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**BIOINDICATION OF THE WATER SALINITY DYNAMICS  
BY THE MICROALGAE COMMUNITIES  
IN THE LENA RIVER DELTA, LAPTEV SEA, RUSSIAN ARCTIC**

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The Lena River in the Laptev Sea forms a vast delta, one of the largest in the world. The Ust-Lensky State Nature Reserve saves biodiversity on the Lena Delta territory beyond the Arctic Circle, in the zone of continuous permafrost. In recent years, large-scale plans for the development of extractive industries are implemented in this Russian Arctic sector. In this regard, the study of biodiversity and bioindication properties of aquatic organisms in the Lena River estuary area is becoming more and more relevant. This study aims to identify the species composition of microalgae in lotic and lentic water bodies of the Lena River Delta and use their indicator property for water salinity. It was a trace indicator of species distribution over the delta and their dynamics along the delta main watercourses to assess the impact of river waters on the Laptev Sea coastal areas. For this, all previously published materials on algae and chemical composition of the region waters as well as data obtained in recent years for the waters of the lower Lena reach were involved. In total, 700 species considered to 10 phyla were analyzed: Cyanobacteria (83), Euglenozoa (13), Ochrophyta (Chrysophyta, Xanthophyta) (41), Eustigmatophyta (4), Bacillariophyta (297), Miozoa (20), Cryptophyta (3), Rhodophyta (1), Chlorophyta (125), and Charophyta (111). The available materials of the field and reference observations were analyzed using several statistical methods. The study results indicate that hydrological conditions are the main factor regulating the spatial structure of the species composition of the microalgae communities in the Lena River Delta. The distribution of groups of salinity indicators across flowing water bodies reflects the effect of water salinity, and this allows suggesting possible sources of this effect. The mechanism of tracking the distribution of environmental indicators itself is a sensitive method, that reveals even their subtle changes in them; therefore, as an integral method, it can be helpful for further monitoring.

**Keywords:** large river, delta, algae, bioindication, statistical mapping, Lena River, Russian Arctic

In terms of their role as natural “recorders” of global environmental changes (Bianchi & Allison, 2009), the ecosystems of the deltas of large rivers, such as the Lena, are recognized important for study. In the estuary, the Lena River forms a delta with an area of 30 thousand km<sup>2</sup>, the third among the most significant river deltas globally and the first on the territory of Russia (Bol’shiyanov et al., 2013). The Lena River lower reaches and the Laptev Sea coastal areas are protected by the Ust-Lensky State Nature Reserve and the most significant Russian biosphere reserve Lena Delta with more than 60 thousand km<sup>2</sup>. The regional water bodies are located beyond the Arctic Circle, north of 71°N, in the zone of continuous

occurrence of permafrost soils, where ephemeral water bodies are widespread in the absence of drainage: streams and hollows. The region is rich in marshes and lakes typical of the Arctic tundra. In the Lena River lower reaches, as in the lower reaches of other large Arctic rivers, large mixing of freshwater and salt water occurs, where so-called marginal zones can form. Recently, an increase in the activity of industrial development of the region has been noted. In 2017, “Rosneft” oil company started seismic exploration on the Laptev Sea shelf. Therefore, the anthropogenic load here increased. Under these conditions, the urgency of maintaining the biodiversity of aquatic ecosystems in the region rises, especially in the marginal zone, where the role of ecotones is very significant, as proven by several researchers (Schilthuizen, 2000 ; Smith et al., 1977). Large rivers, such as the Lena, flowing in the meridional direction, are natural channels for advancing southern species to the North. Such invasive species can thus replenish the flora of the Lena River Delta and coastal areas. Besides, estuarine areas of large rivers are not only biodiversity reserves but also areas of speciation processes (Popa et al., 2016).

Data on algae in water bodies in the Lena River estuary were published in several works. The deposited manuscript of I. Vasil'eva and P. Remigailo contains the first species list for the Lena River lower reaches, comparative floristic analysis of algae, and information on saprobiological state of water bodies in the region (Vasil'eva & Remigailo, 1986). Some data on the species composition of the region algae are presented in the reports of the Tiksin Territorial Administration for Hydrometeorology and Environmental Monitoring (Pavlyukova, 1993a, b), as well as in the references on algae of the Laptev Sea (Druzhkova & Makarevich, 2013 ; Gogorev, 1994 ; Okolodkov, 1998, 1992 ; Sukhanova et al., 2017 ; Timofeev, 1998 ; Zernova et al., 2000). The information available concerns mainly plankton and to a small extent moss pomace. Despite a long history of algological studies, there is no generalization and analysis of the material accumulated. The available data were summarized to analyze the taxonomic composition and spatial structure for the microalgae communities in the lower Lena (Gabyshev et al., 2019a). A species list of algae was published (Gabyshev et al., 2019b) as part of a regional analysis of the climatic gradient effect on algae communities (Barinova et al., 2015, 2014). Data on the physicochemical characteristics of the lakes in the Lena River lower reaches are given in the works of T. Trofimova (2013a ; 2013b).

The work is aimed at assessing the impact of river waters on the coastal sea areas of the Laptev Sea. For this, the species composition of the microalgae communities in lotic and lentic water bodies of the Lena River Delta was identified, in order to determine the species – indicators of water salinity, as well as to trace their spatial distribution over the delta flowing and standing waters and their dynamics along the delta main waterways.

