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Hydrological and biological regimes of lakes of East Antarctica

Andrey N. Sharov[1]*, Alexey V. Tolstikov[2]

[1] *I.D. Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences, Borok 109, Nekouzsky District, Yaroslavl Region, 152742 Russia*

[2] *Northern Water Problems Institute of Karelian Research Centre, Russian Academy of Sciences, pr. Aleksandra Nevskogo 50, Petrozavodsk, Republic of Karelia, 185030 Russia*

**sharov_an@mail.ru*

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Hydrological and biological regimes of different types of lakes of oases of East Antarctica, Thala Hills, Schirmacher Oasis and Larsemann Hills, were studied in the summer of 2010–2011. In lakes covered with ice, inverse temperature stratification is recorded. In the bottom layers of the water, the temperature (about 4 °C) is close to the values characteristic of water with a maximum density. Isothermy is observed on the opened small lakes, and water in some reservoirs warms up to 8 °C. Benthic communities of cyanobacteria and invertebrates are the main biological component of lakes, where there is no classical food chain and a microbial loop prevails. Studies have shown that a 3-meter layer of ice permits a sufficient amount of light even to a depth of 30 m. Light does not limit the development of algae and cyanobacteria. However, the low content of nutrients in the water limits the growth of phytoplankton, causing low values of biomass (less than 0.01 mg/l) and concentration of chlorophyll *a* (0.1–0.45 µg/l). A tendency to climate change around the Schirmacher oasis is recorded. In recent decades, some lakes, which in the middle of the last century were constantly covered with ice, began to open in the summer months. In the period when the lake is covered with ice, homothermy is established with a water temperature of 4 °C. After having opened, the water temperature in the lake drops to 0.5–1 °C because of wind-wave cooling.

Keywords: Antarctic lakes, bottom communities, phytoplankton, chlorophyll, climate change.

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Introduction

Environmental factors, including climate change and human activities, have great potential for influencing the biological communities of lakes through various processes that are especially noticeable in the polar regions, where small changes in glacial conditions and in the supply of nutrients can have a sound response (Filatov and et al., 2013; Quesada et al., 2006). The functioning of research stations may be an important factor in the change of chemical regimes in Antarctic lakes (Sharov and Tolstikov, 2018). For example, wastewater inflow and intensive destruction of rocks by tracked vehicles (increased weathering) can lead to eutrophication of lakes (Ellis-Evans et al., 1997).

East Antarctica is a Precambrian platform. Its sedimentary strata are mainly represented by marine deposits overlain by young glacial deposits. The geological successions indicate significant climate change in this region (Filatov et al., 2013; Vincent and Laybourn-Parry, 2008). Most freshwater lakes in East Antarctica are ice-covered for most of the year. They are considered a sensitive indicator of current climate change in Antarctica. Lakes of Antarctic oases are still a poorly studied natural object (Sharov and Tolstikov, 2018).

The purpose of the work was to identify the features of the current state of the hydrological and biological regimes of typical lakes of Antarctic oases, as well as to compare new data with the results obtained earlier. We focused on the following tasks: to identify the variability of hydrophysical and hydrochemical parameters, to study the features of the structure of biological communities of lakes and the structure of bottom sediments.

Materials and methods

Research on Antarctic lakes was conducted as part of the 56th Russian Antarctic Expedition of the Arctic and Antarctic Research Institute (AARI) from December 2010 to April 2011. Lakes were studied in the oasis of Thala Hills in the vicinity of the Molodezhnaya Station (S 67°40', E 45°51') from 19.12.2010 to 06.02.2011; in the Schirmacher oasis in the vicinity of the Novolazarevskaya Station (S 70°44'–70°64'; E 11°20'–11°55') from 09.02.2011 to 06.03.2011; in the oasis of the Larsemann Hills near the Progress Station (S 69°22', E 76°23') – on 22.03.2011 (Fig. 1).

In the oasis of the Thala Hills 13 lakes were studied; 26 phytoplankton samples, 15 zooplankton samples, 9 samples for analysis of chlorophyll content, 15 hydrochemical samples, 7 columns of bottom sediments were collected. In the Schirmacher oasis, work was carried out on 11 water bodies; 12 phytoplankton samples, 10 periphyton samples, 10 samples or analysis of the chlorophyll content in plankton were collected. In the oasis of Larsemann Hills, three lakes were studied: Progress Lake, Reid Lake, and Stepped Lake. Here, 3 samples of phytoplankton and 2 samples of zooplankton, as well as 3 columns of bottom sediments, were collected.

