ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Comparative Analysis Of Ecological State Of Winter And Summer Phytoplankton In Drainless Mesotrophic Lake (Altai Krai, Russia).

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ABSTRACT

The investigation findings are of interest in the fundamental hydrobiological studies and new methodological approaches to the phytoplankton ecological state assessment. In mesotrophic-eutrophic lake the active vegetation of plankton algae was revealed at the end of winter under snow (0.13-0.34 m) and ice (0.56-0.70 m) layers at water temperature of 0-4.5 °C along the water column (6 m depth). The winter phytoplankton involved species from Chlorophyta, Bacillariophyta, Euglenophyta, Dinophyta, Cryptophyta, Ochrophyta and Cyanobacteria. The maximum abundance and biomass are due to passive plankters, incapable of active phototaxis from *Microcystis, Gomphosphaeria, Chroococcus, Anabaena, Gloeocapsa, Cyanothece, Monoraphidium, Scenedesmus, Dictyosphaerium* and *Hyaloraphidium* genus. In the ice cover period, the species number reaches 52-56, the abundance – 26.4-1056.0 th. cells/l, biomass – 0.2-12.2 g/m^3, the chlorophyll *a* concentration – 1.8-24.1 mg/m^3. Although these characteristic values appeared to be high for the cold period (at low temperature and insufficient light), they were lower than in the summer season (more than 100 species, 0.11-1.74 mln. cells/l, 0.64-18.16 g/m^3 and 27.49-83.40 μg/m^3, respectively). It is noted that algae growth in winter period was limited by the depth of snow cover, but not of the ice. Water temperature affects the species composition and chlorophyll a concentration, but not the algae abundance and biomass. The microscopic method results for determining the plankton algae concentration were compared with the non-contact methods of investigation (spectrophotometric method of light attenuation recording). The assumption that since algae photosynthesis is most active in the blue (wavelength is 400-460 nm) and red (670-800 nm) spectral zones, the absorption of these light waves will be maximum, was confirmed by experimental data. The trend of increasing algae abundance, chlorophyll *a* concentration and spectral light attenuation in the blue and red light from the surface to the bottom during the summer season and the ice cover period at 0.13 m snow depth was noted.

Keywords: summer and winter phytoplankton, chlorophyll *a*, spectral light attenuation, snow and ice depth, water temperature

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ISSN: 0975-8585

INTRODUCTION

The phytoplankton ecology in inland water bodies during the open water period is considered to be one of the most studied aspects [31, 5–7]. The information on phytoplankton functioning during the ice-covered period is lacking, although the Northern hemisphere water bodies are under the ice from two to eight months. This is due to the difficulties of their winter study. However, as data become available, the view that the period of ice in aquatic ecosystems is less important because biological processes either stop or run at an extremely low rate has changed dramatically. In a number of water bodies of moderate, Arctic latitudes and at the Arctic coast the the intensive plankton and cryophyton algae growth was found under the ice and snow layers [1, 36–38; 2, 8–30; 5, 29-32; 14, 129-140; 15, 172–175; 8, 10–17; 9; 10, 435; 16, 328–329; 17, 60–65; 19; 22, 35–37; 23, 20–28; 26; 27, 294–297; 28, 113–125; 29, 1–3; 30, 295-299; 31, 176-180; 33, 164–175]. Typical features of water bodies in the period of ice are low water temperature (0-4°C) and the insufficient of solar radiation, associated with a short day duration, light absorption by ice and snow, as well as a significant light reflection from the ice and especially snow cover. A snow and ice layers also isolates the water from the gas exchange with the atmosphere, wind waves. Due to the settling out of suspended particles, the water transparency is higher in winter than in summer [28, 115; 29, 3].

If the fact of the algae development in the ice column, on its bottom and in the under-ice water layer is no longer a rare scientific fact, the phytoplankton structure conversion along the water column during the period of ice remains a question.

In sharply continental climate, the abiotic conditions in the shallow Lake Krasilovskoe (Altai, Russia) for aquatic communities, including phytoplankton, drastically change in winter and summer periods. Since the lake is drainless, the influence of underwater currents on the structure of communities (algae removal or introduction) is excluded. Therefore, it is the best suited for the study of algae development under the temperature and penetrating solar radiation changes during winter period. This study objectives were: (1) to compare the summer and winter under-ice plankton algae development, (2) to analyze changes in the structure from the surface to the bottom depending on temperature, ice and snow thickness, (3) to find the possibility for application of a new spectrophotometric method of water analysis for non-contact determination of the algae abundance and phytoplankton composition.

Study site

The Lake Krasilovskoe depression (53°18'13" N., 83°36'16" E) (Fig. 1) is located in the inter-ridge lowering on high floodplain terrace of the right bank of the Ob river at an altitude of 220 m a.s.l. The catchment area is 46.1 km^2, the surface area is 0.8 km^2, the length is 2.4 km, the average width is 0.33 km, the average depth is 2.7 m, and the maximum depth is 6.5 m [20, 26–30]. The sampling station is located at the deepest part of the lake.

The lake is drainless; it feeds by surface and ground waters [11, 110]. The lake water is fresh and refers to hydrocarbonate–calcium type, mineralization varies within 31.6-55.4 mg/dm^3, pH is 7.15-8.72, and permanganate value is 6.65–9.16 mg O/dm^3. The content of phosphate phosphorus is 0.01-0.06 mg P/dm^3, nitrite nitrogen is up to 0.062 mg N/dm^3 and ammonium nitrogen is up to 0.71 mg N/dm^3. In spring and summer, the lake water is subjected to chemostratification with respect to the given parameters [4, 10–13].

