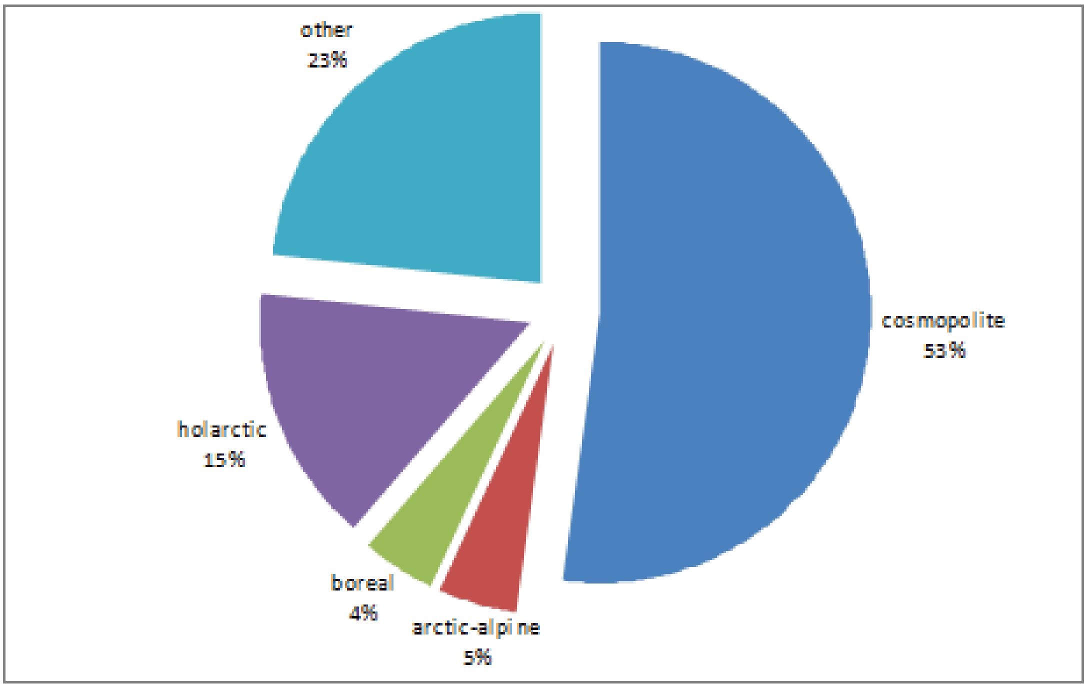

Figure 4: Distribution of soil algae of the northeast of European Russia by geographical preference. **Source:** Authors' own work [16].

In order to find the most important factors affecting the structure of species diversity in the ecosystems of the European northeast, we performed PCA ordination [22] using the occurrence of species in the algal florae under study. As a result, three groups of algal communities typical for mountain tundra, forests and plain tundra were revealed (Figure 5). Their distribution along axis 2 correlates with species richness (number of species). It was not possible to reliably interpret the dependence of the location of the distinguished groups on axis 1. However, the dependence of this distribution on the humidity and vegetation density in the habitats under study is very likely.

4. Conclusion

The algal flora of the Russian European Northeast is well studied. The revealed species diversity is close to that in other regions. In the soils of Kirov region (the River Vyatka basin), 581 species were found [23], while in Siberia (Irkutsk region, the Republic of Buryatia, Transbaikal region) 638 species (705 with interior taxa) of algae were found [24]. Some extra data on the algae of the study area may be obtained from studies of less comprehensively investigated algal complexes in forest, meadow, mountain forest and mire ecosystems. The collection of living cultures of *Cyanoprokaryota* and algae SYKOA (http://ib.komisc.ru/sykoa registered in the World Catalogue of microorganism

