Diversity of the Cyanoprokaryota in polar deserts of Innvika cove North-East Land (Nordaustlandet) Island, Spitsbergen

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Abstract

The study of polar deserts cyanoprokaryotes up to now is few. Foremost this is connected with difficulty visiting of the area. The paper presents the results of a study of cyanoprokaryota on the southern coast of Innvika cove (Fotherbyfjorden bay, North-East Land Island, Spitsbergen archipelago). A total of 74 taxa were observed in various habitats of investigated area. Nine species are reported for the first time for Spitsbergen flora. *Gloeocapsopsis magma* (20 observations), *Nostoc commune* (19), *Microcoleus autumnalis* (17) were the most common species in the investigated samples. The most number of species (42) was found on wet rocks. The similarity Sorensen index between wet rock species, seepage species and pools species is very high. It can mean that for many species the only necessary preference in habitat is a rock substrate and wetting. Most similar are the flora of the Innvika area and flora of the west part of Oscar II Land (61%).

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

DOI: 10.5817/CPR2016-1-7

Introduction

Cyanoprokaryotes in the Arctic ecosystems are a significant element of many vegetation types, sometimes they even dominate there. They form crusts of a large size, they are first to take available substrates and dominate by quantity in the benthos of cold lake. Cyanoprokaryotes in marginal polar desert communities are getting advantage. It is particularly distinct in wet localities.

The study of polar deserts cyanoprokaryotes has always been few. Foremost this is connected to the difficulty of visiting the area (Patova et al. 2015). The polar desert zone on Spitsbergen archipelago covers all North-East Island territory. Currently there are known planktonic cyanoprokaryotes of the lakes from North-East Island (Thomasson 1958). There were specified 13 taxa living in small water bodies from Heimbukta area (Murchisonfjord bay). From Kinnvika area (Murchisonfjord bay) a new species *Leptolyngbya sieminskae* D. Richter et Matuła (Richter et Matuła 2013)

Received April 19, 2016, *accepted* July 10, 2016.

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Acknowledgements: This study was conducted with the support of grants from RFBR No 14-04-98810, No 15-04-06346, No 15-29-02662.

was described. Terrestrial cyanoprokaryotes from Rijpfjorden east coast were studied previously. In this study, 37 species have been found (Davydov 2013). These data were used in preparing the review of polar deserts algae (Patova et al. 2015).

The aim of the study is to make a detailed analysis of cyanobacterial communities on the Innvika cove (Fotherbyfjorden bay, North-East Land Island). The cyanoprokaryotes microflora of the area has never been studied before.

Study area

The investigated area is situated on the southern coast of Innvika cove. It is an innermost part of Fotherbyfjorden bay, North-East Land (Nordaustlandet) Island, Spitsbergen archipelago (Fig. 1). North-East Land Island is the second largest island (14.530 km^2) of the Spitsbergen archipelago. Seventy-seven percent of island (77%) is covered by glaciers. The study area is located between two large ice-caps (Ahlmannfonna and Austfonna). The main part of the territory is a plain occupied around the lake Ringgåsvatnet. The plain is surrounded by steep mountains (Vikvaktaren, Krykkjefloget and nameless peaks) which all are about 300 m above sea level.

In the study area there are rocks of different geological origin. Most territory of the on Innvika cove coast and Innvikdalen Valley (numbers of collection plots as used in Fig. 1 and Table 1: 1-8, 12-16, 18-20) is located within Duvefjorden Migmatite complex (Sirotkin et Tolmacheva 2012). Eastern, southern and western parts of the lake shore Ringgåsvatnet (plots 17, 21-23) are located within Rijpfjorden granitoid suite. The plots 24-25 belong to Ringgåsvatnet augen gneiss. The position of plots 26 is located within metasedimentary Brennevinsfjorden group (Sirotkin et Tolmacheva 2012). This group is represented by a monotonous sequence of quartzites, siltstones and shales (Flood et al. 1969). The plots 9-11 are located within Galtedalen Group which contains conglomerates and sandstones overlain by limestones, dolomites and shale (Tebenkov et al. 2002.). The plots 10-11 are flagged on Persberget Formation, being characterized by massive white and grey quartzites and subordinate grey shale with conglomerates (Flood et al. 1969).

Hydrological conditions in the studied area are influenced by a stream from the glaciers. The streams is filling Ringgåsvatnet and Innvikvatnet lakes, having streamflow into the sea. Water regime depends on snow and ice melting.

