Cyanoprokaryotes of the west part of Oscar II Land, West Spitsbergen Island, Spitsbergen archipelago

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Abstract

The present study provides new information about the diversity of freshwater and terrestrial cyanoprokaryotes of the western part of the Oscar II Land, Spitsbergen (Svalbard) archipelago. Altogether, and 51 taxa were found in different habitats (29 species was found on wet rocks, 21 on the seepages, 18 on the lakes, 11 on the moss tundra), mainly in wet ones. *Nostoc commune, Gloeocapsa kuetzingiana, Microcoleus autumnalis*, and *Microcoleus vaginatus* dominated almost all types of habitats. *Aphanocapsa rivularis* and *Woronichinia karelica* are reported for the first time for Spitsbergen flora. The studied flora is most similar to the flora of the vicinity of settlement Pyramiden. Since all these areas are dominated by carbonate rocks, it can assume that this might be due to the similarity of the geological conditions. In general, the cyanobacterial (cyanoprokaryotes) flora of western part of the Oscar II Land includes widespread, frequent and typical Spitsbergen species.

Key words: Cyanoprokaryota, Cyanobacteria, Arctic, Svalbard, diversity, ecology

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Introduction

Cyanoprokaryotes (Cyanophyta, Cyanobacteria) are one of the most important components of polar biota, especially in the tundra ecosystems. Cyanoprokaryotes are primary colonizers well adapted to the extreme natural conditions in polar terrestrial habitats (Elster 2002). Many cyanobacteria achieve a great ecological success in the polar and alpine environments (Vincent 2007).

A number of papers has been published on diversity of Cyanoprokaryota on Spitsbergen (Svalbard) archipelago (Thomasson 1958, 1961; Willen 1980; Matuła 1982; Plichta et Luścińska 1988; Matuła et Swies 1989; Perminova 1990; Oleksowicz et Luścińska 1992; Skulberg 1996; Davydov 2005, 2008, 2010, 2011, 2013, 2014, 2016; Kaštovská et al. 2005; Turicchia et al. 2005; Komárek et al. 2006, 2012; Stibal et al. 2006; Matuła et al. 2007; Kim et al. 2008, 2011; Richter et al. 2009), but the western part of the Oscar II Land was not

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properly investigated. The mosaic geological composition of rocks has been determining to the choose of the study area. We would hope to found over there the riches of cyanoprokaryotes.

Characteristics of study area

The investigated area is situated on the western coast of West Spitsbergen Island and southern coast of the St. Jonsfjorden, in the western part of the Oscar II Land (Fig. 1).

The landscape is formed by a rugged montane reaching the highest peaks up to 680 m a.s.l. Geological composition of Thorkelsenfjellet, Svartfjella Mountains and neighbouring areas is typical of pre-Carboniferous rocks, including carbonates, pelites, psammites, massive conglomerates and calcareous psammites (Ague et Morns 1985). Almost all area is covered by glaciers, which are typical for Spitsbergen, with topographically influenced ice-masses draining down to the fjord (Kverndal 1991).

The area is covered by numerous lakes, rivers, streams and seepages. Water supply is provided by both the melting glaciers and, to a lesser degree, precipitation. High-water takes place in June and July, mean-water occurs in August.

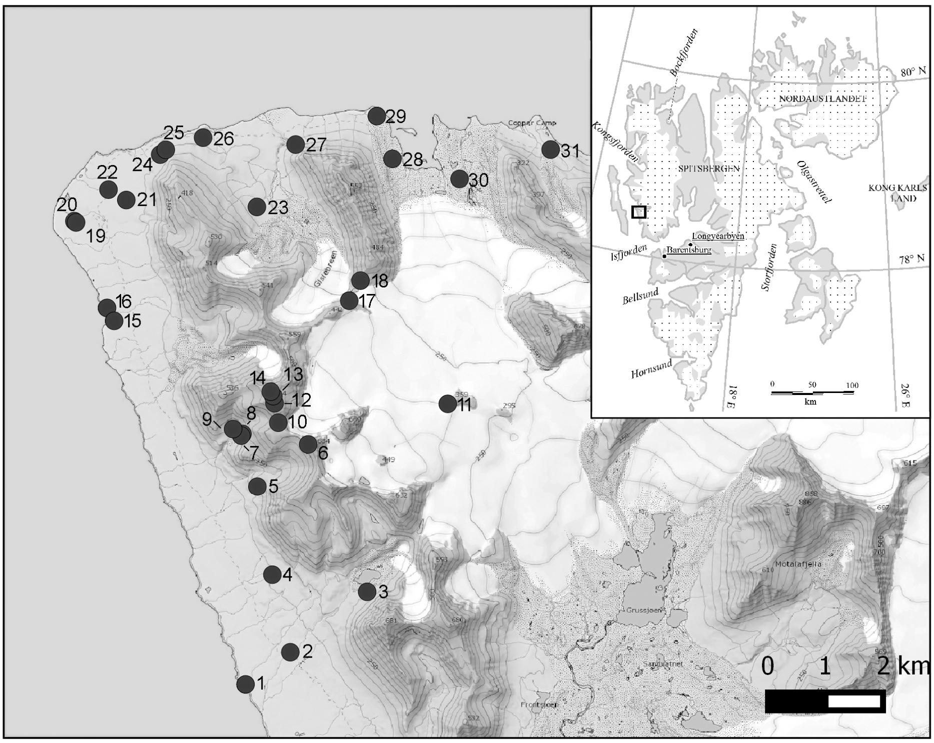

Fig. 1. Position of sample plots in the western part of the Oscar II Land, West Spitsbergen Island, Spitsbergen archipelago, numbers of sample plots as in the Table 1. Free products ©Norwegian Polar Institute ([2]) were used to create maps.