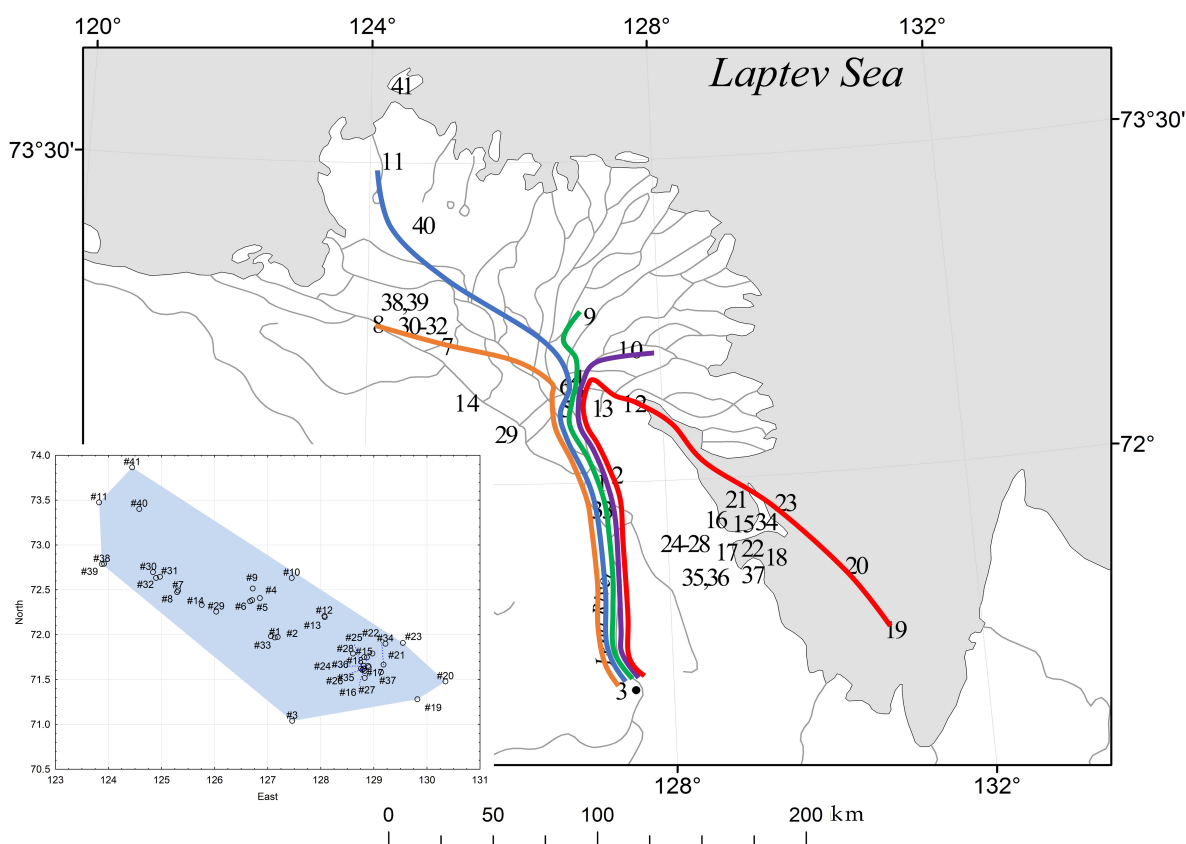
## MATERIAL AND METHODS

The material comes from phytoplankton samples collected in September 2009 in the Lena River (area of Tit-Ary Island) and in August – September 2014 in the Tiksi Bay and Neelova Gulf of the Laptev Sea, as well as in the lakes of the Tiksi Bay and Neelova Gulf and in the Olenyokskaya delta channel, at 41 stations in total. We also included floristic study data from recent references, where species of algae and cyanobacteria were revealed in the delta as mentioned above. Phytoplankton samples were taken using the Apstein plankton net (SEFAR NITEX gas, mesh size 30  $\mu\text{m}$ ) in the littoral and pelagic zones of water bodies from the surface water horizon (0–0.3 m). A total of 100 planktonic and 3 hydrochemical samples were collected; their processing was carried out at the Institute for Biological Problems of Cryolithozone of the Siberian Branch of the Russian Academy of Sciences. For the identification of diatoms, 70 permanent preparations were made by calcining the valves and placing them in a Bio Mount synthetic resin. Microscopic examination of preparations was carried out under microscopes “Laboval” and “Olympus BH-2” according to standard methods. Water chemical analyses followed the methods set out in (Alekin et al., 1973 ; Rukovodstvo po khimicheskomu analizu, 1977).

**Ionic constituents.** Sulfate anions were determined by turbidimetry; chlorides, by mercurimetry; hydrocarbonates, by back titration; water hardness, by complexometric titration using eriochrome black; calcium, titrimetrically with trilon B; and potassium and sodium cations, by flame photometry.

**Other chemicals.** Water pH was evaluated electrometrically using a Multitest IPL-101 titrator; phenols, by fluorimetric method using a Flyuorat-02 fluorimeter.

The investigated territory was conditionally divided into five hydrologically homogeneous areas in accordance with their position on the land and hydrological and morphometric features of water bodies (Fig. 1). The Lena River lower reach (st. 1–6) (LowLenaRiv) included a stretch of the Lena River from Chekurovka settlement to Stolb Island. The Lena River Delta (st. 7–14) (LenaDelta) united the main distributary channels (Olenyokskaya, Bol'shaya Trofimovskaya, Saardakhskaya, Arangastakhskaya, Bykovskaya, and Gusinka), as well as the Lena River near the Tyllakh River estuary and near Chay-Tumus location. The near-shore zone (st. 15–23) represented the Laptev Sea coastal areas (Neelova Gulf, Tiksi Bay, and Buor-Khaya Gulf) and the freshened part adjacent to the delta. A separate group (Lakes, st. 24–32) included nine lakes of glacial, water-erosion, erosion-thermokarst, and river origin, located along the shores of the Tiksi Bay, Neelova Gulf, and Olenyokskaya distributary channel. Samples from moss pomace, tundra swamps, mountain streams, and hollows of the shores of the Tiksi Bay, Kosistyy Cape, Bykov Peninsula, spurs of the Kharaulakh Range, Tit-Ary Island, Danube (Danube Island), and Erga-Muora-Sise (Erge-Muora-Sise) were united in the swampy area group (st. 33–41) (SwampAreas). Five waterways were identified for the passage of the river along the Lena Delta, indicated by colored lines in Fig. 1.