The climate of Spitsbergen is determined by its high latitude position. The average daily summer temperature is just above zero, that the summer humidity is very high, and that the total precipitation is relatively high. According to the Verlegenhuken weather station [1] average daily temperature during the sampling varied from 3.3 to 7.8°C.

The vegetation of North-East Land belongs to polar desert zone type (Aleksandrova 1980, Möller 2000, Cooper 2011).

Microclimatic conditions influence soil properties. Soil profile is shallow and typical for the high Arctic. Soil cover is patterned and depends on the micro-relief which has been formed by cryoplanation, sloping processes and erosion. An important role in the maintenance of those areas is played by permafrost, which retards infiltration of precipitation and of melt waters (Oleksowicz et Luscinska 1992).

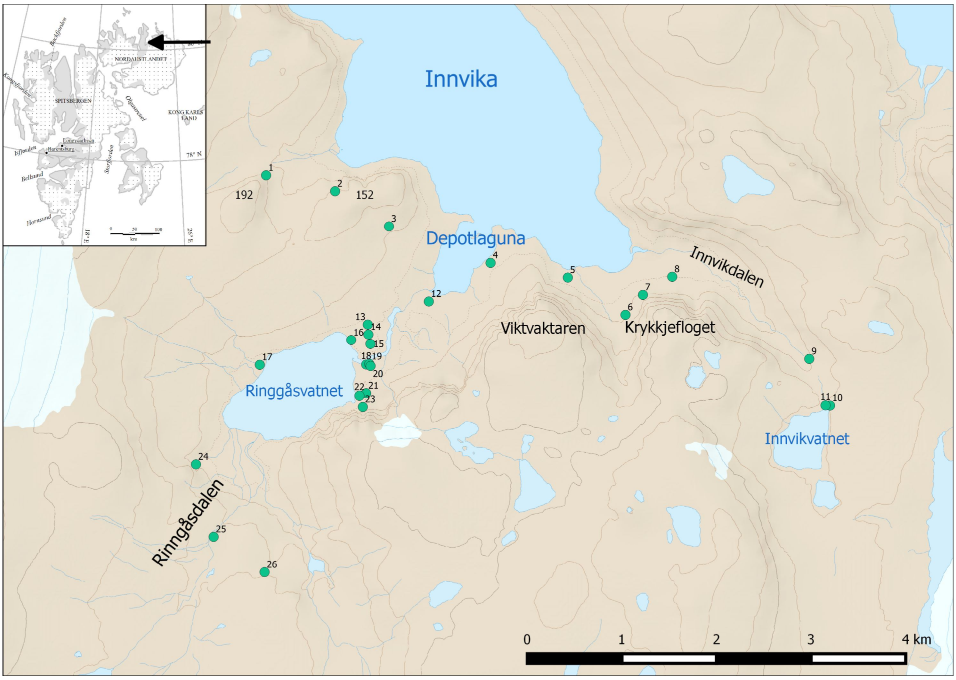

Fig. 1. Position of sample plots in the southern coast of Innvika cove, North-East Land Island, Spitsbergen archipelago, numbers of sample plots as in the Table 1.

Methods

Samples were collected during 22–29 July, 2011 in the area covering western and southern part of Innvika cove coast, Innvikdalen, Grådalen, Ringgåsdalen valleys, Vikvaktaren, Krykkjefloget mountain slopes (*see* Fig. 1, Table 1). In total, 134 samples were collected. The illuminance was determined using lux meter TKA-PKM (TKA Scientific Instruments, Russia). As the absolute illumination level is depend on the day time and weather conditions and is not allow for differences in habitat, we were measuring the relative habitat illuminance. The relative illuminance is the proportion (%) of the total illuminance on this territory at the current time.

Free products Norwegian Polar Institute [2] were used to create maps (Fig. 1). The species of cyanoprokaryota were identified, measured and photographed using the optical microscope AxioScope A1 (Zeiss©). The presence or absence of species on the samples was recorded; the abundance of species was not considered. For species identification, essential monographs were used (Komárek et Anagnostidis 1998, 2005; Komárek 2013). Information on habitats and description of localities submitted into the CYANOpro data base [3] (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 was determined with the Sørensen index (KS) (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.

Results and Discussion

A total of 74 cyanobacterial taxa were identified in the habitats of investigated area (Table 2). The flora of this territory can be characterized as diverse compared to 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).

Gloeocapsopsis magma (20 observations), *Nostoc commune* (19), *Microcoleus autumnalis* (17) were the most common species in the investigated samples.