No.	φ	λ	E	Description of localities
1	78.4138	12.5139	10	Southern part of Svartfjellstranda coast, valley between Svartfjella mountain and Jørgenfjellet mountain. Wet tundra on the bank of the stream. On the soil.
2	78.4191	12.5475	50	Southern part of Svartfjellstranda valley between Svartfjella mountain and Jørgenfjellet mountain, Svartfjellbekken brook. Fast stream. On the rock.
3	78.42899	12.6051	112	Valley between Svartfjella mountain and Jørgenfjellet mountain. Moraine hills before a small glacier. The crust on the sand between boulders.
4	78.43105	12.53105	50	Southern part of Svartfjellstranda coast. Fast stream. On the boulder under water.
5	78.44472	12.51652	152	Svartfjella mountain, slope of NW exposure. Waterfall on the fast stream. On the calcareous boulder in a stream under water.
6	78.45162	12.55458	545	Svartfjella mountain, slope of W exposure. Stone run. Crust on the wet gleysols.
7	78.45255	12.50225	250	Svartfjella mountain, slope of W exposure. Overhanging boulder. Wet rock outcrops.
8	78.45282	12.50317	250	Svartfjella mountain, slope of W exposure. Wet rock outcrops. On the cleft.
9	78.45351	12.49575	213	Svartfjella mountain, slope of W exposure. On the boulder in fast stream.
10	78.4548	12.53064	512	Svartfjella mountain, slope of W exposure. Small slow stream among the pebbles.
11	78.45881	12.66177	300	Bullbreen glacier. Slope SSW exposure of the nunatak 359 m. On the soil.
12	78.4578	12.5271	650	Peak Svartfjella mountain. Crust on the soil.
13	78.45889	12.52585	674	Peak Svartfjella mountain. Crust on the soil.
14	78.45957	12.5238	645	Peak Svartfjella mountain. Vertical wall of rock of the S exposure.
15	78.46951	12.39962	2	Svartfjellstranda coast. Seepage, on the soil and rock.
16	78.47147	12.39364	8	Svartfjellstranda coast. Becoming dry pond (15 x 25 m, depth to 0.3 m). Bank of the pond and bottom of the pond.
17	78.47421	12.58189	325	Svartfjella mountain, slope of N exposure, scree. On the rock.
18	78.4774	12.58999	302	Bulltinden mountain, slope of the S exposure. On the wall of rock.
19	78.4846	12.3665	8	Müllerneset cape. Seepage about small lake. On the soil.
20	78.48479	12.36514	8	Müllerneset cape. Bank of small lake, litoral. On the pebble.
21	78.48842	12.40486	30	Müllerneset cape. Root of the Thorkelsenfjellet mountain. Snow-fed slow stream. Brown crust on the pebble.
22	78.48991	12.39064	24	Müllerneset cape. First marine terrace, slow stream. On the pebble under the water.
23	78.48824	12.5069	55	Gislebreen glacier valley, between Thorkelsenfjellet mountain and Bulltinden mountain. Slope of the hill of N exposure, seepage.
24	78.4957	12.42973	50	South coast of the St. Jonsfjorden bay. Root of the Thorkelsenfjellet mountain. Slow stream. Brown mat on the bottom.
25	78.49648	12.43393	169	South coast of the St. Jonsfjorden bay. Slope of the Thorkelsenfjellet mountain of NNW exposure. Wet moss tundra. On the soil.
26	78.49862	12.4626	20	South coast of the St. Jonsfjorden bay. First marine terrace. Wet moss tundra, on the soil and on the bottom of pool.
27	78.49816	12.53503	62	South coast of the St. Jonsfjorden bay. Root of the Bulltinden Mountain. Moss-herb community on the NW exposure slope, under bird colony. Temporary pool.
28	78.49657	12.61103	21	South coast of the St. Jonsfjorden bay. Bulltinden mountain. Stream on the E exposure slope. On the sandy bottom of a slow stream. On the sand.
29	78.5031	12.59745	4	South coast of the St. Jonsfjorden bay. Basis of the Bulltinden mountain. Lake (5x3 m) on the moraine unconsolidated debris. Mats on the bottom of lake.
30	78.49388	12.66399	15	South coast of the St. Jonsfjorden bay. Moraine hill of Bullbreen glacier. Depression of soil. On the soil.
31	78.49899	12.73409	41	South coast of the St. Jonsfjorden bay. Moraine hill. Moss community on the S exposure slope. On the soil.

Table 1. Description of localities studied. *Symbols*: No. - Number of locality, φ - Latitude, λ - Longitude, E - Elevation (m a.s.l.).

The climate of central parts of Svalbard usually is characterized by a low annual temperature (4.7°C), and relatively high average annual precipitation (435 mm) (Steffensen 1982). The results of measure air temperature in the study area from July 21st to August 1st showed that it fluctuated between 2.4°C to 9.5°C, (Fig. 2), air humidity between 64.1 to 100% (Fig. 3), photosynthetically active radiation (PAR) varied from 16.2 to 1583.7 μmol m^{-2} s^{-1} (Fig. 2) and soil moisture from 0.2143 to 0.2528 m^3 m^{-3} (Fig. 3).