**Fig. 1.** Location of sampling stations on the Lena River Delta. Waterways are marked with colored lines. Sampling points are shown on the statistical map below in coordinates

**Рис. 1.** Расположение станций отбора проб в дельте реки Лена. Водные пути отмечены цветными линиями. Точки отбора проб показаны на статистической карте ниже в координатах

The ecological preferences of the identified species based on the indication of water salinity (Barinova, 2017a) were determined using a database of algae indicators compiled at the Institute of Evolution, University of Haifa (Barinova et al., 2019, 2006).

Environmental mapping was carried out in the Statistica 12.0 program according to each site parameter values and geographic coordinates. Calculation of similarity was made as the network analysis in JASP (significant only) on the botnet package in R Statistica package of (Love et al., 2019). A similarity tree was constructed with the help of BioDiversity Pro 9.0 program.

## RESULTS

According to the results of our research for the period 2009–2014 at 41 stations and the reference data, 700 species and varieties of microalgae belonging to 10 taxonomic divisions were identified: Cyanobacteria (83), Euglenozoa (13), Ochrophyta (Chrysophyta, Xanthophyta) (41), Eustigmatophyta (4), Bacillariophyta (297), Miozoa (20), Cryptophyta (3), Rhodophyta (1), Chlorophyta (125), and Charophyta (111). All of them turned out to be salinity indicators belonging to five ecological groups (Table 1).

**Table 1.** Sampling stations on the Lena River Delta with their numbers, GPS coordinates, and the numbers of salinity indicators in ecological groups. Abbreviations: hb – halophobes; i – oligohalobes-indifferents; hl – oligohalobes-halophiles; mh – mesohalobes; eh – euhalobes (marine)

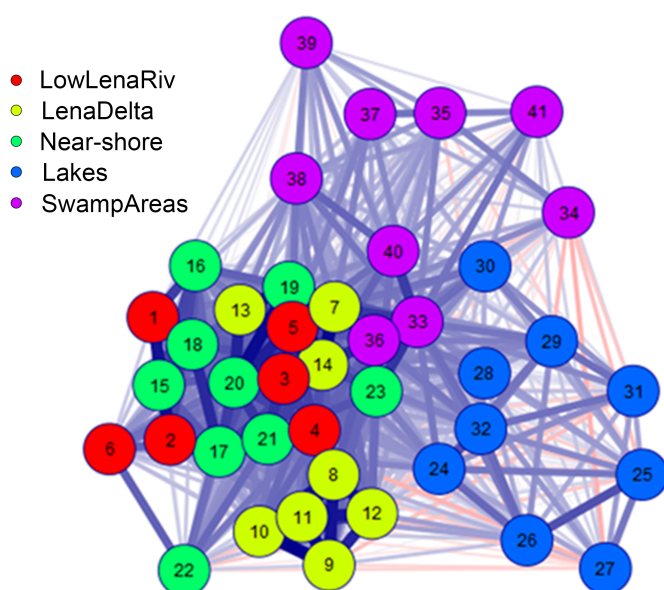
**Таблица 1.** Станции отбора проб в дельте реки Лена с указанием их номеров, GPS-координат и количества индикаторов солёности в экологических группах. Аббревиатуры: hb — галофобы; i — олигогалофы-индифференты; hl — олигогалофы-галофилы; mh — мезогалофы; eh — эвгалофы (морские)

Station	No.	North	East	hb	i	hl	mh	eh
Left bank of a river near Tit-Ary Island	1	71°58'8.2305"	127°8'8.0607"	0	39	7	0	0
Right bank of a river across Tit-Ary Island	2	71°58'27.8234"	127°11'23.6213"	2	41	5	2	0
Left bank of a river near Chekurovka settlement	3	71°02'20.36"	127°27'41.28"	0	10	2	0	0
Near Stolb Island	4	72°24'30.19"	126°51'15.45"	1	37	5	0	0
Near Khokhochu location	5	72°22'22.23"	126°40'09.45"	0	9	1	0	0
Near Stolb Station	6	72°23'6.1677"	126°42'30.0957"	9	128	20	3	0
Gusinka distributary channel	7	72°29'32.30"	125°18'43.96"	0	9	0	0	0
Olenyokskaya distributary channel	8	72°28'26.80"	125°17'44.05"	0	26	6	0	0
Bol'shaya Trofimovskaya distributary channel	9	72°30'51.21"	126°43'03.84"	1	42	9	0	0
Saardakhskaya distributary channel	10	72°37'56.57"	127°27'12.84"	1	37	9	1	0
Arangastakhskaya distributary channel	11	73°28'30.07"	123°49'30.61"	0	19	5	0	0
Bykovskaya distributary channel	12	72°12'33.89"	128°04'05.64"	2	46	11	0	0
Near Tyllakh River estuary	13	72°11'45.26"	128°04'32.04"	1	16	2	1	0
Chay-Tumus location	14	72°19'53.36"	125°45'25.84"	0	5	1	0	0
Neelova Gulf. Area of the abandoned water intake, 16–17 km from Tiksi-1	15	71°44'57.51"	128°49'6.89"	5	58	7	1	0
Neelova Gulf. Oil depot area, 16–17 km from Tiksi-1	16	71°44'48.0754"	128°52'12.1512"	2	47	5	1	0
Tiksi Bay. River port area	17	71°39'06.92"	128°53'34.82"	0	26	8	1	0
Tiksi Bay. District 400 m southwest of River port	18	71°38'15.23"	128°54'20.21"	2	22	5	0	0
Littoral part of Buor-Khaya Gulf	19	71°16'49.03"	129°49'13.20"	0	11	1	1	0
Seaward part of Buor-Khaya Gulf	20	71°28'40.08"	130°20'59.69"	1	20	4	1	0