Nine species are recorded in Spitsbergen flora for the first time: *Chroococcus obliteratus* is widespread in North Temperate Zone, but it was not found in Arctic before, for *Coleodesmium wrangelii* exist several data from Canadian Arctic (Elster et al. 1996) and North Temperate Zone (Komárek 2013). *Gloeocapsa novacekii, Gloeocapsopsis pleurocapsoides, Merismopedia hyalina* were not conducted from Arctic before, they have mostly mountain distribution, *Phormidiochaete nordstedtii* – a single record exist from Arctic (Greenland, Disko Island, Bachmann 1921), *Schizothrix simplicior* have mountain distribution, *Stigonema informe* was found in Greenland (Larsen 1907, Bachmann 1921), also *Tolypothrix fasciculata* was not conducted from Arctic before.

Features of ecology and habitat of cyanoprokaryotes

Diversity of habitats in the area is quite high and typical for the archipelago. The most number of species (42) was found on wet rocks. One should note here the abundance of wet rock surface on the study area and numerous diversity rocks of different complexes: migmatites, granitoids, gneisses, quartzites, amphibolites, siltstones and shales. High differentiation of rock habitats explains most diversity of cyanoprokaryotes species which grow here.

Aphanothece caldariorum, *A. castagnei*, *Coleodesmium wrangelii*, *Gloeocapsa biformis*, *G. novacekii*, *G. rupicola*, *Gloeocapsopsis pleurocapsaoides*, *Schizothrix arenaria* and *Trichocoleus sociatus* were found only on the rocks.

The similarity Sorensen index between wet rock species, seepage species and pools species is very high – 54% and 41% respectively (Fig. 2a). It can mean that for many species the only necessary preference in habitat is a rock substrate and wetting.

Abundance of snowfields in the mountains of Spitsbergen provides a constant flow of water during snowmelt. The runoff from massive snow fields, which are in the upper parts, is forming fast streams with waterfalls and gorge. These habitats have developed cyanoprokaryotes community.

In particular, 24 epilithic taxa on the boulder were found in the fast stream on the study area. *Chamaesiphon polonicus*, *Schizothrix simplicior*, *Trichocoleus delicatulus* are common species here.

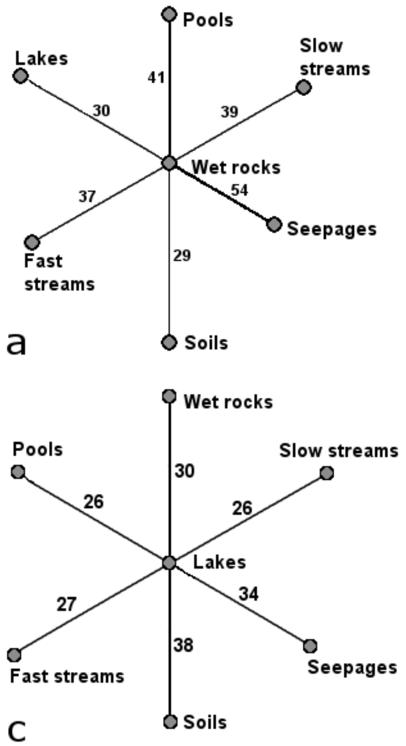

Fig. 2. The graphs of similarity in species composition of cyanoprokaryotes of different habitats (Sørensen index, for the clustering was used the mean distance between elements of each cluster, weighted pair-group method using arithmetic averaging, numbers on ridges are similarity in percent).

There are also many slow streams in the area. A total of 27 species of cyanoprokaryota were found here, among them *Chroococcus varius*, *Leptolyngbya valderiana*, *Microcoleus vaginatus* etc.

Cyanobacterium sp., *Cyanosarcina* sp., *Leptolyngbya* sp., *L. valderiana*, and *Tolypothrix tenuis* f. *terrestris* are specific for slow streams. Twelve species are common in fast and slow streams (*Ammatoidea normannii*, *Aphanocapsa* sp., *Chamaesiphon polonicus*, *Chroococcus obliteratus*, *C. subnudus*, *Cyanothece aeruginosa*, *Dichothrix gypsophila*, *Microcoleus autumnalis*, *Phormidium interruptum*, *P. uncinatum*, *Pseudanabaena frigida*, *P. minima*). Only three of all cyanoprokaryotes (*Chroococcus obliteratus*, *C. subnudus*, *Phormidium interruptum*) were found nowhere except of streams.

Small pools are widespread habitat type in Spitsbergen. In the small pools, 19 species of cyanoprokaryotes were found. *Calothrix breviarticulata*, *Stigonema informe* are specific for small pools. Some species (*Chroococcus pallidus*, *Gloeocapsa ralfsii*, *G. violascea*, *Phormidiochaete nordstedtii*) are growing on the rocks and in pools. For this species rock substrata on the pool bottom is determinative. Therefore, one can observe the great similarity between pools species and rocks species state (Fig. 2b). The likeness of conditions pools and seepages can explain most similarity of species composition of these habitats.