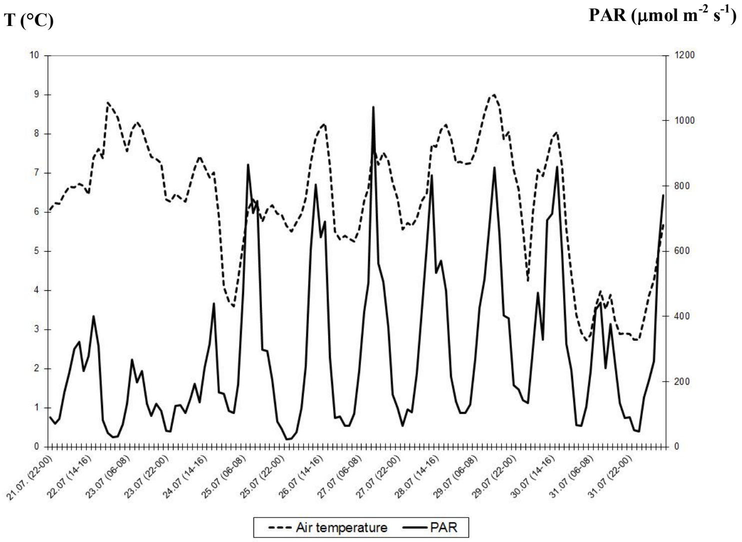

Fig. 2. Air temperature and photosynthetically active radiation (PAR). On the X axis – date and time, on the Y axis (left) – temperature (T), on the Y axis (right) – photosynthetically active radiation (PAR).

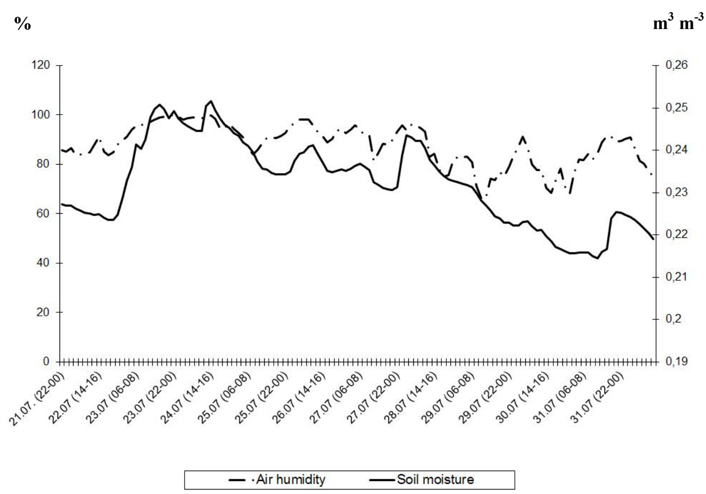

Fig. 3. Air humidity and soil moisture dynamics. On the X axis – date and time, on the Y axis (left) – air humidity, on the Y axis (right) – soil moisture.

Microclimatic conditions had a long-term effect on soil properties. At the study site, soil profile was shallow and typical for the high Arctic. Soil was patterned and depended on the micro-relief which has been formed by cryoplanation, sloping processes and erosion. Permafrost and intensive cryogenic processes occurred in the soil, physical weathering prevailed on the chemical and the slow processes of mineralization of organic material.

The area reported in this study belongs to the Arctic tundra zone (Aleksandrova 1980). Elvebakk et al. (1998) referred the area of Svartfjellstranda shore, Svartfjella and Thorkelsenfjellet Mountains to North-Arctic tundra and the study area reported in this paper to the east of the valley Gislebreen glacier to the Mid-Arctic tundra.

Dry lichen-moss tundra and wet moss tundra occurred on the flat coastal terraces. Plant cover on mountain slopes was situated on eluvia, wet clay and snow patches. The vegetation on mountain tops was very poor and represented by fragmented lichens-dominated plant communities.

Material and Methods

81 samples of cyanoprokaryotes were collected during the period of July, 21st – August 1st, in several plots situated in all typical tundra habitats (Fig. 1, Table 1). Altogether, 9 types of habitats were distinguished, specifically, (i) lakes and ponds; (ii) pools in tundra; (iii) fast running glacial streams and waterfalls; (iv) slow running streams in tundra; (v) wet moss-dominated tundra; (vi) seepages; (vii) wet soils; (viii) wet and dripping rocks; (ix) sand. The least number of samples was collected on the sand (1), in the lakes and ponds (3) and the maximum on the wet rocks (27) and wet soils (11).

The microclimatic data were obtained with a Micro Station HOBO 21-002 (Onset Computer Corporation, Bourne, USA) installed at the point 78.47147°N, 12.39264°E, 8 m a.s.l. (Fig. 2, 3). The following microclimate parameters were measured: air temperature (°C), air humidity (RH, %), PAR (μmol m^{-2} s^{-1}), soil moisture at a depth from 0 to 10 cm (m^3 m^{-3}). The data were recorded and stored in 30 min. interval. The pH was determined using a Testo 205 pH meter (Testo AG, Lenzkirch, Germany). Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were determined by using a digital combo meter Hanna Combo HI 98130 (Hanna instruments, USA).