The work included probing the water column of the lakes using a Quanta CTD probe (USA). For sampling we used a Rutner bathometer (2 l), Apstein plankton net (sieve no. 64) and a tubular bottom scoop (stratometer) in accordance with GOST standard R 52.24.353-2012. Biological samples were fixed with 4% formalin or 96% alcohol; microbiological samples were stored frozen. The primary processing of biological samples was conducted at the Antarctic stations

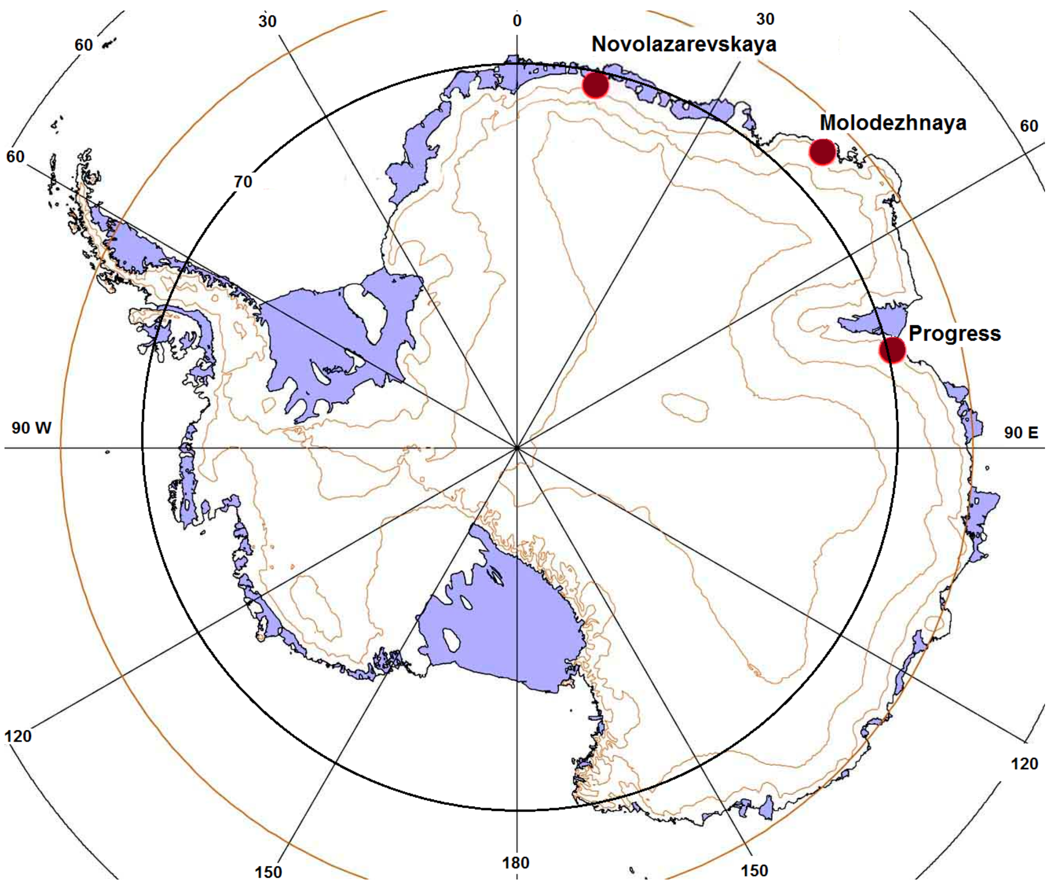

Fig. 1. Areas where research was conducted during the 56th Russian Antarctic expedition.

using the MBS 9 binocular microscope and Biomed and Micromed-1 stereo microscopes. Phytoplankton samples were concentrated in a sedimentation chamber. To determine the concentration of chlorophyll *a* in plankton, water was filtered through filters with a pore diameter of 22 μm.