The lakes of the study area are represented by two large reservoirs Ringgåsvatnet and Innvikvatnet. During our stay, the surface for the most part of Ringgåsvatnet lake and all part of Innvikvatnet lake was covered by the ice. On the littoral zone of lakes on the small pebbles, there are cyanobacterial mats containing 9 species. These are common *Phormidium uncinatum*, *Oscillatoria tenuis*, *Leptolyngbya gracillima*. Also on the littoral of lakes were found *Calothrix parietina*, *Chamaesiphon polonicus*, *Tolypothrix penicillata* and other. The species composition of lake bottom are most similarity to soil and seepages habitats (Fig. 2c).

Seepages with stagnant or slow flowing water of snow melting are typical habitats for Cyanoprokaryota in Spitsbergen. They occur in overmoistened locations on gentle slopes or on terraces. While flowing from the mountain slopes, water often does not form any streams, and floods large areas in the lower flat terraces. Along with soil fungi and mosses, cyanoprokaryotes form unique extensive cryptogamic crust communities. A total of 30 cyanoprokaryotes species were found on seepages (*Chroococcus minutus*, *Leptolyngbya compacta*, *Merismopedia hyalina*, *Rivularia biasolettiana* and other). In this habitat, there should be found rock specific species as well as stream specific species. A high level of similarity between species composition of seepages and rocks (54%), seepages and slow stream (44%) can be observed (Fig. 2d).

The soil species have a good occasion to develop in study area conditions. The reason is that they have no competition with plants. Very large area of soil is free. Soil cyanoprokaryotes play a major role in the initiation of crust development and the early stages of its growth (Pushkareva et Elster 2013). The soil covering has developed very slowly due to arctic climatic conditions and because of impact of cryogenic processes. Thus, the soils have permanent displacement and destruction owing to solifluction, cracking and polygons formation. A total number of 10 cyanoprokaryotes species were found on soils habitats.

The substrate preference

The most abundant substrates in the Arctic polar desert ecosystems are various rock types. They are presented by walls on the mountain slope, some boulders on the screes, blocks and stone. More often the cyanoprokaryotes are surfacing rock substrates with wet conditions. 55 species were found on the rock substrates on the study area.

The second most abundant substrate is a soil. On the soils, there were found 39 cyanoprokaryotes species. Soil profile is very thin, primitive. Soils of polar deserts do not have a pronounced peat horizon. In aerophytic conditions cyanoprokaryotes usually form crusts with fungi, lichens and mosses. From Spitsbergen ecosystems overmoistening soils with seepage community represented are usual. This habitats most frequently are forming a cyanobacterial mats.

Only few species were found on the mosses (11). This group does not contain specific species, all of them can be found on other substrates. A single species was found as epiphytic on the algae or on the sand and mud.

A high level of species composition similarity can be observed between rocks and fine earth (*see* Fig. 3). Probably there exists a common group of species that uses both types of substrates.

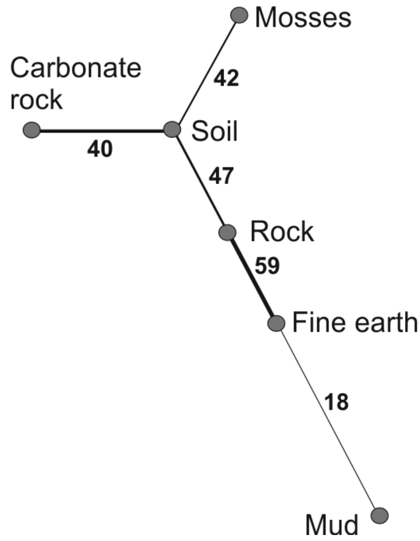

Fig. 3. The graphs of similarity in species composition of cyanoprokaryotes of different substrata (Sørensen index, for the clustering was used the mean distance between elements of each cluster, weighted pair-group method using arithmetic averaging, numbers on ridges are similarity in percent).

The illumination conditions of habitats

The illumination conditions of the study area can distinguish some habitats type. The large rock blocks can form hollows. Algae in these conditions get only some scattered light about 0.1 lux value. On the study area, there are only five species inhabiting these conditions (*Aphanocapsa* sp., *Nostoc commune*, *Leptolyngbya gracillima*, *Chroococcus pallidus*). There are also some shaded sites on the rocky slopes, characterized by low illumination conditions about 1-5 percent of the total illumination, which can be observed in the open area. For such places *Aphanothece saxicola*, *Gloeocapsopsis magma*, *Leptolyngbya* cf. *gracillima*, *Nostoc commune*, *Oscillatoria tenuis* are typical.