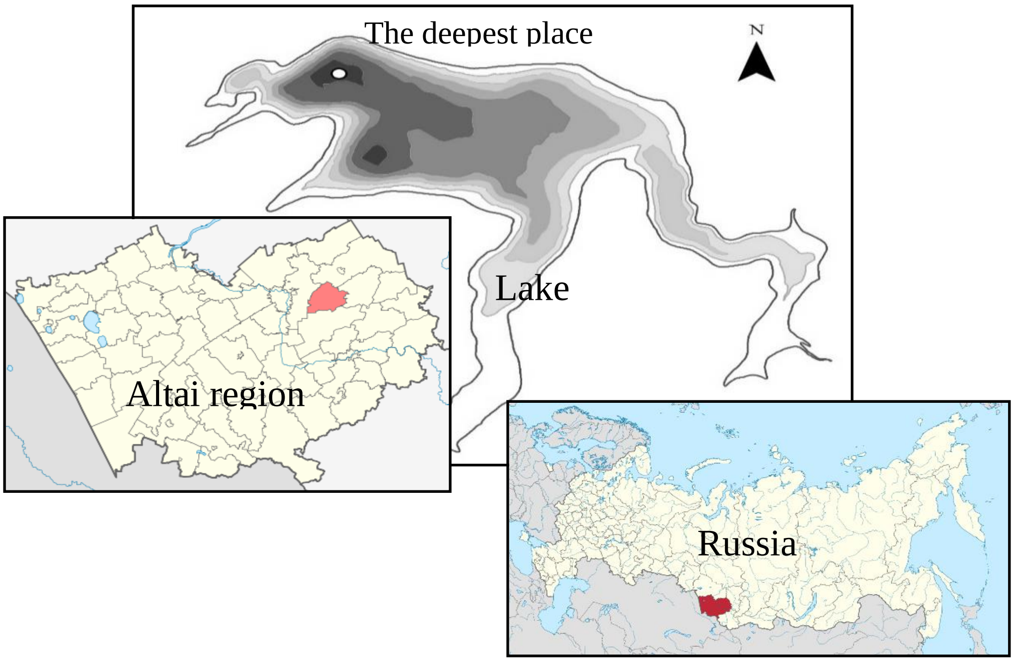


Fig 1: Location of Lake Krasilovskoe

The trophicity varies from mesoeutrophic to eutrophic. The content of phosphate phosphorus (0.08 mg P/dm^3) is higher during the under-ice period than in the open water period.

The lake is characterized by large annual amplitude of water temperature fluctuations at the surface: from 28°C in summer to 0.1°C under the ice in winter. In summer, the Secchi disk water transparency at the maximum depth reached 1.25 m, in winter it was not measured since water samples were taken from the ice hole.

Methods

Water samples were taken on August 2, 2017 (summer low water), February 20, 2018 and March 14, 2017 (winter low water) using a low-volume Rutner bathometer at one of the deepest parts of the lake from the surface to a depth of 6 m with an interval of 1 m. Water temperature from the surface to the bottom was measured synchronously with an interval of 0.5 m and an accuracy of 0.1ºC [6, 185–187]. In the laboratory, spectrophotometric analysis was performed and the spectral light attenuation in the range of 400-800 nm was determined. Phytoplankton concentrated by filtration (Vladipor MFAS-OS-3 filters with a pore diameter of 0.8 μm) was studied with standard hydrobiological methods [18, 32–60]. Algae were identified using the Manual for the identification of freshwater algae of the USSR with the use of light microscope (×650). The algae are presented in accordance with the current nomenclature of AlgaeBase 2017.

The chlorophyll *a* concentration was determined by spectrophotometry of acetone extracts of algae cells using a ПЭ-5400УФ spectrophotometer; the chlorophyll concentration was calculated according to the standard procedure in accordance with GOST 17.1.4.02-90.

Spectrophotometric analysis of water was carried out with a ПЭ-5400УФ spectrophotometer. The water samples were placed in quartz cuvettes 10×10 mm in size with a pathlength of 10 mm. The light attenuation ε in water was calculated in accordance with the Bouguer's law by the formula:

$$\varepsilon = (1/l) \ln (1/T),$$

where ℓ is the working length of cuvette; T = I / I0 is the transparency in relative units; I, I0 is the intensity of the transmitted and incident light, respectively. Spectral transparency was measured in the range of 400-800 nm. Then we calculated the spectral attenuation index ε, which is the sum of absorption (κ) and scattering (σ): $\varepsilon = \kappa + \sigma$.

There are three groups of water components that affect light attenuation [24, 12-27]. These are: 1) a yellow substance (gels), including all dissolved organic compounds that strongly absorb ultraviolet and blue rays; 2) a suspended substance (solid flow), which is understood as all the particles present in the water. They cause a very strong light scattering in water, which is weakly dependent on the emission wavelength. This group involves clay minerals, sand, quartz grains and fragments and other minerals, whole and destroyed skeletons of plankton and other organisms; 3) phytoplankton, which forms the third, special group of suspension. Chlorophyll a, needed for photosynthesis, produces very strong absorption bands in the blue and red parts of the spectrum, by which the phytoplankton abundance is determined.