Results and discussion

Lakes in the Thala Hills and Schirmacher oases are lake systems whose basins are located at different levels relative to each other and are interconnected by temporary streams breaking through ice dams once a year or once every several years when it is sufficiently warm. This results in significant volumes of water to be redistributed, respectively, there is a fluctuation in the level of lakes and the structure of lake ecosystems changes. This process has the most powerful impact on the ecosystems of lakes in the long term. The frequency of breakthroughs, apparently, reflects climate fluctuations, since theoretically this should occur in the warmest years after the accumulation of significant volumes of water in the lakes. However, this problem requires more research.

Deep glacial lakes are characterized by inverse temperature stratification, while isothermy is observed in shallow water bodies opened from ice in summer. Heat comes from meltwater runoff, as well as intense solar radiation passing through the ice sheet. Of great importance in the thermal regime of lakes is the appearance of nearshore ice-free areas in the warm season.

Molodezhnaya Station (Thala Hills oasis)

Three types can be recognized in the studied lakes of the Thala Hills oasis based on the structure of the water mass and the volume of water.

Deep lakes covered with ice throughout the year. They are characterized by inverse temperature stratification; the temperature of bottom waters is about 4 °C. In summer, ice-free areas are formed nearshore. Only two of the studied lakes belong to this type: Lake Lagernoe (depth 5 m) and Lake Glubokoe (depth 30 m).

Small lakes freezing to the bottom. In the warm season, ice-free areas form along the shores, but most of the lake is covered with ice. There are three lakes of this type (lake Ovalnoe, Lake Stokovoe, and Lake Razlivnoe), their depth is about 3 m.

Small lakes (more than 10, most are unnamed), the ice cover of which completely disappears in the summer, and the water is isothermal.

When comparing our results with the data obtained over a long period of time (Kaup, 1998; Simonov, 1971), no noticeable change in the hydrophysical parameters in the lakes of the Thala Hills oasis was recorded. Consequently, no striking examples of climate change have been recognized in this Antarctic region.

Lake Glubokoe (Thala Hills) is the largest lake near the Molodezhnaya Station. The bottom of the lake is rocky and covered with a multilayered cyanobacterial mat. The black-green layered structure of the sediments indicates the cyclical nature of various lighting conditions and the oxygen regime. As defined by Stal (1995), cyanobacterial mats in Lake Deep can be categorized as smooth type. Cores of bottom sediments collected in the lake from maximum depths (30 m) during the study period were about 40 cm long, and a clear upper layer (15 cm) of these deposits was represented by bacterial mucus from cyanobacteria.

In lake Glubokoe, the values of water temperature were observed at about 0 °C directly in the drilled holes, 4–4.1 °C in the subglacial water layer of and 4.2–4.3 °C in the bottom water layer (Fig. 2).

The mean values of electrical conductivity ranged from 0.020 mS/cm on the surface to 0.042 mS/cm in the lake water column and 0.053 mS/cm in the bottom water layer. According to Kaup (1998), the pH in lake Glubokoe in 1968 amounted to 6.8, and in 1988 to 7.1. During our observations, the pH corresponded to 7.3–7.5 for a horizon immediately below the ice. The pH values in the bottom water layer changed from 6.7 (December 2010) to 7.2 (February 2011). The mean pH of the water corresponded to a neutral reaction of the medium, however, variations associated with the biological activity of the lakes were recorded. For instance, during January 2011, a shift in pH values was observed in the alkaline region in the subglacial (up to 7.5) and bottom (7.2) layers. The oxygen concentration is characterized by its low content in the bottom layer (35–40%) in December 2010 and an increase to 80–90% in January 2011.

In the water column of Lake Glubokoe, concentration of chlorophyll *a* was at the detection limit and ranged from 0.1 to 0.45 μg/L (Sharov et al., 2015). The values of primary production in 2011 are comparable to those recorded in October–December 1988, when the fluctuation range was from 0.2 to 4.8 mg C/(m^3 • day) (Kaup, 1998). According to the concentration of chlorophyll *a* in 2011, Lake Glubokoe is a ultra-oligotrophic lake, which is typical of most polar lakes (Vincent and Layburn-Parry, 2008). The concentration of chlorophyll *a* in Lake Glubokoe is comparable with those of other lakes of East Antarctica, such as Lake Verkhneye, Lake Druzhby and Crooked Lake (less than 1 μg/L) (Henshaw and Laybourn-Parry, 2002), as well as with those of lakes in other Antarctic regions (0.5–3.0 μg/L) (Andreoli et al., 1992; Contreras et al., 1991; Laybourn-Parry et al., 1992). Higher concentrations of chlorophyll *a* were found in the deepest zone because of sedimentation (Contreras et al., 1991; Priddle et al., 1986).