The cyanoprokaryotes species were identified using a morphological approach. The species were measured and photographed using the optical microscope AxioScope A1 (Zeiss©). For species identification, essential monographs were used (Komárek and Anagnostidis 1998, 2005; Komarek 2013). Information on habitats and description of localities submitted into the CYANOpro data base ([1], Melechin et al. 2013).

To estimate the widths of ecological niche, the Stephenson's formula (1988) was used: $NB=1/(n\Sigma Pij^2)$, where n – the number variants of habitats, Pij – the proportion of i-th species in this variant habitat j, which is calculated as the ratio of the number of samples i-th species on the j-th variant the total number of samples of this species. Niche breadth (NB) values range from 0 to 1.

Similarity of local floras was determined with the Sørensen index (KS) (as recommended *i.e.* by Wolda 1981) (weighted pair-group method using arithmetic averaging) in the program module GRAPHS (Nowakowskiy 2004): KS = 2a/(2a+b+c), where a – number of species common to both sets, b – number of species unique to the first set, c – number of species unique to the set.

Factor analysis of the species distribution in particular habitats was conducted in the program Statistica 10.0. The frequency of occurrence of species in habitats was taken into account.

Results and Discussion

A total of 51 cyanobacterial taxa were identified in the habitats of investigated area (Table 2). The cyanoprokaryotes flora was less diverse comparing with some other areas of Spitsbergen, *i.e.* Revelva valley (100 species of cyanoprokaryotes, Matuła et al. 2007), Petunia bay (more than 80 morphospecies, Komárek et al. 2012), area of settlement Pyramiden (73 species, Davydov 2014). However, the flora of cyanoprokaryotes in western part of the Oscar II Land was richer than flora of the Grønfjorden westcoast (43 species), of Grønfjorden east coast (22 species) and of Rijpfjorden east coast (37 species). The relatively small number of species in the western part of the Oscar II Land can be explained by a short period of data collection. A greater number of days would allow investigating more different localities with different environmental conditions.

In spite of generally low biodiversity, *Nostoc commune* (32 observation), *Gloeocapsa kuetzingiana* (14 observation), *Microcoleus autumnalis* (14 observation), *Microcoleus vaginatus* (11 observation) were the most common species in the investigated samples (Table 2).

Features of ecology and habitat of cyanoprokaryotes

Diversity of habitats in the area was quite high and typical for the archipelago. The most number of species (29) was found on wet rocks (Fig. 4a). These habitats are common on steep mountain slopes with monolithic rock walls. Abundance and melting of snowfields in the mountains of Spitsbergen provides a constant flow of water during snowmelt. In the drier rocky habitat, cyanoprokaryotes do not grow. In the area investigated, the number of wet rocky habitats was relatively small (5 out of 31). *Calothrix parietina, Gloeocapsa ralfsii, Gloeocapsa violascea* and *Gloeocapsopsis magma* are typical species on wet rocks.

The mountain slopes were covered with loose soil small particles (usually below 5 mm), therefore, no continuous cyanobacterial vegetation was observed (Fig 4b). This was particularly true for the places where creep process and solifluction took place. Few species usually occurred on soils, for example, *Aphanothece caldariorum, Nostoc commune, Tolypothrix distorta*. Two species were found on sandy slopes and eight species on the wet soil (Fig. 4c).

Flat coastal and mountain terraces had continuous vegetation dominated by mosses and lichens. Drier areas were predominantly occupied by lichen communities, and *Nostoc commune* could be always found there. Moss-dominated tundra thanks to the habitats with constant moisture had several species occurring commonly in the ecosystem: *Gloeocapsa kuetzingiana, Petalonema incrustans, Nostoc commune* and *Gloeothece confluens* (a total of 11 species).

Seepages with stagnant or slowly flowing water from melt snow are typical habitats for Cyanoprokaryota in Spitsbergen (Fig. 4d). They occurred in overmoistened locations on gentle slopes or on terraces. Flowing from the mountain slopes, water often does not form streams, and floods large areas in the lower-located flat terraces.