RESULTS

In the temperate zone and sharply continental climate, winter and summer conditions are quite different. The air temperature in winter is below 0^0C, therefore, from the end of October to the beginning of April water bodies in Altai Krai are covered with ice and almost always with snow. In February, in the deepest part of Lake Krasilovskoe, the ice thickness was 0.56 m and the snow depth was 0.34 m, in March, 0.70 m and 0.13 m, respectively. Water temperature increased from the water surface under the ice to the bottom (Fig. 2) from 0.1 to 4.5 °C during the period of ice and decreased from 24.2 to 13.6 °C in summer.

The change of water transparency in depth measured by the absorption of light waves of different length was similar in different parts of the spectrum within each observation period and differed significantly between the periods.

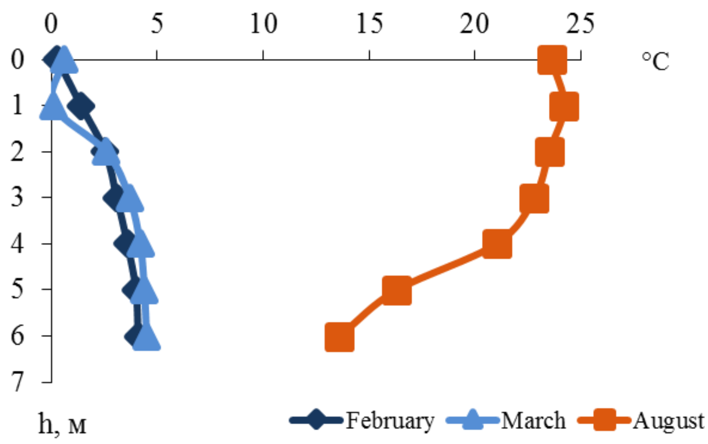


Fig 2: Water temperature in different months and depths

Since the most intense algae photosynthesis is in the blue spectrum, less in the red and does not occur in the green one [12; 25] the graphs (Fig. 3) show the dynamics of light absorption of these wavelengths along the water column. Light in the blue part of the spectrum is absorbed most intensely as compared to the red one. In summer and March, with a thin snow cover (0.13 m), the light absorption of all wavelengths tends to increase with depth. In February, with a significant snow thickness (0.34 m), light absorption did not change. Maximum values were observed at depths of 2 m and 5 m.