In the water column, a few specimens of planktonic algae and zooplankton organisms were found. The maximum abundance of planktonic organisms was observed in January, during the period of high air tem-

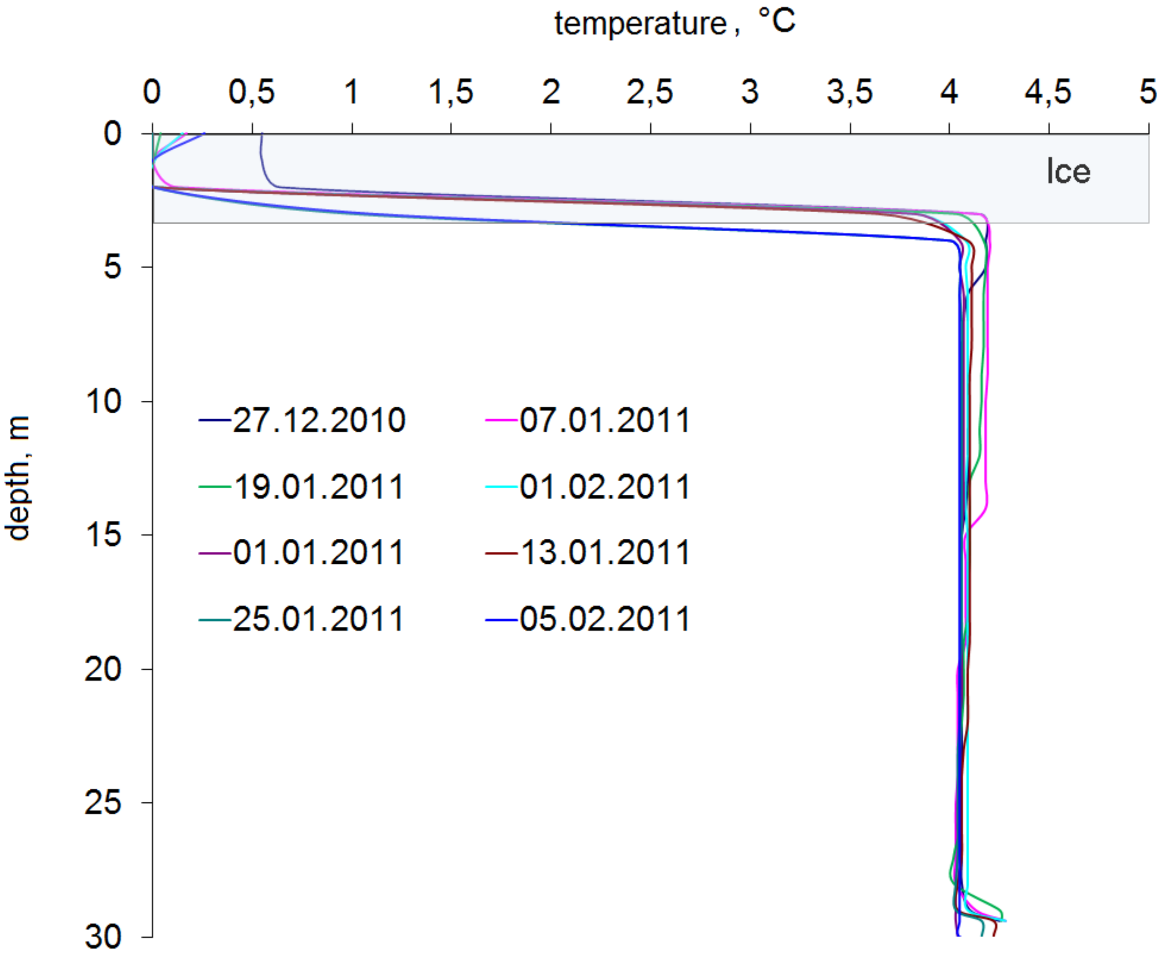

Fig. 2. Results of measuring water temperature in Lake Glubokoe (Thala Hills oasis).

peratures in the area of the lake. We did not observe planktonic organisms in the samples taken from the upper layer (0–5 m) of water under the ice but found them in integrated (entire water column) net samples and on the surface of bottom sediments. It is likely that they are concentrated in the bottom water layer.