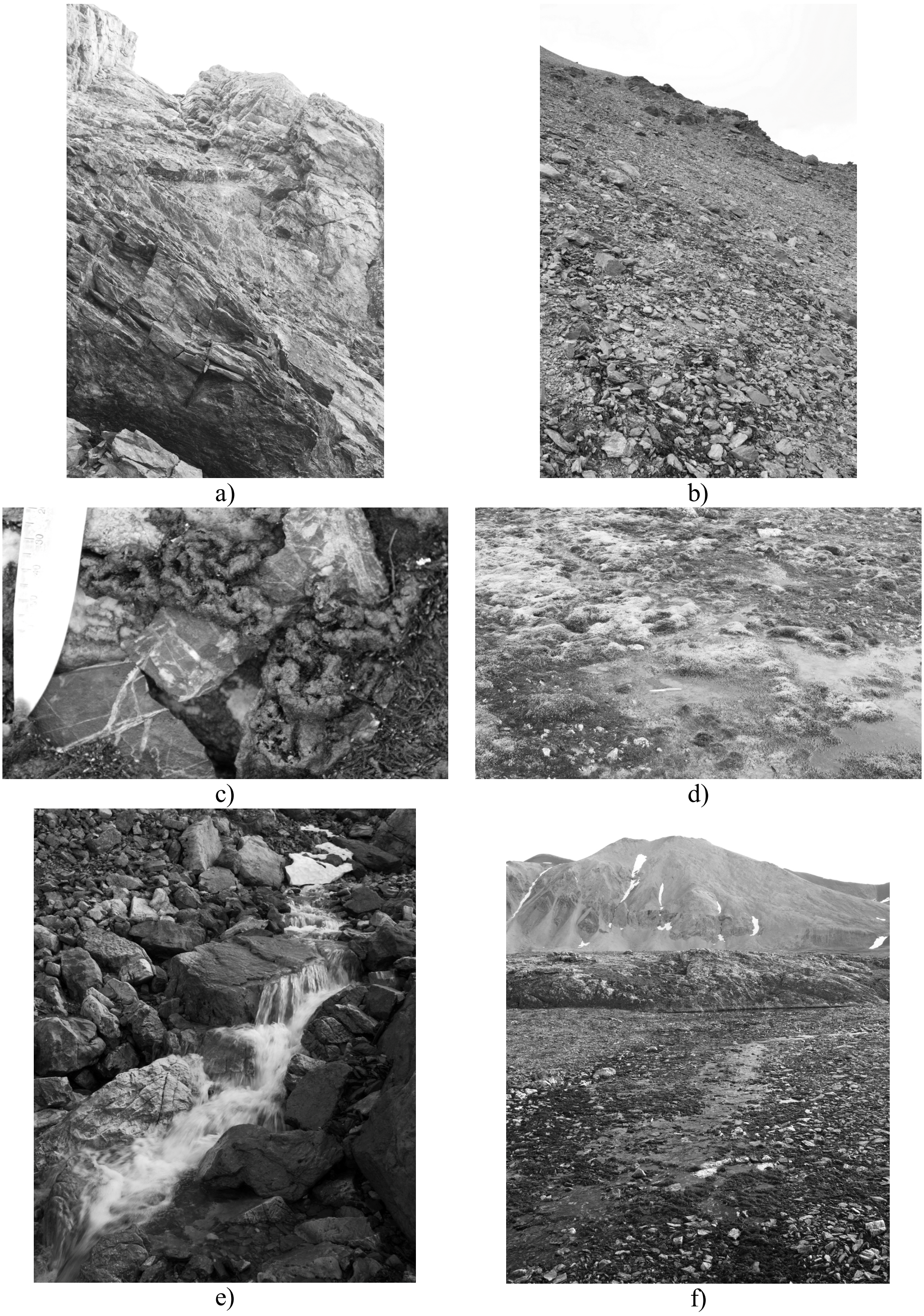

Fig. 4. The typical habitats of cyanoprokaryotes: a – wet rock, b – mountain slope, c – crusts on the soil, d – seepage, e – fast stream, f – slow stream.

Species/habitat types	L	P	FS	SS	WT	S	WS	WR	SA	NS	NB
Aphanocapsa fonticola Hansg.	16									**3**	**0.11**
Aphanocapsa grevillei (Berk.) Rabenh.		24, 26								**2**	**0.11**
Aphanocapsa muscicola (Menegh.) Wille	16					15		8, 14		**7**	**0.26**
Aphanocapsa parietina Näg.								7		**1**	**0.11**
Aphanocapsa rivularis (Carm.) Rabenh.				22	1	15, 19				**4**	**0.30**
Aphanocapsa sp.	16									**1**	**0.11**
Aphanothece castagnei (Bréb.) Rabenh.								8		**1**	**0.11**
Aphanothece saxicola Näg.								7		**1**	**0.11**
Calothrix aeruginosa Voronich.								8		**1**	**0.11**
Calothrix breviarticulata W. West et G.S. West	29						30			**2**	**0.22**
Calothrix parietina Thur. ex Born. et Flah.								7, 8, 18		**8**	**0.11**
Chamaesiphon polonicus (Rost.) Hansg.			4, 9			15				**5**	**0.21**
Chroococcus cohaerens (Bréb.) Näg.								7		**1**	**0.11**
Chroococcus helveticus Näg.								8		**1**	**0.11**
Chroococcus minutus (Kütz.) Näg.	16, 20				1	19				**5**	**0.25**
Chroococcus pallidus (Näg.) Näg.	16					19	11, 12			**6**	**0.22**
Chroococcus sp.	16		5					8		**3**	**0.33**
Chroococcus spelaeus Erceg.						23		7		**2**	**0.22**
Chroococcus subnudus (Hansg.) Cronb. et Komárek						19				**1**	**0.11**
Chroococcus turgidus (Kütz.) Näg.		24				15, 19		7		**4**	**0.30**
Cyanosarcina chroococcoides (Geitl.) Kováčik	16									**1**	**0.11**
Cyanosarcina sp.		26				19				**2**	**0.22**
Cyanothece aeruginosa (Näg.) Komárek		26						7		**2**	**0.22**
Dichothrix gypsophila (Kütz.) Born. et Flah.	16, 20			21, 22	25	15, 19				**9**	**0.36**
Geitlerinema acutissimum (Kuff.) Anagn.		24						8		**2**	**0.22**
Gloeobacter violaceus Rippka et al.							11, 12	14	3	**5**	**0.25**
Gloeocapsa kuetzingiana Näg.	16				25	15		7, 8, 18		**14**	**0.20**