Also at low illumination (6 - 10% of the total), *Ammatoidea normannii*, *Calothrix parietina*, *Chamaesiphon polonicus*, *Gloeocapsopsis magma*, *G. pleurocapsaoides*, *Microcoleus autumnalis*, *Nostoc commune*, and *Stigonema ocellatum* are detected.

Eleven species were found at 11-20% of the total illumination (*Chroococcus cohaerens*, *C. varius*, *Gloeocapsa sanguinea*, *G. violascea*, *Gloeocapsopsis magma*, *Microcoleus vaginatus*, *Nostoc commune*, *Nostoc* sp., *Stigonema minutum*, *Tolypothrix fasciculata*, *T. tenuis*). In habitats with a middle level of illuminations (21-30%), cyanoprokaryotes were not detected. The variability of species is relative to exposure of their growth surfaces. Most species grow at medium (30-70%) and high (70-100%) illumination. *Ammatoidea normannii*, *Aphanothece saxicola*, *Calothrix parietina*, *Chamaesiphon polonicus*, *Chroococcus pallidus*, *Gloeocapsopsis magma*, *Leptolyngbya gracillima*, *Microcoleus autumnalis*, *Nostoc commune*, *Oscillatoria tenuis*, *Stigonema ocellatum* can be called indifferent to illumination.

Number of locality	Latitude	Longitude	Elevation (m a.s.l.)	Description of localities
1	80.12598	22.98589	71	Slope of a hill (192 m peak) N exposure. **1a.** Under the rocky ledge. On the soil. **1b**. The foot of a rocky outcropping. The fast stream. On the bottom at a depth of 5-7 cm.
2	80.12359	23.0224	75	Slope of a hill (152 m peak) N exposure. Under the rocky ledge on a horizontal surface and vertical wet wall. On the rock and mosses.
3	80.11958	23.0492	53	Slope of a hill (152 m peak) SSE exposure. **3a**. On the lower surface of moss floating in a pool. On the mosses. **3b.** Slow stream of 15-30 cm wide, 1 cm deep under the water on the rocks and mosses.
4	80.11481	23.10189	2	Depotlaguna, 15 meters from the see-coast. Stream flowing down the slope of the hill Vikvaktaren. Under water at the bottom. On the sand.
5	80.11242	23.14294	8	Depotlaguna. The basis of Vikvaktaren mountain. Polar desert, mosses community. The small fast stream (0.1 m width, 0.05 m deep). Epilithic on the pebbles at the bottom of the stream (0.02 m deep) and on the mosses on the wall of boulder.
6	80.10817	23.17153	40	Grådalen valley. The basis of Krykkjefloget hill, NE exposure slope. **6a**. On the rock. **6b**. The bank of the slow stream.
7	80.10981	23.18261	40	The basis of Krykkjefloget hill, NE exposure slope, under a bird colony. On the wet soil.
8	80.11111	23.2	7	Innvikdalen valley. The basis of Krykkjefloget hill, NE exposure slope. **8a**. Seepage. On the soil. **8b**. Waterfall on the fast stream. On the rock and cleft in stream.
9	80.10156	23.26833	100	Innvikdalen valley. The northern slope of the wet rock.
10	80.09692	23.27605	110	Innvikvatnet lake area. Vertical rock wall, slope south-western exposure. The granite-quartz rock.
11	80.097	23.2736	110	Innvikvatnet lake area. At the bottom of a stream flowing out of the Innvikvatnet lake.
12	80.11201	23.06521	11	Depotlaguna. The seepage between boulders. On the rock and soil.
13	80.11064	23.03014	22	The bank of the stream. Local depression between two hills. The crust on the soil.