Numerous single green microalgae cells (2–5 μm) were present in the samples throughout the entire studied period. Large phytoplankton representatives, such as colonies of four cells (10–15 μm) of cyanobacteria *Chroococcus turgidus* (Kützing) Nägeli, 1849 and species of green algae and diatoms (8–35 μm), were significant components in plankton only in January. The most common species in plankton were the green algae *Pediastrum duplex* var. *gracillimum* West & G.S. West, 1895 and *Chlamydomonas* sp., and also the cyanobacteria *Planktolyngbya limnetica* (Lemmermann) Komárková-Legnerová & Cronberg, 1992 and *C. turgidus* (Sharov et al., 2015).

Diatoms do not play an important role in the plankton of Lake Glubokoe; in different periods, only a few species with a low abundance were found. The most frequent among them were *Cyclotella kuetzingiana* Thwaites, 1848, *Diatoma tenuis* C. Agardh, 1812, *Synedra* sp., and *Fragilaria* sp.

The rotifers *Lepadella patella* Müller, 1773, *Keratella cochlearis* Gosse, 1851, and *Mniobia* sp. with a very low abundance of 0–25 specimen/l are found in zooplankton.

The main biocenosis of Lake Glubokoe is represented by cyanobacterial mats, in which, in addition to cyanobacteria, green and diatoms are present. Representatives of cyanobacteria of the genera *Oscillatoria, Phormidium, Nostoc, Pseudanabaena,* and *Lyngbya* dominated in the bottom mats.

Invertebrates associated with cyanobacterial mats were represented by rotifers (*Lepadella patella*, and several species of Bdelloidea) and tardigrades; no nematodes were recorded. Several species of bdelloid rotifers of the family Philodinidae dominated, reaching a fairly high abundance (up to 1000 specimens/m^2). Tardigrades of the family Macrobiotidae are also a common component of bacterial mats, but their abundance was noticeably lower (100–500 specimens/m^2).

The extremely short summer season (approximately 1–1.5 months) and the almost complete absence of nutrients from the catchment due to many years of ice cover result in a limited role of phytoplankton with a predominance of small taxa such as picoplankton (< 2 μm), which is most likely a common feature of many lakes in this region. For example, in the lakes of northern Victoria Land, picoplankton accounted for 50% of all phytoplankton (Andreoli et al., 1992). In addition, the phytoplankton of Crooked Lake (Westfall Hills, East Antarctica) can also be referred to picoplankton (Laybourn-Parry et al., 1992). The appearance of small algae and cyanobacteria in such lakes may be an adaptation to improve nutrient transfer due to an increase in the specific surface area of these organisms (Gibson et al., 2006).

Due to the high transparency of water and the absence of snow cover on ice, solar radiation penetrates to the bottom of deep lakes (Fig. 3). In Lake Glubokoe, despite a three-meter layer of ice in the summer, 10–15% of the measured incoming solar radiation reaches a depth of 30 m, amounting to 3 W/m^2. The amount of incoming short-wave radiation (0.4–0.7 μm) averages 276 W/m^2 (up to a maximum of 1200 W/m^2). The average illumination in the entire water column was more than 14 W/m^2.

It is known that light limits the development of phytoplankton only at 7.0–1.6 W/m^2 (Reynolds, 2006). According to I. Hawes (1990), the low abundance of phytoplankton in Antarctic lakes can be explained by the fact that, although the light intensity increases the rate of photosynthesis, the temperature remains low and limits protein synthesis and, consequently, the growth of organisms. In addition, in conditions of acute nutritional deficiency, a high level of illumination can be fatal for biota (Talling, 1979). However, there are a few exceptions; for example, in Watts Lake (Westfold Hills) photosynthesis was not detected in July by mid-winter, but reached a level of 0.21 μg C/(l • hour) in August and rises to a maximum of 6.39 μg C/(l • hour) in mid-September (Heath, 1988). Evidence suggests that phytoplankton can be adapted to low light levels, low temperatures, and nutrient restriction (Gibson et al., 2006; Sharov et al., 2015). A significant part of planktonic bacteria (up to 75%) has exo-enzymatic potential and, therefore, can use more carbohydrates, proteins, and lipids (Ellis-Evans, 1981).