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Station	No.	North	East	hb	i	hl	mh	eh
Neelova Gulf	21	71°47'26.36"	128°58'25.53"	0	31	5	1	0
Tiksi Bay	22	71°39'56.63"	129°11'01.62"	11	145	20	13	2
Fresh part of the Laptev Sea	23	71°54'27.78"	129°32'51.89"	0	2	1	0	0
Melkoye (in the vicinity of Tiksi Bay)	24	71°39'4.46"	128°48'27.57"	2	21	5	0	0
Dirin-Kyuyel (vicinity of Tiksi Bay)	25	71°36'23.43"	128°47'2.29"	0	15	5	0	0
Vtoroye (vicinity of Tiksi Bay)	26	71°37'10.75"	128°48'24.48"	0	9	2	1	0
Sevastyan (vicinity of Tiksi Bay)	27	71°31'3.03"	128°49'37.40"	1	8	1	0	0
Ladannakh (vicinity of Neelova Gulf)	28	71°47'21.09"	128°36'28.86"	2	28	0	0	0
Vulkan (Olenyokskaya distributary channel)	29	72°15'20.97"	126°1'51.73"	1	15	0	0	0
Lyglay (Olenyokskaya distributary channel)	30	72°41'50.23"	124°50'18.33"	1	15	1	0	0
Kuogastaah (Olenyokskaya distributary channel)	31	72°37'57.75"	124°53'49.93"	3	11	1	0	0
Batyylaakh (Olenyokskaya distributary channel)	32	72°38'42.93"	124°58'15.08"	3	14	2	0	0
Tit-Ary Island	33	71°59'00.76"	127°03'43.15"	0	0	0	0	0
Bykov Peninsula	34	71°53'53.59"	129°13'06.90"	11	32	3	0	0
Kharaulakh Range	35	71°37'18.61"	128°45'33.75"	1	8	0	1	0
Depression of the tundra surface by a tracked vehicle	36	71°35'46.39"	128°49'34.14"	1	6	0	0	0
Kosistyy Cape	37	71°34'57.56"	129°08'06.93"	3	13	0	0	0
Flarks	38	72°47'14.33"	123°52'38.34"	3	17	1	3	0
Water from mosses	39	72°47'25.77"	123°55'04.31"	0	13	0	0	0
Erge-Muora-Sise Island	40	73°24'05.74"	124°34'53.14"	0	1	1	2	0
Danube Island	41	73°51'55.51"	124°26'50.24"	1	6	0	0	0

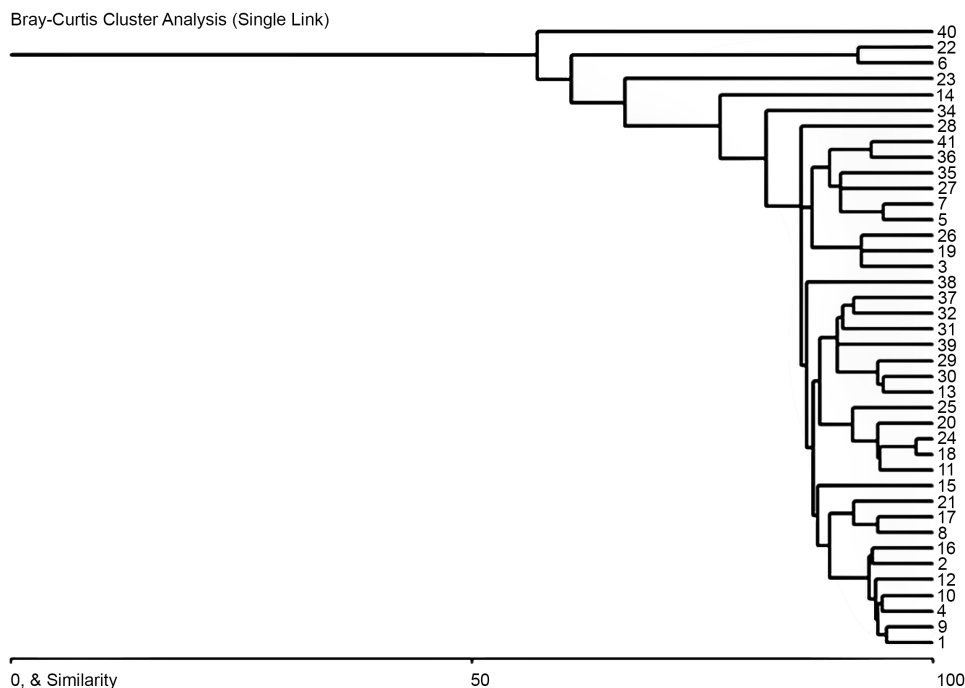
In order to reveal the internal connections in the microalgae communities studied, we applied a statistical approach to calculating the correlation in the analysis of JASP at a similarity level of more than 50 %. The network graph, for which we divided the communities by hydrological similarity into five groups, showed that the most similar were the communities of flowing waters in the river itself and its delta (Fig. 2). This group also included the community of the near-shore zone. The communities of lakes and swamps, on the other hand, formed two separate clusters, which had little resemblance both to flowing waters and to each other.



**Fig. 2.** Correlation graph of JASP for the species composition of communities at the stations of the Lena River Delta. Hydrologically homogeneous stations of five groups are marked with different colors in the legend

**Рис. 2.** График корреляции JASP для видового состава сообществ на станциях дельты реки Лена. Гидрологически однородные станции пяти групп выделены разными цветами в легенде

The similarity tree of the composition of salinity indicators, according to Bray – Curtis (Fig. 3), showed a high percentage of similarity for the entire dataset. However, the analysis made it possible to identify the communities of st. 40, where mesohalobes made up 50 %, as well as st. 6 and 22, where the species richness in general and, respectively, the number of indicator species were the highest since the communities of these stations were the most well studied. This result requires further expansion of the analysis of the indicator species composition.