14	80.1097	23.0297	20	The seepage, puddle 30 cm deep, out of the water. On the soil.
15	80.10878	23.03009	5	**15a**. Fast stream in a rapid current. On the pebbles on the bottom of the stream (-0.01). High illumination. Horizontal. Under water. On the rock. **15b**. The bank of the stream, pool. Among filamentous algae in the lateral surface of the boulder. Under water (depth to 0.15 m).
16	80.1094	23.0199	22	The north shore of Ringgåsvatnet lake, littoral. At the bottom of the lake.
17	80.10825	22.9681	41	The west shore of Ringgåsvatnet lake, slow stream. On mosses at the bottom.
18	80.10689	23.02622	17	The shore of Ringgåsvatnet lake. On mosses at the bottom.
19	80.1069	23.028	20	Ringgåsvatnet lake area. The seepage, puddle 30 cm deep, out of the water. On the soil.
20	80.1067	23.0285	20	Ringgåsvatnet lake area. The seepage on the bank of the stream. Underwater. On the rock and mosses.
21	80.1042	23.024	35	The east shore of Ringgåsvatnet lake. Vikvaktaren mountain, slope of western exposure. Gentle slope to the lake. **21a**. Crusts of the mosses and algae, outside water, on a horizontal surface, in well-lit conditions. It's wet. **21b**.The slow stream among the rocks. At the bottom, at a depth of 1 cm. **21c**. Seepage, algae crusts, which are implemented liverworts. Under water. **21d**. Boulder on which the water flows melting snow. Red-brown mats.
22	80.10406	23.02017	28	The east shore of Ringgåsvatnet lake. On the slope of Vikvaktaren mountain. The pool on a horizontal surface, in water. On the rock.
23	80.10297	23.02117	70	The east shore of the Ringgåsvatnet lake. Slope of a hill western exposure. Rock with scarps closest to the base ledge. On the rock.
24	80.09971	22.9258	40	Ringgåsdalen valley. Slope of rock of N exposure. On the rock.
25	80.0927	22.93002	109	Ringgåsdalen valley. Slope of rock of eastrern exposure. **25a**. Fast stream, on the rock underwater. **25b**. Small slow stream, on the bouloder, underwater.
26	80.08871	22.95512	130	Ringgåsdalen valley. **26a**. The slope of rock, on the cleft. Rock outcrops. **26b**. On the vertical wall out of the water. **26c**. On the vertical wall, fast stream.

Table 1. Description of localities studied.

Species/habitat types	WS	S	SS	WR	P	L	FS	BC	NS	NB
Ammatoidea normannii W. West et G. S. West	21a		11, 21b	2, 24, 26b	22		15a		**9**	**0.46**
Aphanocapsa grevillei (Berk.) Rabenh.	12	12	11, 21b		3a, 12				**7**	**0.47**
Aphanocapsa muscicola (Menegh.) Wille		19		2, 26b					**3**	**0.22**
Aphanocapsa sp.		12, 19	3b, 12, 17, 20, 21b	2, 10, 24	3a, 22	16	26c		**14**	**0.57**
Aphanothece caldariorum P. G. Richter				2					**1**	**0.13**
Aphanothece castagnei (Bréb.) Rabenh.				10					**1**	**0.13**
Aphanothece cf. *microscopica* Näg.		14, 19			22				**4**	**0.2**
Aphanothece saxicola Näg.		12		1a, 2, 6a, 10	12				**7**	**0.23**
Aphanothece sp.			3b		3a				**2**	**0.25**
Calothrix breviarticulata W. West et G. S. West					12				**1**	**0.13**
Calothrix parietina Thur. ex Born. et Flah.				2, 24		16			**5**	**0.18**
Chamaesiphon polonicus (Rost.) Hansg.	21a	19	21b	9, 21d, 24		16	5, 8b		**13**	**0.47**
Chroococcus cohaerens (Bréb.) Näg.		8a, 12, 14, 19		3, 6a, 23, 26a					**8**	**0.25**
Chroococcus minutus (Kütz.) Näg.		14							**1**	**0.13**
Chroococcus obliteratus P. G. Richter			25b				15a		**2**	**0.25**
Chroococcus pallidus (Näg.) Näg.				2, 24	22				**4**	**0.2**
Chroococcus sp.							1b		**1**	**0.13**
Chroococcus spelaeus Erceg.		12, 19						7	**3**	**0.23**
Chroococcus subnudus (Hansg.) Cronb. et Komárek			12				1b		**2**	**0.25**
Chroococcus varius A. Braun			21b	2, 23					**3**	**0.23**
Coleodesmium wrangelii ([C. Ag.] Born. et. Flah.) Borzì ex Geitl.				9					**2**	**0.13**
Cyanobacterium sp.			21b						**1**	**0.13**
Cyanosarcina sp.			21b						**1**	**0.13**
Cyanothece aeruginosa (Näg.) Komárek		14	12	2			15a		**4**	**0.5**
Dichothrix gypsophila (Kütz.) Born. et Flah.		8a, 12, 19	20	6, 9, 10, 23,			15a		**12**	**0.33**
Geitleribactron sp.							1b		**1**	**0.13**
Gloeocapsa biformis Erceg.				23					**1**	**0.13**
Gloeocapsa compacta Kütz.	12			2					**3**	**0.23**
Gloeocapsa fusco-lutea (Näg.) Kütz.							15a		**1**	**0.13**
Gloeocapsa kuetzingiana Näg.		8a, 12		2, 9, 10	12		26c		**10**	**0.2**
Gloeocapsa novacekii Komárek et Anagn.				23					**1**	**0.13**
Gloeocapsa ralfsii (Harvey) Kütz.				9, 10	3a			7	**5**	**0.28**
Gloeocapsa rupicola Kütz.				23					**1**	**0.13**
Gloeocapsa sanguinea (C. Ag.) Kütz.		21c		2, 10, 23			1b		**7**	**0.23**
Gloeocapsa tornensis Skuja							15a		**1**	**0.13**
Gloeocapsa violascea (Corda) Rabenh.				2, 6a, 9, 10, 23	12			7	**10**	**0.19**
Gloeocapsopsis magma (Bréb.) Komárek et Anagn.	21	12		2, 4, 6a, 23, 24, 26b			26c		**20**	**0.18**
Gloeocapsopsis pleurocapsoides (Nováč.) Komárek et Anagn.				24					**1**	**0.13**
Leptolyngbya cf. *gracillima* (Zopf ex Hansg.) Anagn. et Komárek			20	1a, 2					**6**	**0.32**
Leptolyngbya compacta (Kütz) Komárek		6b							**1**	**0.13**
Leptolyngbya foveolarum (Mont. ex Gom.) Anagn. et Kom.							5		**1**	**0.13**
Leptolyngbya gracillima (Zopf ex Hansg.) Anagn. et Kom.		19, 14	20	6a, 23, 24, 26b	22	16			**10**	**0.32**
Leptolyngbya sp.			21b						**1**	**0.13**