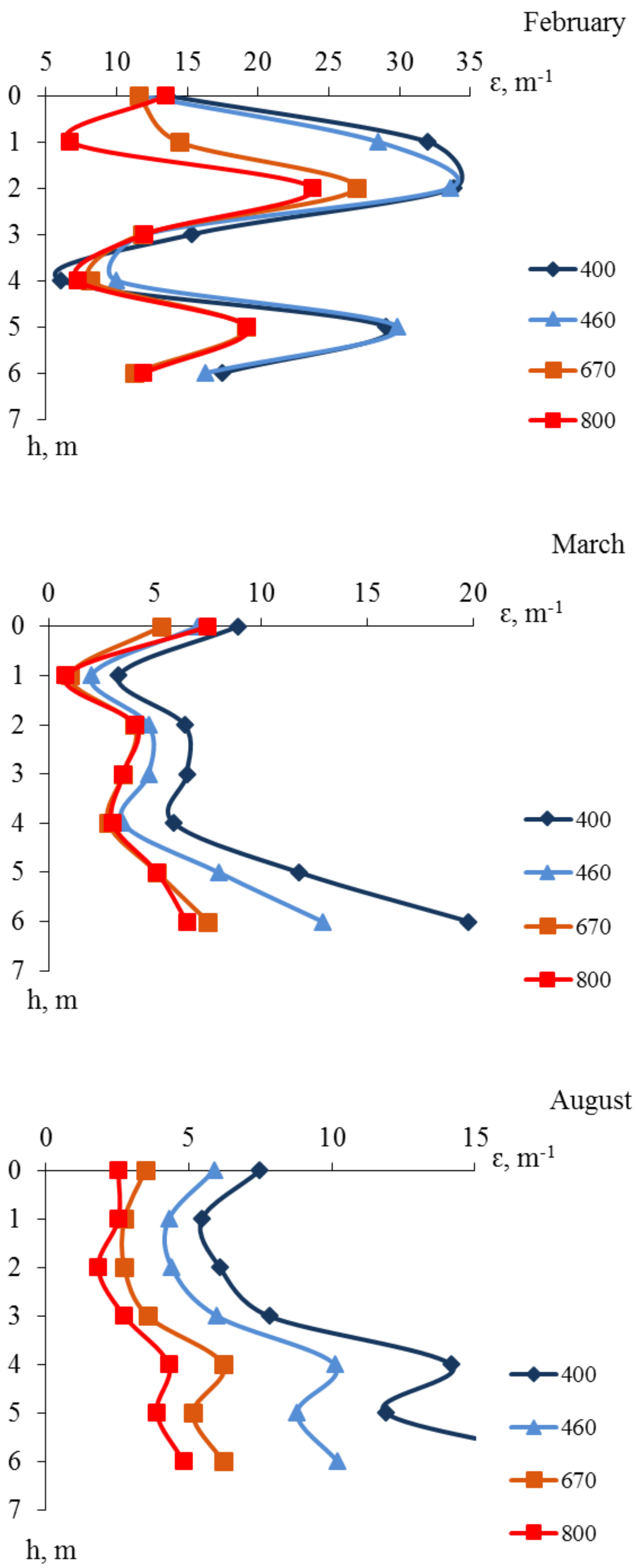


Fig 3: The absorption coefficient of light waves in different months and depths

Throughout the whole period of investigations, 141 phytoplankton species were identified in Lake Krasilovskoe: Chlorophyta – 72 species (51.1% of the total species composition), Bacillariophyta – 18 species (12.8%), Euglenophyta – 13 species (9.2%), Ochrophyta – 5 species (3.5%), Cryptophyta – 4 species (2.8%), Dinophyta (Miozoa) – 3 species (2.1%), and Cyanobacteria – 26 species (18.4%). During the period of ice cover, especially in February, when the snow is thick, many algae from all phylums could not be identified to the species since the morphological features of cells changed against the summer forms. The content and appearance of chromatophores and chloroplasts have changed, and some algae were in resting phase (cysts).

The greatest species diversity was characteristic of the summer season (more than 100 species), the least was observed in March (52 species), when snow depth was 0.13 m (Fig. 4). In February, when the ice was covered with a thick snow (0.34 m), among 56 species of algae and cyanobacteria found only few were vegetative. Thus, of 16 species of diatom algae, chromatophores are noted only in five species, the rest were represented by empty valves. Among green algae (*Scenedesmus, Tetraedron, Pediastrum*) empty cell membranes are abundant, and their number increases at the bottom (5-6 m).

In August, the largest number of species was noted among green algae: g. *Scenedesmus* (16 species), g. *Monoraphidium* (6), g. *Raphidocelis* (3), g. *Staurodesmus* (3 species); in March – g. *Scenedesmus* (7 species), in February – g. *Scenedesmus* (9 species and varieties). Almost all species found during the period of ice cover vegetate in summer as well.

In August, the number of species in the surface layer of water (0-1 m) was 1.5 times less than at depths of 2-6 m (21-24 → 31-36 species, respectively).

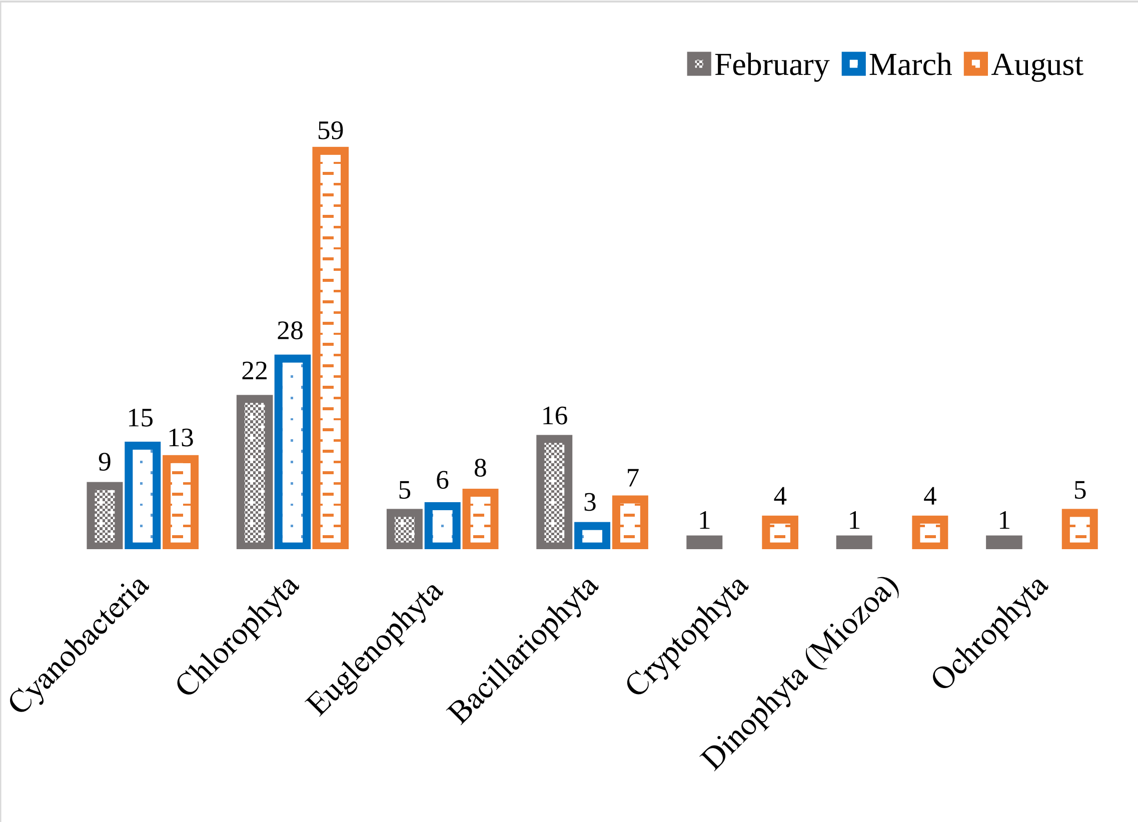


Fig 4: Phytoplankton taxonomic groups in the months with (February, March) and without (August) ice

In March, under the ice (0-1 m), the number of species was 2 times less than at a depth of 2-4 m and 3 times less than at the bottom (7-8 species → 13-18 species → 20-25 species, respectively). In February, under a thicker layer of snow in the water column of 0-2 m, the number of species ranged from 11-14 and increased at a depth of 3-6 m by about 2 times up to 19-24 species. Thus, all the periods showed a tendency of increasing species diversity from the surface to the bottom. In winter, the color of green algae chloroplasts intensified with the depth, which was indicative of an increase in the "vital activity" of cells from ice to bottom.