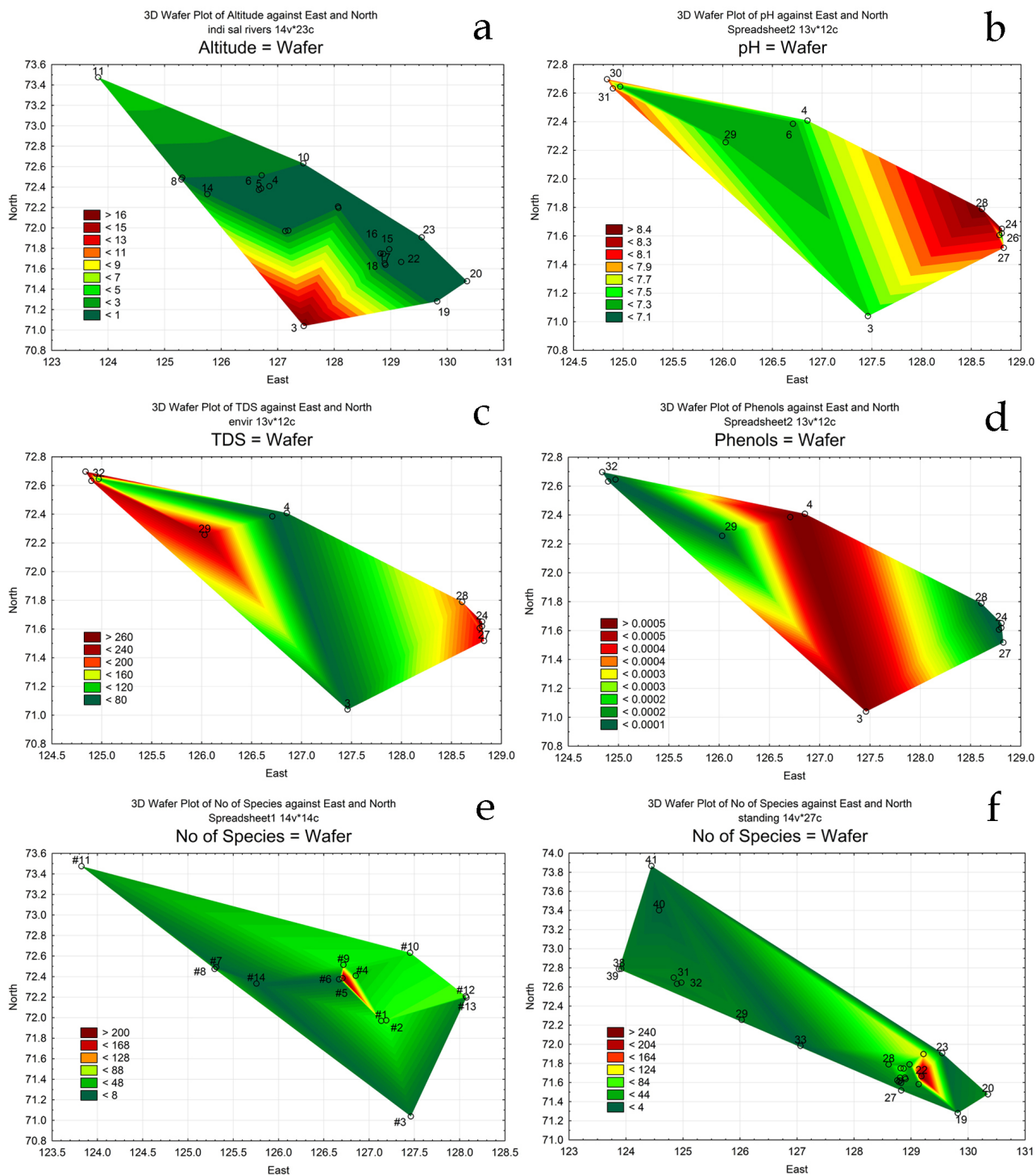
**Fig. 3.** Similarity tree of the composition of salinity indicators according to Bray – Curtis at the stations of the Lena River Delta

**Рис. 3.** Дерево подобию состава видов — индикаторов солёности по Брей — Кёртису на станциях в дельте реки Лена

Statistical maps were constructed to clarify the distribution of indicator species and environmental variables (Figs 4 and 5). Fig. 4a shows that the distribution of stations located in the flowing area of the delta only, which have a specific gradient in their altitude above the sea level, turned out to be adequate to the river relief in the investigated area and its delta. Statistical maps reflect the accurate distribution of variables on our material and can be used for further analysis. The distribution of pH values (Fig. 4b) shows increasing, when the stations are located near the coast or on the desalinated sea area in the Tiksi Bay vicinity. This distribution indicates a significant effect of the river water on the sea since seawater is always alkaline.

The distribution of total dissolved solids reveals increased concentrations in the delta lakes in the east and west, while the central part of the delta appears fresher on the map (Fig. 4c). Phenols are a natural component of freshwaters, and they are usually associated with the least saline waters (Barinova, 2017b). The distribution map of phenol concentrations turns out to be similar to the distribution map of the total mineralization, only in the opposite sense. The most phenol-saturated waters are located at the extension of the main river channel (Fig. 4d).

The distribution of taxonomic richness in the communities of the stations of lotic (Fig. 4e) and lentic waters (Fig. 4f) of the study area shows a significant homogeneity of distribution with protruding points of the most accessible and, accordingly, the most well studied st. 6 and 22.



**Fig. 4.** Statistical maps of the distribution of variables of the environment and microalgae communities over the area of the Lena River Delta: a – distribution of stations altitude only for watercourses in the delta; b – distribution of water pH; c – distribution of total dissolved solids; d – distribution of phenols; e – distribution of the number of algal species in the communities of lotic stations; f – distribution of the number of algal species in the communities of lentic and coastal areas of the sea stations

**Рис. 4.** Статистические карты распределения переменных среды и сообществ микроводорослей по территории дельты реки Лена: а — распределение высот станций только для водотоков в дельте; б — распределение pH воды; в — распределение общего количества растворённых частиц; д — распределение фенолов; е — распределение количества видов водорослей в сообществах лотических станций; ф — распределение количества видов водорослей в сообществах лентических станций и прибрежных участков морских станций

The distribution of the percentage composition of salinity indicators over the delta area is shown in Fig. 5. Since the importance of hydrology for the distribution of the microalgae communities in the study area was previously revealed, we divided the data on the composition of salinity indicators for 41 sites into groups related to rivers and channels (st. 1–22) and to lakes and swamps (st. 23–41).