Leptolyngbya valderiana (Gom.) Anagn. et Komárek			11, 12						**2**	**0.13**
Merismopedia hyalina (Ehrenb.) Kütz.		12							**1**	**0.13**
Microcoleus autumnalis (Trev. ex Gom.) Strunecky et al.			4, 21b	2, 9, 21d, 24			1b, 5, 26c		**17**	**0.37**
Microcoleus vaginatus Gom. ex Gom.			20	9, 23					**2**	**0.25**
Nodosilinea bijugata (Kong.) Perkerson et Kovacik		19	21b	9	3a				**5**	**0.45**
Nostoc commune Vauch. ex Born. et Flah.	12	12, 19, 21c		2, 5, 23, 24	3a, 12			7	**19**	**0.3**
Nostoc sp.		19		2, 23		16	15a		**5**	**0.45**
Oscillatoria tenuis C. Ag. ex Gom.	12	14		1a	22	16			**6**	**0.56**
Petalonema crustaceum C. Ag. ex Kirchn.		14		2					**2**	**0.25**
Phormidiochaete nordstedtii (Born. et Flah.) Komárek				1a, 2, 6a, 10	3a		26c		**6**	**0.57**
Phormidium aerugineo-caeruleum (Gom.) Anagn. et Komárek							15a		**1**	**0.13**
Phormidium interruptum Kütz. ex Gom.			21b				8b		**2**	**0.25**
Phormidium sp.				2			1b		**2**	**0.25**
Phormidium uncinatum Gom. ex Gom.	21a		3b, 11, 17, 20, 25b			18	25a		**9**	**0.26**
Pseudanabaena frigida (Fritsch) Anagn.		12, 14	4, 21b				15a		**4**	**0.38**
Pseudanabaena minima (G. S. An) Anagn.		19	4, 21b		15b, 22		5		**7**	**0.47**
Rivularia biasolettiana Menegh.		8a							**1**	**0.13**
Schizothrix arenaria (Berk.) Gom.				23					**1**	**0.13**
Schizothrix simplicior Skuja					12		26c		**2**	**0.25**
Stigonema hormoides [Kütz.] Born. et Flah.	21								**1**	**0.13**
Stigonema informe Kütz. ex Born. et Flah.					3a				**1**	**0.13**
Stigonema minutum [C. Ag.] Hass. ex Born. et Flah.	13	12, 21c		2, 6a, 23, 26b					**12**	**0.21**
Stigonema ocellatum [Dillw.] Thur. ex Born. et Flah.				2, 23, 24		16			**8**	**0.16**
Tolypothrix distorta Kütz. ex Born. et Flah.	12	12	3b, 12						**4**	**0.33**
Tolypothrix fasciculata Gom.				23					**1**	**0.13**
Tolypothrix penicillata Thur. ex Born. et Flah.		19				16			**2**	**0.25**
Tolypothrix sp.		14		2					**2**	**0.25**
Tolypothrix tenuis Kütz. ex Born. et Flah.			21b	23					**2**	**0.25**
Tolypothrix tenuis Kütz. f. *terrestris* J. B. Petersen			21b						**1**	**0.13**
Trichocoleus delicatulus (W. West et G.S. West) Anagn.				2			15a		**2**	**0.25**
Trichocoleus sociatus (W. West et G. S. West) Anagn.				2					**1**	**0.13**