High development during the biological summer (August) was demonstrated by the green chlorococcales (Table 1) from genus *Scenedesmus*, *Coelastrum*, *Dictyosphaerium*, *Mucidosphaerium*, *Pediastrum*, volvocales from genus *Chlamydomonas* and charophytes from genus *Staurastrum*. Among cyanobacteria, *Microcystis aeruginosa* and not identified small cyanobacteria with a cell diameter of 1-3 mkm were abundant. Cryptophytes *Chroomonas coerulea* (Geitler) Skuja was found in large quantities at a depth of 4 m. The scarce *Euglena hemichromata* Skuja formed a part of dominant by biomass species due to its large size.

Table 1: Dominant algae species along water column in Lake Krasilovskoe in different months

Depth, m	Dominant species, % of total concentration	Dominant species, % of total biomass
	February	
0	*Anabaena* sp. (34), *Achnanthes* sp. (15)	*Chlamidomonas* sp. (30), *Trachelomonas* sp. (23)
1	*Microcystis pulverea* (64)	*Microcystis pulverea* (90)
2	Not identified small cyanobacteria (20), *Microcystis* sp. (14), *Gloeocapsa* sp. (10), *Trachelomonas* sp. (10)	*Microcystis pulverea* (48), *Trachelomonas* sp. (11)
3	*Microcystis pulverea* in colonies, *Synechococcus aerugenosus* (18), *Monoraphidium komarkovae* (11)	*Microcystis pulverea* (51), *Microcystis aeruginosa* (42)
4	*Hyaloraphidium contortum* (15), *Monoraphidium komarkovae* (14)	Not identified golden (22), not identified cryptophytes (15), cysts of green algae (11), Fragilaria sp. (9)
5	*Microcystis aeruginosa* в колониях, *Scenedesmus caudato aculeolatus var. spinosus* (15), *Dictyosphaerium subsolitarium* (15), *Hyaloraphidium contortum* (14), *Monoraphidium komarkovae* (13)	*Microcystis aeruginosa* (30), not identified dinophytes (29), *Pseudopediastrum boryanum* (10)
6	*Microcystis aeruginosa* (39), *Chroococcus vacuolatus* (37)	*Microcystis* sp. (58), *Microcystis aeruginosa* (12)
	March	
0	*Gomphosphaeria lacustris* (97)	*Gomphosphaeria lacustris* (57), *Cyanodictyon reticulatum* (40)
1	*Gomphosphaeria lacustris* (99)	*Gomphosphaeria lacustris* (97)
2	*Microcystis pulverea* (47), *Gomphosphaeria lacustris* (46)	*Microcystis pulverea* (57), *Gomphosphaeria lacustris* (31)
3	*Gomphosphaeria lacustris* (82), *Microcystis pulverea* (17)	*Microcystis pulverea* (92)
4	*Gomphosphaeria lacustris* (83), *Microcystis pulverea* (16)	*Microcystis pulverea* (95)
5	*Gomphosphaeria lacustris* (59), *Microcystis pulverea* (40)	*Microcystis pulverea* (94)
6	*Gomphosphaeria lacustris* (74), *Microcystis pulverea* (24)	*Gomphosphaeria lacustris* (56), *Microcystis pulverea* (41)
	August	
0	Not identified small cyanobacteria (17), *Scenedesmus caudato aculeolatus* var. *spinosus* (12), *Coelastrum astroideum* (10)	*Euglena hemichromata* (16), *Microcystis pulverea* (16), *Staurastrum saltator* (10), *Pediastrum duplex* (9)
1	*Pediastrum duplex* (25), *Mucidosphaerium pulchellum* (23), *Coelastrum astroideum* (10)	*Pediastrum duplex* (24), not identified dinophytes (22)
2	*Microcystis aeruginosa* (11), *Chlamydomonas proboscigera* var. *conferta* (9), *Staurastrum saltator* (9)	*Microcystis aeruginosa* (33), *Staurastrum saltator* (9), *Chlamydomonas proboscigera* var. *conferta* (8)
3	*Pediastrum duplex* (11), Not identified small cyanobacteria (9), *Microcystis aeruginosa* (8)	*Microcystis aeruginosa* (89)
4	*Chroomonas coerulea* (16), *Enallax costatus* (8),	*Microcystis aeruginosa* (47), *Euglena*

	Desmodesmus magnus (8), *Dictyosphaerium granulatum* (8)	*hemichromata* (33), *Chroomonas coerulea* (5)
5	*Microcystis aeruginosa* (30), *Dictyosphaerium granulatum* (27), *Desmodesmus denticulatus* (5)	*Microcystis aeruginosa* (26), *Desmodesmus denticulatus* (15), *Dictyosphaerium granulatum* (8)
6	*Microcystis aeruginosa* (66), *Dictyosphaerium granulatum* (8)	*Microcystis aeruginosa* (93)

In March, under a 0.13 m layer of snow and 0.70 m of ice along the water column, cyanobacteria *Gomphosphaeria lacustris* Chodat and *Microcystis pulverea* (H. C. Wood) Forti were dominant in number and biomass.