Fig. 5 shows the pairwise distribution of the same groups of indicators in lotic and lentic waters. Thus, oligohalobes-indifferents in lotic waters were better represented in the river itself and its western channels (Fig. 5a). Simultaneously, this indicator taxa group was more noticeable in lakes and swamps along the delta margins but not near flowing waters (Fig. 5b). Halophiles in river waters were concentrated on the east coast (Fig. 5c). In contrast, two different points were noted for lentic waters in the west and east, where this group of salt-tolerant species predominated in the communities (Fig. 5e). Mesohalobes were concentrated in flowing waters in the Tiksi area (Fig. 5f). The distribution of these indicators of increased salinity for lentic waters coincided with the distribution of halophiles west of the delta (Fig. 5f).

The distribution of groups of salinity indicators along waterways in the Lena River Delta was studied in the dynamics of indicator species of various ecological groups, as was done earlier for the Nile Delta (Salem et al., 2017). Thus, stations were located in the order of water flow, starting from st. 3 on the river itself, the southern point, then, on each of the paths along their channel, and further, continuing along the desalinated sea area as the stations move away if any (Fig. 6). The scale of salinity indicators on each graph is located as the indicated variable (salinity) increases. It includes all groups, regardless of whether indicators are present in waterway communities or not.

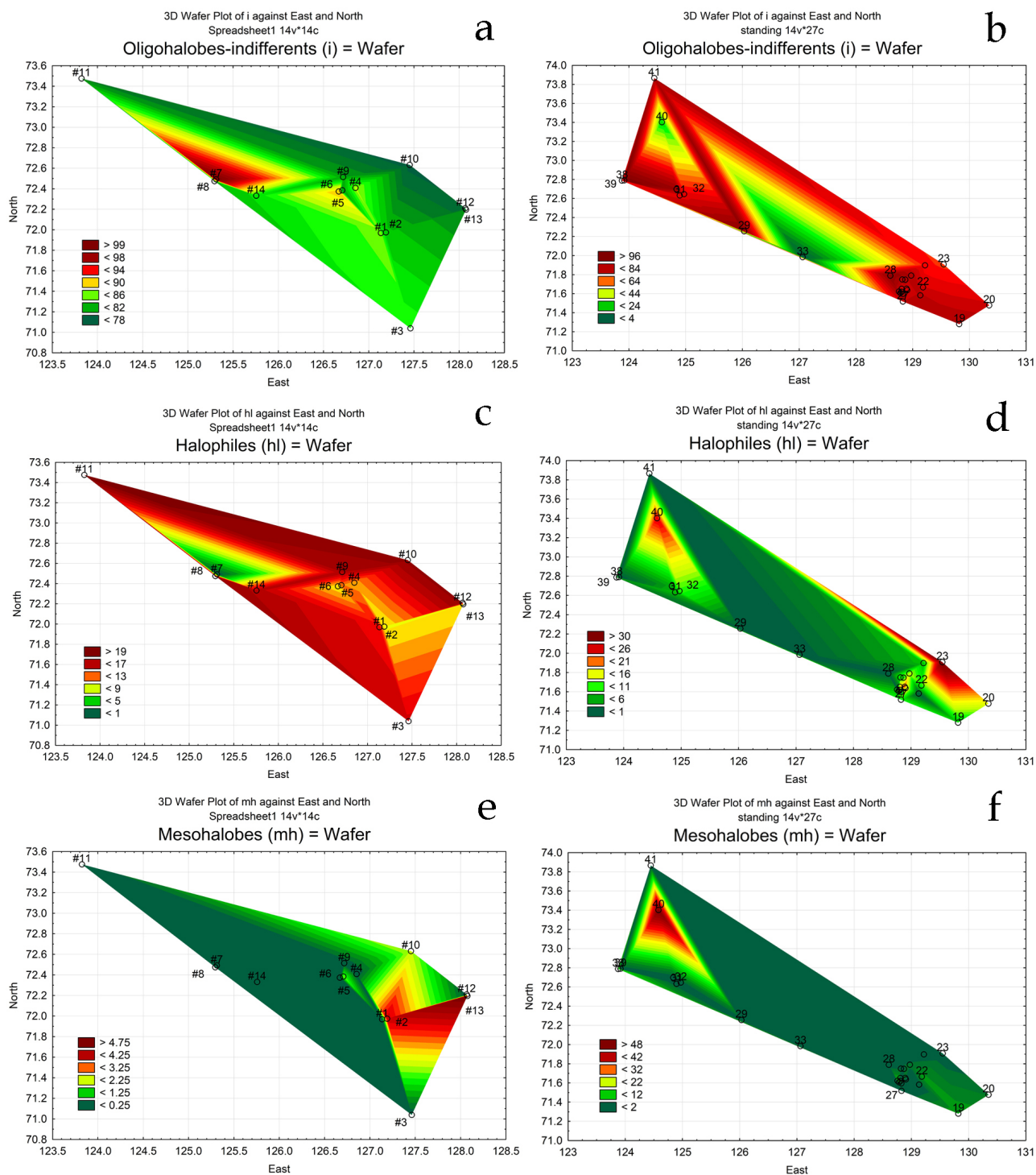
The waterway through the Bykovskaya channel is the most saturated with stations (17) and the most well studied (Fig. 6a). The number of species has two peaks – at st. 6 (Near Stolb Station) and st. 22 (Tiksi Bay) – where the microalgae communities are most explored due to sampling stations availability. The trend line shows first an increase in species richness along the river and then a decrease in the number of species as it approaches the coast and at sea. The trend in the number of species is maximum where the percentage of halophiles + mesohalobes decreases: at st. 15 and 16 in the Neelova Gulf. There is a poorly expressed participation of euhalobes and a noticeable increase in mesohalobes closer to the coast and in the desalinated sea area. The sum of the percentages of halophiles + mesohalobes in the community has a noticeable rise towards the coast reflecting the sea effect.

In the communities of waters flowing through the Bol'shaya Trofimovskaya channel, euhalobes, marine species, are not identified (Fig. 6b). Mesohalobes are weakly involved. There is a noticeable increase in the percentage of oligohalobes-halophiles towards the coast. The number of species has the same peak at st. 6, and the trend in the number of species shows a rise in species richness towards the coast.