Human exposure can contribute to chemical changes in surface waters on the catchment, which leads to an increase in the amount of nutrients in the lake (Kaup et al., 2001). In 1967–1968 (MacNamara, 1970) phosphate content in Lake Glubokoe reached 460 μg R/l, ammonia 1300 μg N/l as a result of water pollution from the Molodezhnaya Station. The possibility of eutrophication of lakes when nutrients come from anthropogenic sources in various regions of Antarctica, including the Thala Hills in 1960–1980, has already been shown previously (Kaup, 1998). The results of previous studies (Sharov and Tolstikov, 2018; Sharov et al., 2015) indicate the emerging process of cleansing and the return of Lake Glubokoe to a natural state. Perhaps this is because after the shutdown of the Molodezhnaya Station in most seasons since 1998, the supply of nutrients from the catchment area decreased.

A detailed study of the species composition of bottom cyanobacterial mats (at a depth of 5 m and 27 m) in Lake Glubokoe was carried out in 1969–1970. by identifying bacteria and algae after laboratory cultivation (Starmach, 1995). A total of 85 algal taxa were identified for all lakes in the Thala Hills: Cyanobacteria – 54, Chrysophyceae – 1, Xanthophyceae – 10, and Chlorophyceae – 20 taxa, including 15 taxa in Lake Glubokoe (Starmach, 1995). All species of algae and cyanobacteria found in 2010–2011 (Sharov et al., 2015) at a depth of 30 m in Lake Glubokoe were already discovered in 1969–1970 (Starmach, 1995).

The ecosystem of Lake Glubokoe is characterized by poor species composition of the biota. The most common animals are bottom rotifers and tardigrades. These invertebrates live on the surface of bottom sediments and cyanobacterial mats, not dropping below the upper layer a few centimeters thick; their source of food is bacterial detritus. The organisms found here were found in cyanobacterial mats from various lakes in other Antarctic regions, including small lakes in the Thala Hills region (Dartnall and Hollowday, 1985; Hansson et al., 2012; Hodgson et al., 2010; Ingole and Parulekar, 1993 ; McInnes and Pugh, 1998; Opalinski, 1972; Sanyal, 2004; Verlecar et al., 1996, etc.).

Other lakes in the area of the Molodezhnaya Station were investigated once, in the summer season of 2011 (Filatov et al., 2013). The species composition of phytoplankton was extremely poor. Benthic forms of algae and cyanobacteria predominated in the lakes, however, as a result of wind-wave mixing of water, part of the organisms of phytobenthos and phytoperiphyton appeared in large numbers in plankton. The species composition of phytoplankton was generally similar to Lake Deep, dominated by cyanobacteria from the genera *Oscillatoria* and *Phormidium*. The total biomass of phytoplankton averaged 0.02 ± 0.01 mg/L, and the chlorophyll *a* content was 0.2 ± 0.1 μg/L.

Novolazarevskaya Station (Schirmacher oasis)

Eleven lakes in the area of Novolazarevskaya station were investigated at the end of the 2011 summer season. Lakes in the region are relatively well studied thanks to long-term research that began in 1959. The studied lakes in the Schirmacher oasis include three different types: permanently covered with ice (Smirnova, Ledyanoe), opened (Verkhneye, Skuas, Glubokoe, Geodezistov, Krasnoe, Zub), epishelf (Privalnoe). A good indicator of climate change is the long-term dynamics of ice cover variability in the warm period, its thickness and coverage area. It is known (Zakharov, 1970) that Lake Glubokoe in the 1960–1970s was