In February, when snow and ice depth is 0.34 m 0.56 m, respectively, a significant growth is observed in cyanobacteria *Anabaena sp*., *Chroococcus vacuolatus* Skuja (*Gloeocapsa vacuolata* (Skuja) Hollerbach, Kosinskaja & Poljanskij), *Microcystis pulverea*, *M. Egido* (Kützing) Kützing, *Gloeocapsa sp*., *Cyanothece aeruginosa* (Nägeli) Komárek) (*Synechococcus aerugenosus* Nägeli), green chlorococcales *Monoraphidium komarkovae* Nygaard, *Scenedesmus caudato aculeolatus* var. *spinosus* (Deduss.) Pankow, *Dictyosphaerium subsolitarium* Van Goor, *Hyaloraphidium contortum* Pascher & Korshikov in Korshikov. Closer to the surface, green volvocales *Chlamidomonas* sp. and euglenic *Trachelomonas* sp. predominate in biomass (but not in number) due to a large size.

The distribution of the total number and biomass of phytoplankton is uneven in depth (Fig. 5). In August, the total number of algae (excluding the depth of 4 m) increases from the surface to bottom from 0.11 to 1.74 mln. cells/l. This is mainly due to the increase in the number of green and cryptophytic algae and cyanobacteria. Biomass had two peaks: at a depth of 3 m (14.34 g/m^3) and 6 m (18.16 g/m^3). At other depths, it was much lower.

In March, under a thin layer of snow, the number of algae varied within 26.4-1056.0 th. cells/l, increasing from the surface to a depth of 6 m. The phytoplankton biomass decreased from the surface to a depth of 3 m from 2.1 to 0.8 g/m^3 and began to increase in a depth range of 4 to 6 m from 2.0 to 12.2 g/m^3.

In February, when the snow is thicker, the variations in algae abundance in the water column is minor (48.8-140.8 th. cells/l). The changes in depth are not observed. Biomass varies between 0.2 and 5.3 g/m^3 with two peaks: 5.3 g/m^3 at a depth of 1 m and 3.5 g/m^3 at a depth of 3 m.

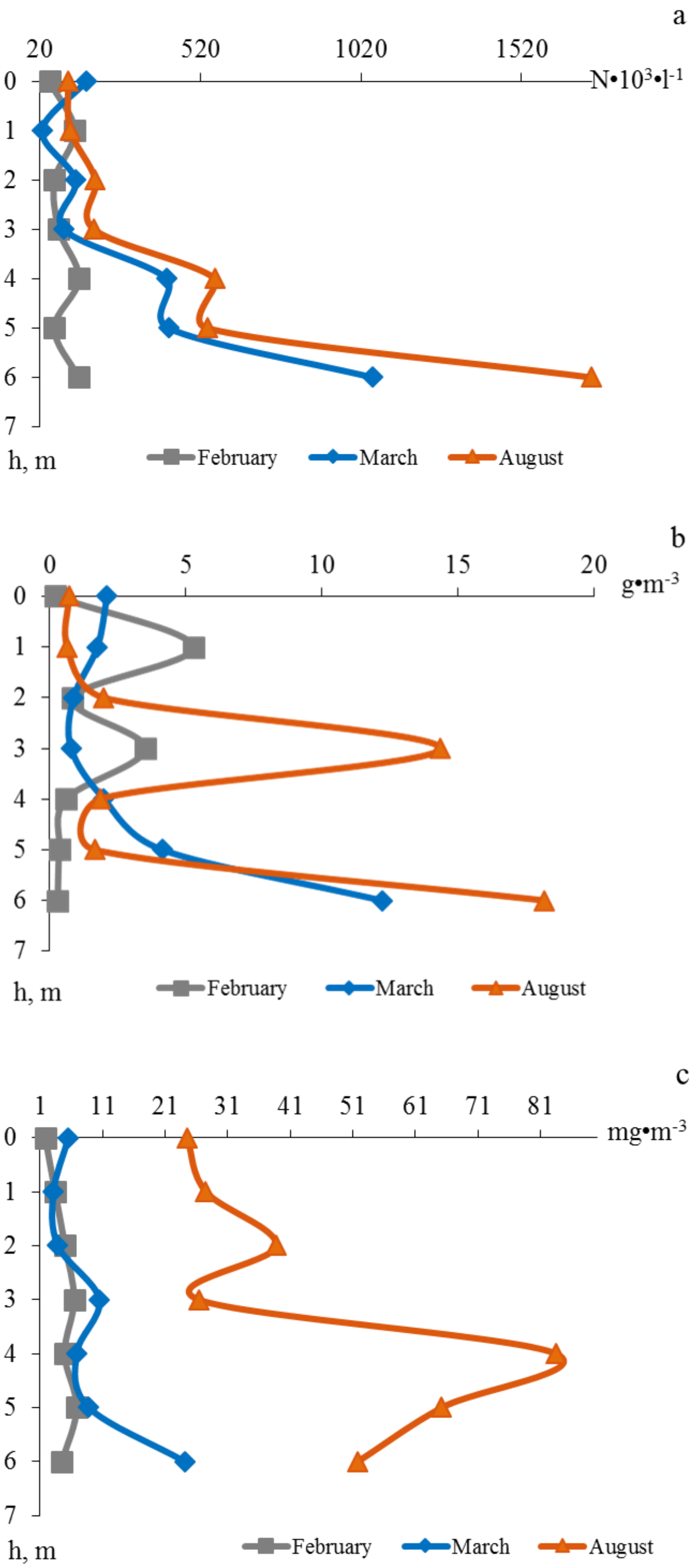


Fig 5: Abundance of total phytoplankton in months with (February, March) and without (August) ice: a – algae concentration [$N•10^3•L^{-1}$], b – biomass [$g•m^{-3}$], c – chlorophyll *a* concentration [$mg•m^{-3}$]