In the communities of waters flowing through the Olenyokskaya channel, euhalobes do not participate, mesohalobes are weakly involved, and an increase in the percentage of oligohalobes-halophiles is also weakly expressed (Fig. 6c). The number of species is the same as at Bykovskaya, the maximum is at st. 6, but it significantly decreases towards the coast and the sea. In the communities of waters flowing through the Saardakhskaya channel, euhalobes also do not participate, mesohalobes are weakly involved, and there is a noticeably stable increase in the percentage of oligohalobes-halophiles on approaching the coast (Fig. 6d). The number of species follows the distribution along the riverbed. The trend in the number of species shows an increase when approaching the coast.

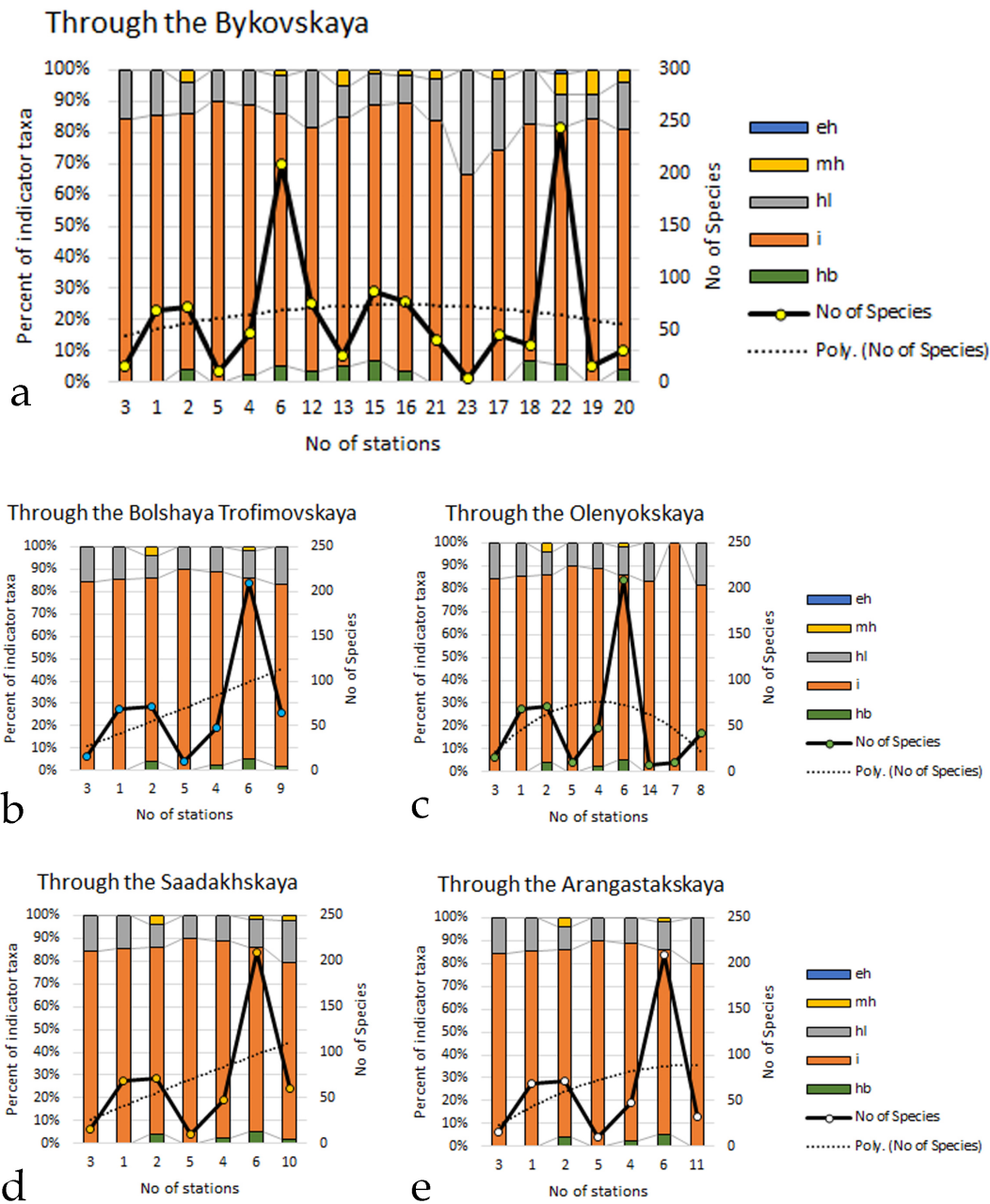
There are no euhalobes in the waters flowing through the Arangastakhskaya channel, mesohalobes are weakly involved, and a noticeable increase in the percentage of oligohalobes-halophiles is recorded (Fig. 6e). In other waterways, most of which are represented by the riverbed, st. 6 has maximum species richness. However, the trend in the number of species indicates its increasing towards the coast.





**Fig. 5.** Statistical maps of the distribution of the number of salinity indicator species over the Lena River Delta area: a, c, e – for lotic waters; b, d, f – for lentic waters

**Рис. 5.** Статистические карты распределения количества видов — индикаторов солёности в районе дельты реки Лена: а, с, е — для проточных вод; б, д, f — для непроточных вод



**Fig. 6.** Histograms of the distribution of salinity indicator species along waterways of the Lena River Delta (see explanation in the text)

**Рис. 6.** Гистограммы распределения видов — индикаторов солёности вдоль водотоков дельты реки Лена (см. объяснение в тексте)

DISCUSSION

A statistical analysis of the similarities revealed hydrology as a regulating factor for the composition of the microalgae communities in the Lena River Delta habitats studied. The species composition of algae in the main channel of the Lena River has a high degree of similarity with the composition of the communities of the lower river delta and the coastal area of the sea into which the river flows. This result is understandable since, along with the river runoff, the river microflora is also carried to the coastal sea area, which significantly affects the formation of the microalgae communities in the Neelova Gulf, Tiksi Bay, and Buor-Khaya Gulf.