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

The second groups of species (*Aphanothece castagnei*, *Chroococcus cohaerens*, *C. varius*, *Gloeocapsa kuetzingiana*, *G. ralfsii*, *G. sanguinea*, *G. violascea*, *Microcoleus vaginatus*, *Stigonema minutum*, *Tolypothrix tenuis*, *T. fasciculata*, *Dichothrix gypsophila*) can grow in habitats with low but not extreme low illumination.

The third group (*Phormidiochaete nordstedtii*, *Phormidium interruptum*, *Stigonema informe*, *Pseudanabaena frigida*) of species can be detected in habitats with middle illumination. Probably other species do prefer high illumination.

The smallest width of ecological niche (NB = 0.13) was typical for most species (28). *Phormidiochaete nordstedtii* (0.57), *Oscillatoria tenuis* (0.56) and *Cyanothece aeruginosa* (0.5) had the widest ecological amplitudes – these species had the greatest ecological flexibility in the studied habitats. High values of NB are showed *Chamaesiphon polonicus, Pseudanabaena minima* (0.47), *Ammatoidea normannii* (0.46), *Nodosilinea bijugata* (0.45).

Among 28 taxa common for three floras Innvika area, west part of Oscar II Land (Davydov 2016) and Pyramiden area (Davydov 2014) for some species there were brought out some similarity of NB values. For *Aphanothece castagnei*, the average value was 0.13, for *Chroococcus pallidus* – 0.21, for *C. spelaeus* – 0.2, for *C. subnudus* – 0.18, for *Gloeocapsa kuetzingiana* – 0.18, for *G. sanguinea* – 0.26, for *G. violascea* – 0.19. The objective characteristics of species can be prepared after the obtaining of more significant number of data.

Innvika area and Rijpfjorden east coast are located in a short distance, but the comparison of Innvika and Rijpfjorden flora shows a small similarity (35%, Fig. 4). Reasons for the differences are explained by the diversity and mosaic of geology complexes. Most similar are the flora of the Innvika area and flora of the west part of Oscar II Land (61%). This is probably related to the study mountainous areas slopes and crests of flora of Oscar II Land. Conditions on the tops of the mountains at altitudes above 500 meters above sea level in the southern parts of Spitsbergen form polar deserts.

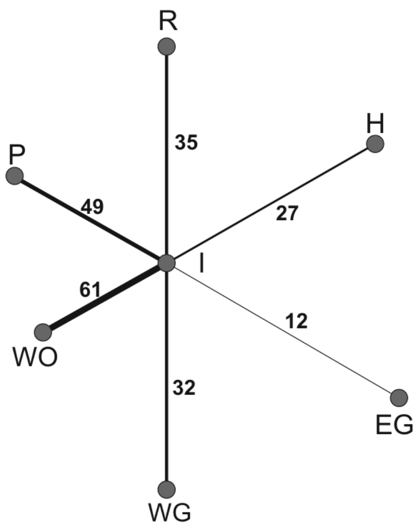

Fig. 4. Complete graph of similarity of cyanoprokaryotes flora in some areas on Spitsbergen (Sørensen index, for the clustering was used the mean distance between elements of each cluster, weighted pair-group method using arithmetic averaging, numbers on ridges are similarity in percent). EG – Grønfjorden east coast (Davydov, 2008), H – Revelva valley (Matuła et al., 2007), I – Innvika cove, 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 (Davydov, 2016).

Conclusions

The cyanoprokaryotes flora in polar desert of the Innvika area is rich and diversified, being the evidence of numerous ecological niches, where individual species find favorable conditions for their development. The middle position among the habitats is occupied by seepages. Here the rock species as well as species inhabiting streams and pools were found, *i.e.* they are suitable for many species. The results of this study suggest that most species of study area do prefer high illumination conditions. A few species should be considered indifferent to illumination.

Nine species are first time records for Spitsbergen flora. Innvika area flora and flora of the west part of Oscar II Land are mostly similar.

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