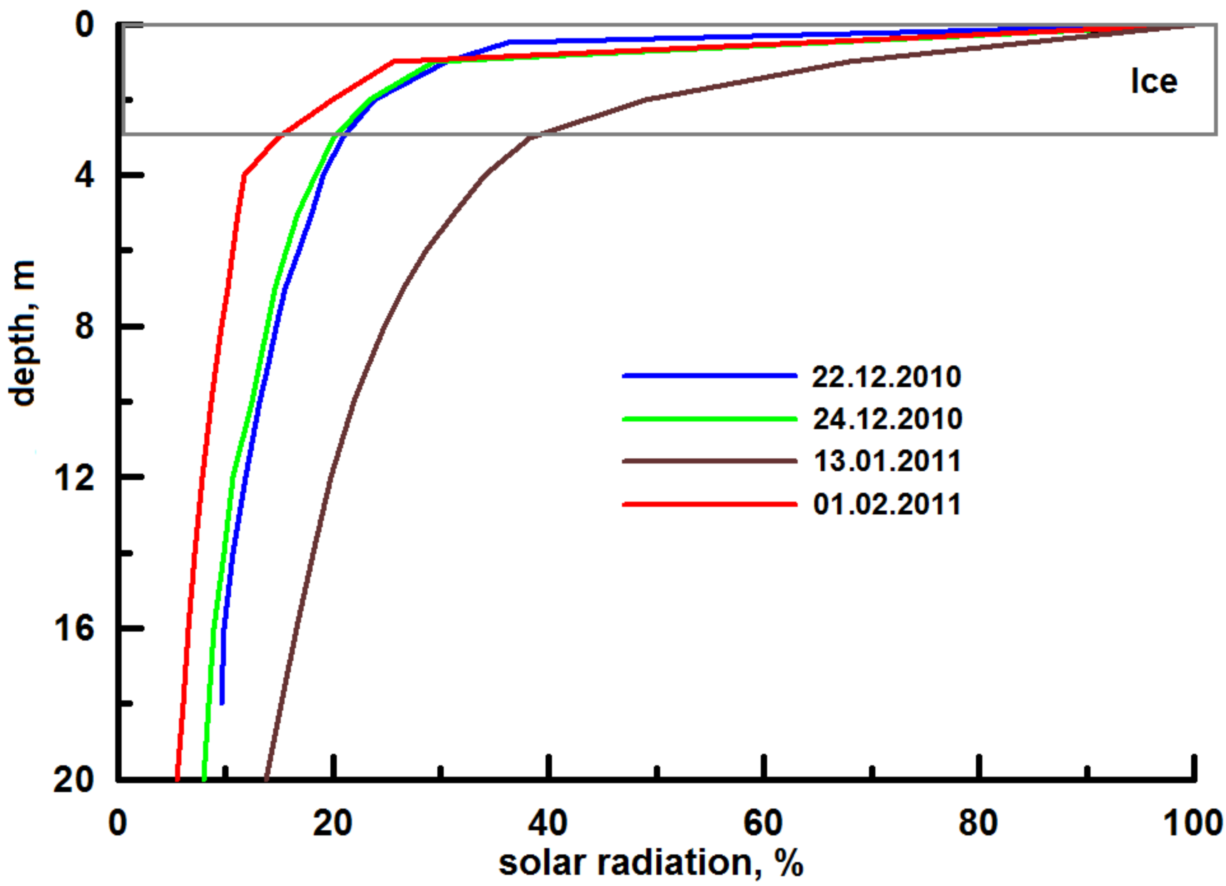

Fig. 3. Change in incoming short-wave radiation (Lake Glubokoe, Thala Hills oasis).

not opened, and the thickness of the ice in it reached 3–3.5 m. Currently, Lake Glubokoe in the Schirmacher oasis is completely free of ice cover every summer. In addition, on the 1972 map (T-05478 dated 05/29/1972, prepared by the Soyuzmorniiproekt as of January 1961) it can be seen that the configuration of some lakes (for example, Upper and Glubokoe) is different from the modern one, since part of the surface was covered by snowfields that are now absent. All this probably indicates climate warming in the area of the Schirmacher oasis.

Compared with the reservoirs of the Thala Hills oasis, ablation processes are more active in the Schirmacher oasis, which leads to an increase in the period of open water at the opening lakes, including the deepest reservoirs. After the ice melts, convection occurs rather quickly, the temperature stratification of the opening lakes is disrupted, and the water mass isothermal sets in. The dynamics of hydrophysical parameters of the glacial lakes of the Schirmacher oasis during our studies also showed the development of convection in them due to melt water. In general, the same processes were recorded here as in the deep lakes of the Tal Hills oasis (Lagernoe and Glubokoe) in late January – early February. Among the objects of our research, direct stratification was recorded only in the epishelf of Lake Privalnoe, but the gradients were shown to be low.

The content of chlorophyll *a* in the water of the studied lakes ranged from 0.05 to 0.25 µg/L. The lowest concentrations were found in Lake Verkhneye, whose water is used to supply the station. These concentrations are extremely low even for the lakes of Antarctica (Andreoli et al., 1992; Contreras et al., 1991; Henshaw and Laybourn-Parry, 2002; Laybourn-Parry et al., 1992).