Gloeocapsa ralfsii (Harvey) Kütz.								8		**3**	**0.11**
Gloeocapsa sanguinea (C. Ag.) Kütz.					1	19		7		**5**	**0.30**
Gloeocapsa violascea (Corda) Rabenh.								7, 8, 14, 18		**8**	**0.11**
Gloeocapsopsis magma (Bréb.) Komárek et Anagn.								7		**1**	**0.11**
Gloeothece confluens Näg.	16				21					**2**	**0.22**
Leptolyngbya gracillima (Zopf ex Hansg.) Anagn. et Komárek						15		7, 8		**9**	**0.20**
Leptolyngbya valderiana (Gom.) Anagn. et Komárek				22		19				**3**	**0.20**
Microchaete sp.								8		**1**	**0.11**
Microcoleus autumnalis (Trev. ex Gom.) Strunecky et al.		24, 27	2, 4, 5	10, 24	25			7		**14**	**0.45**
Microcoleus vaginatus Gom. ex Gom.	16					6, 15	6, 31	8		**11**	**0.40**
Nodosilinea bijugata (Kongiss.) Perkerson et Kova?ik	29									**1**	**0.11**
Nostoc commune Vauch. ex Born. et Flah.	16, 20, 29, 29		4		21, 25, 26	6, 19	6, 11, 12, 30, 31	7, 8, 14, 17, 18	3	**32**	**0.5**
Nostoc sp.			5		26	15, 23	13	8		**6**	**0.5**
Oscillatoria tenuis C. Ag. ex Gom.						6, 15				**4**	**0.11**
Petalonema incrustans [Kütz.] Komárek	16				26			8		**3**	**0.33**
Phormidium uncinatum Gom. ex Gom.			9	28		6, 15		8		**6**	**0.33**
Phormidium sp.							13			**1**	**0.11**
Rivularia cf. *beccariana* (De Not.) Born. et Flah.	16									**1**	**0.11**
Tolypothrix distorta Kütz. ex Born. et Flah.	16				1, 21		11, 31			**7**	**0.32**
Tolypothrix penicillata Thur. ex Born. et Flah.								7, 8		**2**	**0.11**
Tolypothrix tenuis Kütz. ex Born. et Flah.						19		7		**5**	**0.16**
Tolypothrix sp.						15				**1**	**0.11**
Trichocoleus delicatulus (W. West et G. S. West) Anagn.			5							**1**	**0.11**
Woronichinia karelica Komárek et Kom.-Legn.		24, 26								**2**	**0.11**

Table 2. List of cyanoprokaryotes taxa found in habitats. Numbers in the columns correspond to the numbers of localities in Table 1. FS – fast running glacial streams and waterfalls; SS – slow running tundra streams; WT – wet moss tundra; P – tundra pools; S - seepages; WS – wet soils; WR – wet and dripping rocks; SA – sand; L – lakes and ponds; NS – number of samples, NB - values for niche breadth.

At such sites, soil fungi, mosses, and cyanoprokaryotes formed unique extensive cryptogamic crust communities. A total of 21 cyanoprokaryotes species were found on the seepages. These species may also occur in stagnant ponds and in wet tundra. This confirms ecotone character of the habitats. In this study, *Microcoleus vaginatus, Leptolyngbya gracillima, Leptolyngbya valderiana* were typical species found in seepages habitats. They formed extensive communities. Sometimes *Chroococcus subnudus, C. spelaeus. Oscillatoria tenuis,* and *Phormidium uncinatum* were found. These species are also typical for the sites with stagnant water.

Small pools are widespread habitat type in Spitsbergen. Their mean area is no more than 1.2 m^2, depth from 5 to 20 cm. A total of 7 species of cyanoprokaryota were found in the pools, among them *Aphanocapsa grevillei, Chroococcus turgidus, Woronichinia karelica* most frequently.

The lakes on the investigated territory had relatively small areas ranging from 100 to 600 m^2. The lake depth was not more than 0.5 m. Like pools they gradually dried up during the summer, and had low values of TDS (0.05 ppt) (Table 3). In the lakes, 18 species cyanoprokaryotes were recorded. The benthic fouling *Aphanocapsa fonticola, Cyanosarcina chroococcoides, Nodosilinea bijugata, Rivularia* cf. *beccariana* were found only in the lakes.

Streams in investigated area could be divided into two groups: the fast and slow ones. Fast streams (Fig. 4e) are glacial runoff, with the rapid flow and low temperature (1.6 – 2.8°C) (Table 3) and usually with muddy water containing a lot of suspended particles. Fast streams were characterized by low values of TDS (0.04–0.07 ppt) (Table 3). In the streams, epilithic cyanoprokaryotes are usually present only. In this study, 7 species were found, among them *Chamaesiphon polonicus* and *Trichocoleus delicatulus* were the most often ones.

The slow snow-fed streams (Fig. 4f) are widely distributed in the study area. They were characterized by clear water, temperature slightly lower than the air temperature (6.2–7.9°C) (Table 3), and low speed of the current. Most of them had a low value of total dissolved solids (0.13–0.14 ppt) (Table 3). The number of cyanoprokaryotes species varied. In the study area, only 5 species were found, among them *Dichothrix gypsophila, Microcoleus autumnalis, Phormidium uncinatum, Aphanocapsa rivularis* were the most widespread.

Cyanoprokaryota composition on nunataks and mountain peaks was extremely poor, only *Nostoc commune* was usual species is these habitats.