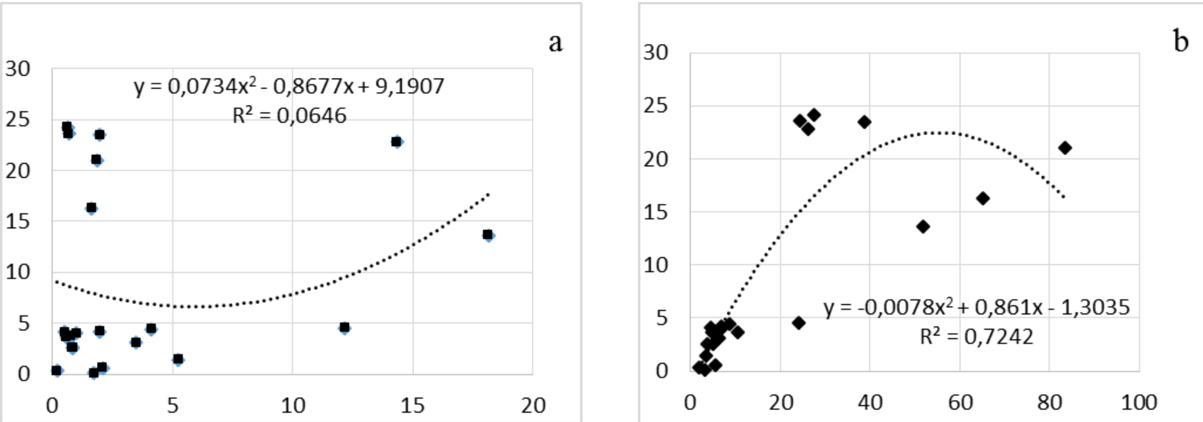
The content of chlorophyll *a* (as a phytoplankton biomass marker and the main pigment responsible for photosynthetic algae activity) generally reflected the overall trend of seasonal changes in phytoplankton abundance. In summer, its concentration was much higher as compared to the winter period of ice (24.5-65.2

mg/m^3 and 1.8-24.1 mg/m^3, respectively). In turn, in February under a thick layer of snow, its concentration is lower than in March under a thin snow layer (1.8-6.8 mg/m^3 and 3.1-24.1 mg/m^3, respectively).

In August and March, the tendency toward the increase of chlorophyll *a* concentration as well as phytoplankton biomass from the surface to the bottom was noted, but their peaks did not coincide in depth.

The distribution of chlorophyll *a* in the water column varied in depth; the limits of variation were maximal in the open water period, less significant under a thin layer of snow of 0.13 m and the least at the thick layer of snow (0.34 m).

Unexpectedly, we did not find any simultaneity of changes in algae biomass and chlorophyll *a* concentration.



No positive correlation between temperature and total algae biomass (Fig. 6, a) was revealed, but a statistically significant negative correlation between water temperature and chlorophyll concentration was noted (R=85%, p≥0.05, n=21) (Fig. 6, b).

Fig 6: Relationship between temperature and total biomass of phytoplankton (a), temperature and chlorophyll *a* concentration (b)

The tendency of simultaneous from surface to bottom increase of light absorption in the blue and red parts of the spectrum as well as algae abundance (number, biomass), chlorophyll *a* concentration was observed, but this dependence is not proved. Therefore, more observations are called for.

DISCUSSION

Comparisons to literature shows, that, in Lake Krasilovskoe, the abundance and chlorophyll *a* concentration of summer phytoplankton, its distribution in depth, and temperature conditions are typical of shallow mesotrophic and eutrophic water bodies of temperate latitudes. In early August, the maximum water temperature (23.6-24.2°C) was noted in the upper layer to a depth of 1 m, lowering to the bottom to 13.6 °C. The phytoplankton abundance and chlorophyll *a* concentration tend to increase from the surface to the bottom.

Since algae photosynthesis rate is high in the blue part of the spectrum of penetrating solar radiation and lower in the red part, we can assume that the absorption of light energy in these spectrum parts will vary with the change of algae abundance. This trend occurs with variations in depth. Strong synchronicity was not noted since the "disturbance" was due to the occurrence of microscopic greenish and brown aquatic fungi, macrophyte residues, protozoa and zooplankton organisms. All of them also absorb or reflect solar radiation in certain parts of the spectrum. This phenomenon calls for further investigation.

As for algae, the obtained data on high light waves absorption in the blue part of the spectrum, increase of chlorophyll *a* concentration, and morphological characteristics (chloroplasts and chromatophores in algae cells at the bottom are of the same rich color as in the upper water layers) show that algae photosynthesis increases from the surface to bottom. It is hard to explain due to the fact that in August, when water transparency is 1.25 m (with Secchi disk), the photosynthetic layer in the lake does not exceed 3-3.5 m. Active algae photosynthesis far beyond the phototrophic layer was also revealed in the shallow lakes of the Trans-Baikal territory [16, 329].