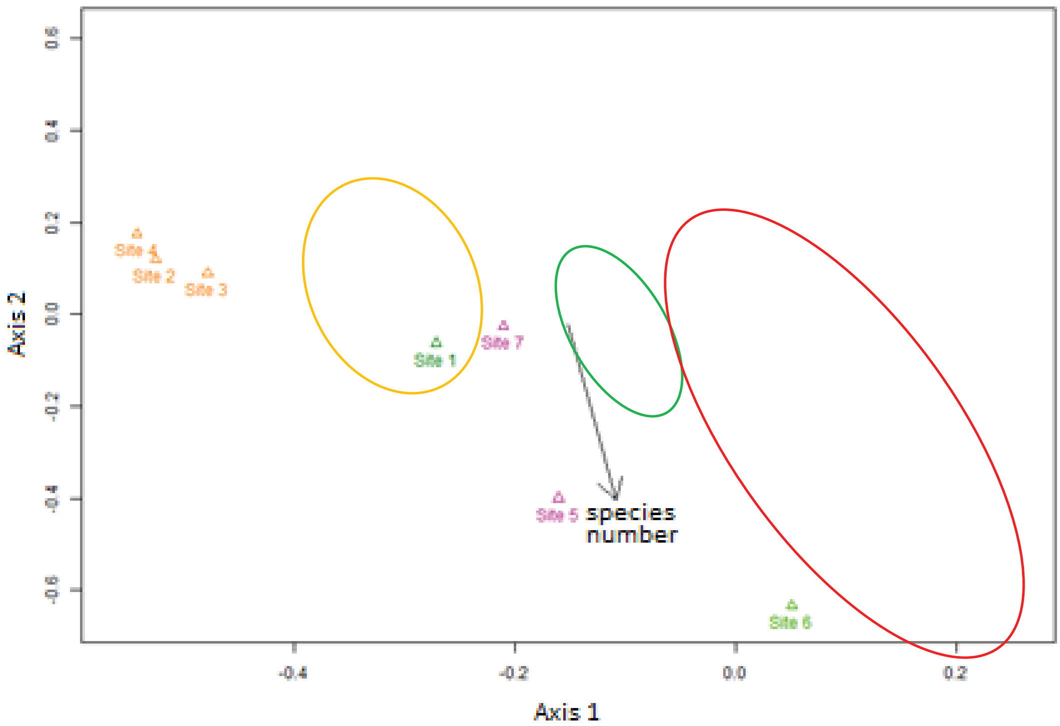

Figure 5: Ordination of the studied sites by algal species composition with vectors reflecting correlation between ordination axes and number of species. The length of the vector 'species number' reflects the meanings of the correlation coefficient (r = −0.7, P = 0.05) with axis 2. Groups of communities: site 1 – forests, site 2–4 – mountain tundra, site 5–7 – tundra. Source: Authors' own work.

culture collections GCM No 1125) contains more than 200 strains of microalgae, isolated from the terrestrial habitats of different plain and mountain areas of the European Arctic and Subarctic.

Acknowledgement

The research was supported by project No AAAA-A16-116021010241-9 and RFBR Nos 18-04-00643 and 18-04-00171.

References

[1] Shtina, E. A. and Gollerbakh, M. M. (1976). *Ecology of Soil Algae*. Moscow: Nauka.

[2] Dorogostayskaya, E. V. and Novichkova-Ivanova, L. N. (1967). About changes of algal flora of tundra soils under their development. Botanicheskij zhurnal, vol. 52, no. 4, pp. 461–468.

[3] Getsen, M. V. (1985). Algae in the Ecosystems at the Far North (On the Example of Bolshezemelskaya Tundra). Leningrad: Nauka.

[4] Getsen, M. V., Stenina, A. S., and Patova, E. N. (1994). Algal Flora of the Bolshezemelskaya Tundra under Anthropogenic Impact. Ekaterinburg: Nauka.

[5] Zimonina, N. M. (1998). Soil Algae of Oil Contaminated Lands. Kirov: Vyatka State Humanitarian University.

[6] Stenina, A. S., Teteryuk, B. Y., and Patova, E. N. (2001). Plant communities of riverside ecotones of the lake in the River Vangyr Valley at the Subpolar Urals, Botanical Studies at the protected areas of the European Northeast, Syktyvkar. Proceedings of the Komi Scientific Centre UrB RAS, no. 165, pp. 20–36.