The widths of ecological niche (NB) of most Cyanoprokaryota species (24) was minimal (0.11), but for most of them there was only single observation. Species, which were found more than one time in the same habitat type, had the narrow ecological niche. They were *Aphanocapsa fonticola, Aphanocapsa grevillei, Calothrix parietina, Gloeocapsa ralfsii, Gloeocapsa violascea, Oscillatoria tenuis, Tolypothrix penicillata* and *Woronichinia karelica*.

The high value of NB had a flexible (ubiquist) species such as *Microcoleus autumnalis, Microcoleus vaginatus, Nostoc commune, Phormidium uncinatum, Tolypothrix distorta* and *Nostoc commune.* High humidity (Fig. 3) contributed to the distribution of some tolerant species (*Nostoc commune*), which can be found everywhere.

Majority of polar cyanobacteria does possess effective mechanisms to cope with high PAR and UV-B radiation. Among them, synthesis of secondary metabolites represents the process that provides typical colors for cyanobacterial soil crusts and mats. Most crusts and cyanobacterial mats have a black (*Microcoleus autumnalis, Gloeocapsa violascea*), red-orange (*Microcoleus vaginatus*) or orange-brown (*Phormidium uncinatum*) pigmentation of the upper layer. Many Cyanoprokaryota species avoid radiation by migrating to deeper layers within the microbial mats (*Leptolyngbya gracillima, L. valderiana* and *Oscillatoria* *tenuis*). Factor analysis was used to show the influence of various ecological factors on the distribution of species (Fig. 5). Based on the diagrams we suggest that factor 1 is the permanent moisture and factor 2 is the value of moisture. The species which occured in permanent water bodies and watercourses (streams, lakes and pools) and demanded permanent moisture (*Aphanocapsa fonticola, Tolypothrix distorta, Woronichinia karelica*, etc.) formed a group in the positive part of the scale of both factors (Fig. 5).

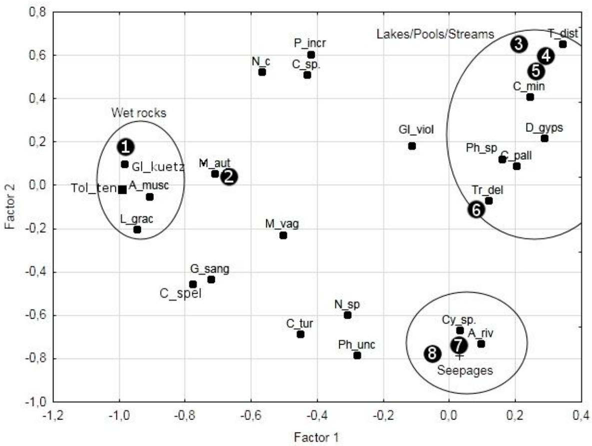

Fig. 5. Factor analysis of the species distribution in habitats. Factor 1 is the permanence of moisture and Factor 2 is the value of moisture: **1** - *Aphanocapsa parietina*, *Aphanothece castagnei*, *A. saxicola*, *Calothrix aeruginosa*, *Calothrix parietina*, *Chroococcus cohaerens*, *C. helveticus*, *Gloeocapsa ralfsii*, *G. violascea*, *Gloeocapsopsis magma*, *Microchaete* sp.; **2** - *Calothrix aeruginosa*, *Geitlerinema acutissimum*; **3** - *Aphanocapsa fonticola*, *Aphanocapsa* sp., *Cyanosarcina chroococcoides*, *Nodosilinea bijugata*, *Rivularia* cf. *beccariana*; **4** - *Calothrix breviarticulata*; **5** - *Gloeothece confluens*; **6** - *Aphanocapsa grevillei*, *Woronichinia karelica*; **7** - *Chamaesiphon polonicus*; **8** - *Chroococcus subnudus*, *Oscillatoria tenuis*, *Tolypothrix* sp.; **+** - *Leptolyngbya valderiana*; **A_musc** - *Aphanocapsa muscicola*; **A_riv** - *Aphanocapsa rivularis*; **Gl_viol** - *Gloeobacter violaceus*; **C_min** - *Chroococcus minutus*; **C_pall** - *Chroococcus pallidus*; **C_sp.** - *Chroococcus* sp.; **C_spel** - *Chroococcus spelaeus*; **C_tur** - *Chroococcus turgidus*; **Cy_sp** - *Cyanosarcina* sp.; **D_gyps** - *Dichothrix gypsophila*; **Gl_kuetz** - *Gloeocapsa kuetzingiana*; **G_sang** - *Gloeocapsa sanguinea*; **L_grac** - *Leptolyngbya gracillima*; **M_aut** - *Microcoleus autumnalis*; **M_vag** - *Microcoleus vaginatus*; **N_c** - *Nostoc commune*; **N_sp** - *Nostoc* sp.; **P_incr** - *Petalonema incrustans*; **Ph_sp** - *Phormidium* sp.; **Ph._unc** - *Phormidium uncinatum*; **T_dist** - *Tolypothrix distorta*; **Tol_ten** - *Tolypothrix tenuis*; **Tr_del** - *Trichocoleus delicatulus*.