According to literature data, there are several states of ice phytoplankton. (1) A significant growth of phytoplankton and cryoperiphyton is observed in the absence of snow cover under the transparent ice of any thickness [17, 62–64; 31, 177-178]. (2) Vegetation and photosynthetic activity of algae occur even at snow cover, but with lower intensity. (3) There are no algae or they are at rest under a layer of snow and ice in the absence of light [19]. (4) In winter period, the phytoplankton is dominated by flagellates of dinophytes, cryptophytes and euglena algae, capable not only to active movement, but to hetero- and mixotrophic nutrition as well. They are concentrated in the water surface layer under the ice [27, 7; 30, 299–300].

The diversity of the states is explained by hysteresis, which is typical for shallow continental lakes of the temperate zone [28, 112]. It is based on a large variety of climatic, hydrographic, hydrological, hydrophysical, and hydrochemical conditions of small lakes.

During the period of ice in comparison with the summer period, a lower level of vegetation was revealed, particularly, the number of species and chlorophyll *a* concentration was two and more times less. The negative effect of low temperature and ice thickness on the algae development was not found. However, there is a dependence of quantitative indicators, including the pigment characteristics of algae on snow thickness (0.34 m in February and 0.15 m in March) and, accordingly, on the penetrating solar radiation.

The under-ice phytoplankton of Lake Krasilovskoe is unique as compared to other mesotrophic-eutrophic water bodies since the mobile forms of algae in phytoplankton both during summer and winter under-ice periods are few in number in all layers of water. These are mainly passive green and blue-green plankters (single-celled and colonial), which are incapable of active phototaxis. That is, they cannot actively move to the surface, where winter conditions for photosynthesis are more favorable [30, 295].

However, the occurrence of algae with green chromatophores in winter samples testifies to their active vegetation [15, 175; 19; 29, 5]. The abundance of such algae at the bottom in summer and in March with thin snow cover is high, despite the lack of light. The assumption that algae gradually settle is not entirely reliable, since it was enough time for algae to settle out and die from the time of ice and snow cover formation at the end of October.

The predominance of small-cell forms of algae and cyanobacteria in plankton can be indicative of high photosynthetic activity of the phytoplankton biomass unit [16, 329], even with the seemingly complete absence of light absorbed by ice and especially snow cover. At the same time, it is known that 0.2-70% of solar radiation penetrates into water body through a layer of ice and snow [26; 27; 28, 115–116; 30, 296–297; 31, 175; 32, 128–135; 33, 166–167]. Besides, in winter, when the suspended matter deposition takes place, the transparency of water and, accordingly, the conditions for deeper light penetration, especially in the blue part of the spectrum, improve [16, 328–329; 28, 114–115].

Perhaps, photosynthetic pigments of other groups take an active part in photosynthesis under insufficient light [33, 171–172]; therefore, in our work, the correlation between phytoplankton abundance and chlorophyll *a* concentration is not found.

It is not improbable that algae of all groups, especially during the period of ice, turn, as in other water bodies, to hetero- and mixotrophic nutrition [7, 14; 28, 122–123; 29, 4; 30, 299–300; 31, 177–178], as in mesotrophic-eutrophic lake (Lake Krasilovskope) the nutrients in the water are sufficient. Besides, in shallow lakes, a constant entering of mineral forms of nitrogen and phosphorus from the bottom is observed [13-16, 329].

SUMMARY

Species composition and abundance of summer phytoplankton, chlorophyll *a* concentration, the distribution pattern of these parameters in depth are similar to that in shallow mesotrophic and eutrophic water bodies of the temperate zone.

In winter period of ice, the phytoplankton number (26.4-1056.0 th. cells/l) and biomass (0.2-12.2 g/m^3), and chlorophyll *a* (1.8-24.1 mg/m^3) concentrations varied within the limits characteristic of some water bodies of Western, Eastern Europe, European part of Russia, Transbaikalia, the Far East and North America.

During the period of ice in Lake Krasilovskoe, at thin snow layer (0.13 m), a significant development of small cyanobacteria forming the colonies took place. The colonial cyanobacteria dominated in the 0-2 m water column under a thick layer of snow (0.34 m), and at the bottom (6 m), while in the middle layers of water column (3-5 m) the number of unicellular green chlorococcal algae and cyanobacteria reached high values.

The intensity of cell color in the period of ice with a thin snow cover differed little from that in summer and did not change with depth. This may be indicative of a high "vital activity" of cells at insufficient light.

No negative influence of low temperature on the abundance of algae during the period of ice was revealed, although the species composition varies in winter compared to the summer situation.

Presumably, according to morphological characteristics and chlorophyll *a* concentration, green, euglena, dinophyte, cryptophyte, ochrophyte algae and cyanobacteria show high photosynthetic rate even at low light at the bottom in summer or during the period of ice along the water column. This may be evidenced (so far approximately) by a new spectrophotometric method for water analysis. Assuming that the most active algae photosynthesis occurs at light wavelengths of 400-460 nm, it becomes clear why the light absorption in the blue part of the spectrum is the highest.

In general, as for all researchers of the period of ice at water bodies, this work on revealing the patterns of phytoplankton vegetation and features of its structure under the ice and snow layers raised more questions than gave answers to them.

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