[7] Dorokhova, M. (2003). Diatom algae as indicators of technogenic changes in soils adjacent to coal mine. Acta Botanica Warmiae et Masuriae, no. 3, pp. 145–154.

[8] Andreyeva, V. M. (2004). Terrestrial nonmotile green algae (chlorophyta) of the Vorkuta Tundra (Komi Republic). Novosti Sist. Nizsh. Rast., vol. 37, pp. 3–8.

[9] Andreyeva, V. M. (2005). Nonmotile green algae (chlorophyta) from soils of the right-bank of the River Ortina (Estuary of the River Pechora). Novosti Sist. Nizsh. Rast., vol. 41, pp. 3–7.

[10] Patova, E. N. and Dorokhova, M. P. (2005). Soil algae and the nature of tundra in open coal mining (the Yunyaginskoe Mine), in The Reaction of Components of Plant Communities to Pollution. Soil Algae, pp. 126–143. Syktyvkar: Republican Environmental Center for the Study and Protection of Eastern European Tundra.

[11] Andreyeva, V. M. and Czaplygina, O. Ya. (2006). Terrestrial Nonmotile Green Microalgae (Chlorophyta) in Area of Industrial Pollution of Vorkuta (Komi Republic). Novosti Sist. Nizsh. Rast., vol. 40, pp. 13–18.

[12] Andreyeva, V. M. and Czaplygina, O. Ya. (2007). Terrestrial nonmotile green microalgae (Chlorophyta) of the Polar Urals. *Novosti Sist. Nizsh. Rast.,* vol. 41, 15–18.

[13] Novakovskaya, I. V. and Patova, E. N. (2011). *Soil Algae of Spruce Forests and Their Changes under Aerotechnogenic Impact*. Syktyvkar: Komi Science Center Ural Div. RAS.

[14] Novakovskaya, I. V., Patova, E. N., and Shabalina, J. N. (2012). Soil Algae of Mountain Tundra Communities of Pre-Polar Urals (Yugyd Va National Park). *Botanicheskij zhurnal*, vol. 97, no. 3, pp. 305–320.

[15] Novakovskaya, I. V. and Patova, E. N. (2013). Algae of mountain tundra soils in the north End Polar Urals. *Bul. MOIP. Otd. biol.,* vol. 118, no. 5, pp. 57–66.

[16] Novakovskaya, I. V. and Patova, E. N. (2018). Soil algoflora of the northeast of the European Part of Russia. Novosti Sist. Nizsh. Rast., vol. 2. (in print).

[17] Ettl, H. and Gärtner, G. (2014). Syllabus der Boden-, Luft-und Flechtenalgen 2. Auflage. Stuttgart: G. Fischer.

[18] Komárek, J. (2013). Cyanoprokaryota III: Nostocales, Stigonematales, Süßwasserflora von Mitteleuropa. Bd. 19/3. Berlin: Springer Spektrum.

[19] Komárek, J. and Anagnostidis, K. (1998). Cyanoprokaryota I. Teil: Chroococcales, Süßwasserflora von Mitteleuropa. 19/1. Heidelberg, Berlin: Spektrum, Akademischer Verlag.

[20] Komárek, J. and Anagnostidis, K. (2005). Cyanoprokaryota II, Teil: Oscillatoriales, Süβwasserflora von Mitteleuropa. 19/2. München: Elsevier Spektrum Akademischer Verlag.

[21] Barinova, S. S., Medvedeva, L. A., and Anisimova, O. V. (2006). Biodiversity of Algae-Indicators of the Environment. Tel Aviv: Pilies Studio.

[22] Novakovskiy, A. B. (2016). Cooperation of Excel and Statistical Package R to proceed the data in ecology. *Newsletter of the Institute of Biology KSC RAS*, no. 3, pp. 26–33.

[23] Shtina, E. A. (1997). *Algal Flora of the River Vyatka Basin*. Kirov: Kirov Regional Printing House.

[24] Egorova, I. N. and Sudakova, E. A. (2011). Algae in the terrestrial ecosystems of Siberian Baikal, in *Algae: Taxonomy, Ecology and Use in Monitoring*, pp. 100–104. Ekaterinburg: UB RAS.