The species found in seepages grew with constant water supply, but had much lower demand for moisture, formed a group of the following species *Aphanocapsa rivularis, Chroococcus subnudus, Oscillatoria tenuis*. The species occurring on the rocks were most tolerant to the value and stability of moisture supply, and they are located in the part of the scale which is characterized by small and unstable moistening (Fig. 5). The aerophytic cyanoprokaryotes (*Aphanocapsa parietina*, *Aphanothece castagnei*, *Gloeocapsa violascea*, *Gloeocapsopsis magma*, *etc*.) grew on the wet rocks. Species with wide ecological niche were intermediate between the three groups.

Number of locality	t (°C)	pH	EC (mS)	TDS (ppt)	Habitat
4	2.8	8.62	0.13	0.07	Fast stream
5	1.7	8.4	0.16	0.07	Fast stream
6	4.7	7.3	-	-	Wet soil
9	1.6	8.4	0.09	0.04	Fast stream
15	5.4	8.35	0.09	0.04	Seepage
16	7.6	9.2	0.1	0.05	Lake
21	7.5	8.6	0.27	0.13	Slow stream
22	7.9	8.24	0.28	0.14	Slow stream
24	6.2	8.34	0.27	0.14	Slow stream
27	2.5;	7.2	-	-	Pool

Table 3. Physical properties on the typical sites where samples were collected.

Distribution of Cyanoprokaryota species on the Spitsbergen archipelago

Comparing species distribution found in this study to the biodiversity of the archipelago, one may assume that below specified 12 species might be classified as widespread, because they were found in more than 7 localities: *Aphanocapsa muscicola, Calothrix parietina, Chroococcus cohaerens, C. turgidus, Cyanothece aeruginosa, Dichothrix gypsophila, Gloeocapsa kuetzingiana, Microcoleus autumnalis, M. vaginatus, Nostoc commune, Phormidium uncinatum*, and *Tolypothrix tenuis*. Additionally, 12 species were considered as frequent and were found in 5-6 localities: *Aphanocapsa grevillei, A. parietina, Aphanothece caldariorum, A. castagnei, A. saxicola, Chroococcus minutus, C. pallidus, Gloeocapsa sanguinea, G. violascea, Gloeocapsopsis magma, Leptolyngbya gracillima, Oscillatoria tenuis*. Some of them (*Aphanocapsa parietina, Chroococcus minutus, Gloeocapsopsis magma*) are typical for the Arctic, and other (*Gloeocapsa sanguinea, G. violascea, Oscillatoria tenuis*) occur in the Arctic sporadically and can be found only in suitable habitats.

The eleven species were not rare, but rather sporadic species. They were found in 4 localities. The sporadic species were *Aphanocapsa fonticola, Calothrix breviarticulata, Chamaesiphon polonicus, Chroococcus spelaeus, C. subnudus, Gloeocapsa ralfsii, Leptolyngbya valderiana, Nodosilinea bijugata, Petalonema incrustans, Tolypothrix distorta,* and *Trichocoleus delicatulus*. This group, however, consisted of the species with unclear distribution in Spitsbergen, which is a consequence of insufficient number of studies and rather small number of findings.

The six rare species (*Calothrix aeruginosa, Chroococcus helveticus, Cyanosarcina chroococcoides, Geitlerinema acutissimum, Gloeothece confluens* and *Tolypothrix penicillata*) were found only in 2 localities. They are probably not rare in Spitsbergen and could be found in other areas too. Two species, *Aphanocapsa rivularis* and *Woronichinia karelica*, were recorded for the first time on Spitsbergen.

Floristic comparison

Fig. 6 shows the difference between cyanobacterial floras in various territories of the Spitsbergen. The studied flora of the Oscar II Land is most similar to flora of the vicinity of settlement Pyramiden (similarity coefficient 55%) and with flora of the west coast of Grønfjorden (36%). It can be assumed that this is due to the similarity of the geological conditions, specifically because of all these areas are dominated by carbonate rocks. The predominance of carbonates determines the high pH level in the lakes and streams, and that can be traced in all localities where measurements were taken.

The floras of these three areas include 14 common species, among them are widespread species *Aphanocapsa grevillei, A. muscicola, A. parietina, Calothrix parietina, Gloeocapsa kuetzingiana, Nostoc commune, Phormidium uncinatum* and *Tolypothrix distorta*.

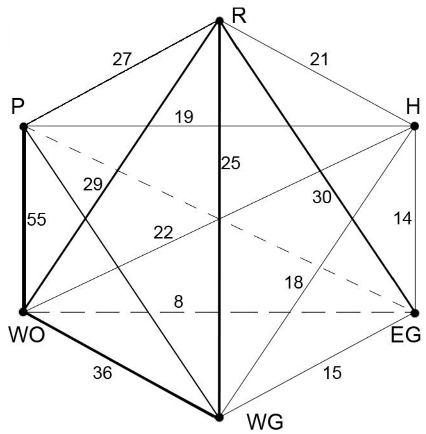

Fig. 6. Complete graph of similarity of Cyanoprokaryota flora in some areas on Spitsbergen (Sørensen index, for the clustering was used the mean distance between elements of each cluster (weighted pair-group method using arithmetic averaging, numbers on ridges are similarity in percent). EG – Grønfjorden east coast (Davydov 2008), H – Revelva valley (Matuła et al. 2007), P – vicinity of settlement Pyramiden (Davydov 2014), R –Rijpfjorden east coast (Davydov 2013), WG – Grønfjorden west coast (Davydov 2011), WO – west part of Oscar II Land.

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