The identified low-mineralized area of the delta (see Fig. 4c) is a continuation of the river main channel. It can be assumed that the freshwater outflow shows the paleochannel of the river since the sea level fluctuation in this area reaches 1.5 meters, and the elevation gradient on the delta is 0–4 m. Simultaneously, salinity is higher in the west and northwest (10–14 and 8–10 ‰, respectively) (Bol'shiyanov et al., 2013).

Even though the concentrations of natural phenols in the delta waters have a gradient at the lowest level, practically at the boundary of determination, this gradient does exist (Fig. 4d). It can be suggested that, along with the distribution of total dissolved solids gradient, it may indicate the direction of river water outflow.

The statistical map, as a method tested on communities of continental and coastal marine ecosystems (Barinova, 2017c) and recommended for use in EU countries (Dedić et al., 2020), allows revealing hidden trends by the dynamics of the mapped indicators. Maps can reveal otherwise undetectable connections in ecosystems. Thus, statistical maps of the distribution of salinity indicator groups in the Lena River Delta allowed us to identify two trends. The communities of flowing waters react to approaching the coast by increasing the proportion of indicators of chloride increased concentrations (Barinova, 2017b). Salinity indicators in lakes and swamps show that they have local natural sources of chlorides in the west of the delta, on the one hand, and one can assume the effect of salt mists, on the other (Barinova & Stenina, 2013).

We identified waterways through the channels, which begin from the Lena River main channel, to trace salinity effect on the flowing water communities.

The different degree of floristic study, which reveals the maximum number of species on the sites most accessible for research, was the problem for calculation. There, severe climatic conditions, undeveloped landscape, and the lack of infrastructure affect the number of indicator taxa. We tried to remove this effect by calculating the percentage of participation of different group indicators for each community. It turned out that, despite the differences in the total number of species, the indicators show a rise in the proportion of groups of increased salinity as the river approaches the coast in each waterway, as it was revealed for the Nile River Delta waterways (Salem et al., 2017). The most well studied Bykovskaya channel and its surroundings have marine species in their communities since we continued the line of stations towards the sea.

Nevertheless, communities even in the desalinated coastal area contain most freshwater indicators found higher in this waterway. This result indicates the real effect of the channel water on the desalinated sea area. However, other waterways did not have marine species in the communities but showed an increase in the percentage of halophilic species, although their terminal stations (st. 9, 10, and 11) were at some distance from the seacoast. It can be attributed to both the effect of tides, which reach 1.5 meters in this area of the Laptev Sea (Bol'shiyanov et al., 2013), and extremely low delta elevation gradient. Possible influence of salt mists was revealed in another Arctic coastal reserve (Barinova & Stenina, 2013) by indicator species of algae.

**Conclusion.** The study shows that hydrology is a factor regulating the species composition of the microalgae communities in the Lena Delta. The distribution of groups of salinity indicators along flowing streams shows the effect of water salinity and suggests possible sources of this effect. The mechanism of tracking the dynamics of salinity by distributing algae-indicators became a sensitive method that reveals even subtle changes in environmental variables. Therefore, as an integral method, it can be helpful in further monitoring.

#### Highlights:

1. Correlations revealed hydrology as the primary regulator factor for the microalgae communities in the Lena River Delta area.
2. Indicators of water quality in the Lena Delta communities are represented by 700 taxa.

### 3. Gradient of salinity in the delta is revealed by statistical mapping and dynamics of salinity indicators across the main river flows.

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## БИОИНДИКАЦИЯ ДИНАМИКИ СОЛЁНОСТИ ВОД ПО СООБЩЕСТВАМ ВОДОРΟΣЛЕЙ В ДЕЛЬТЕ РЕКИ ЛЕНА, МОРЕ ЛАПТЕВЫХ, РОССИЙСКАЯ АРКТИКА

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Река Лена, впадая в море Лаптевых, образует обширную дельту, одну из крупнейших в мире. Весь эстуарий, включая приморский участок, входит в состав Усть-Ленского государственного природного заповедника. Территория расположена за Полярным кругом, в зоне сплошной вечной мерзлоты. В дельте есть многочисленные русла и множество мелких водоемов — озёр, ручьёв, котловин, болот. Изучение экосистем дельт крупных рек имеет особое значение из-за их роли в качестве естественных «регистраторов» глобальных изменений окружающей среды. Когда большие реки впадают в море, в зоне смешения морской и пресной воды образуются особые экотонические сообщества водных организмов, которые могут играть важную роль в поддержании биоразнообразия регионов. Несколько лет назад в этом российском секторе Арктики началась реализация масштабных планов по развитию добывающих отраслей. В связи с этим всё более актуальными становятся исследование биоразнообразия и изучение биоиндикационных свойств водных организмов в районе устья реки Лена. Целью данной работы было определить видовой состав водорослей проточных и непроточных водоёмов дельты реки Лена и использовать их свойства как индикаторов солёности воды. Чтобы оценить влияние речных вод на прибрежные участки моря Лаптевых, необходимо проследить распространение видов-индикаторов по дельте и их динамику по основным её водотокам. Для этого были использованы все ранее опубликованные сведения по водорослям и химическому составу вод региона, а также данные, полученные для вод нижнего течения Лены за последние годы. Имеющиеся материалы натурных наблюдений проанализированы с применением нескольких статистических методов. Результаты исследования свидетельствуют о том, что гидрологические условия являются основным фактором, регулирующим пространственную структуру видового состава водорослевых сообществ дельты реки Лена. Распределение групп индикаторов солёности по проточным водоёмам отражает влияние солёности воды, что позволяет предположить, каковы возможные источники этого влияния. Сам механизм отслеживания распределения показателей среды — это чувствительный метод, который выявляет даже незначительные их изменения, поэтому он, как интегральный метод, может быть полезен для дальнейшего мониторинга.

**Ключевые слова:** большая река, дельта, водоросли, биоиндикация, статистическое картографирование, река Лена, Российская Арктика