In the Schirmacher oasis region, 218 species of cyanobacteria and algae are known (The Shirmacher..., 1995). In addition to the plankton of lakes, this number includes organisms that inhabit bottom, rock and snow habitats. During our research, the phytoplankton of lakes was characterized by an extremely low abundance. In addition to cyanobacteria genera characteristic of the Antarctic (*Oscillatoria*, *Nostoc*, *Gloecapsa*, *Chroococcus*, *Phormidium,* and *Lyngbya*, and also the species *Stenomitos frigidus* (= *Pseudanabaena frigida*) (F.E. Fritsch) Miscoe and J.R. Johansen, 2016, the assemblage contains typical phytoplankton taxa of northern lakes: the diatoms *Aulacoseira granulata* (Ehrenberg) Simonsen, 1979*, Lindavia comta* (= *Cyclotella comta*) (Kützing) Nakov, Gullory, Julius, Theriot and Alverson, 2015*, Tabellaria fenestrata* (Grunow) Skabichevskii, 1960*, Diatoma elongatum* (Lyngbye) C. Agardh, 1824*, Asterionella formosa* Hassall, 1850*, Fragilaria pinna-*

ta Ehrenberg, 1843, green algae *Crucigenia* spp., *Scenedesmus* spp., and charophytes *Cosmarium* spp. The main accumulations of organisms were in cyanobacterial mats and periphyton. The cyanobacteria *Stenomitos frigidus* (*Phormidium frigidum*) (F.E. Fritsch) Miscoe and J.R. Johansen, 2016. prevailed at the bottom of the lakes.

Progress station (Larsemann Hills oasis)

Investigations in the vicinity of the Progress station were conducted in March 2011. Progress, Reid, and Stepped Lakes were studied, in which the inverse temperature stratification was recorded at that time. The oxygen saturation at the time of measurement in all lakes was 100% over the entire thickness of the water mass. Compared to other Antarctic lakes, an increased water salinity is recorded in the Larsemann Hills oasis, apparently due to the influence of rocks composing the lake basin, as well as the proximity of the Cooperation Sea.

Lake Progress contains an epilimnion 18 m deep, metallimnion from 18 to 22 m in depth, and the hypolimnion from 20 to 31 m in depth. In the bottom water horizon of the the temperature (about 4 °C) is close to the values characteristic of water with a maximum density. The salinity of the water mass at the bottom is 0.2‰, which is the lowest of all the lakes of the Larsemann Hills oasis. The pH values are close to those of a neutral medium (7.12 on the surface and 7.34 in the bottom layer).

The depth of Reid Lake near the Australian field base Low reaches about 5 m, the ice thickness is up to 40 cm. At the point of our measurements, the water temperature (4.2 °C) corresponded to the values typical of water with a maximum density. This is the most saline of the three lakes we studied (1.6 on the surface, 2.5‰ at the bottom). The pH is 7.18.

In Lake Stepped, maximum depth was 5 m, the ice thickness during the measurements was 20 cm. The water temperature in the icehole was 0.80 °C, under the ice was 3.33 °C, and at the bottom it was 4.48 °C. The salinity of the lake is 1.1‰, the pH is 7.07.

In the lakes, black colored bottom sediments and intense gas emission with a characteristic swamp smell were detected, which indicates ongoing anaerobic processes. On Reid and Stepped Lakes massive floating of cyanobacterial mats was observed. Most of them were frozen in ice on various layers, and dried mats lay on the shores of the lake. The surface layer of bottom encrustations contains accumulations of various species of cyanobacteria, algae and bdelloid rotifers. The mats are mostly composed of the filamentous cyanobacteria Oscillatoriales. The bottom mats of Stepped Lake contain tardigrades (10 specimens/mg), nematodes and two species of rotifers *Lepadella patella* and Philodinidae sp., various species of cyanobacteria and dead diatoms. In the water column, the cladoceran *Daphniopsis studeri* Ruhe, 1914 was present in large numbers (more than 1000 specimens/m^3), and their number increased at the bottom. The abundant development of invertebrates in Stepped Lake is probably due to the nesting of skuas on the shores, which bring a large amount of nutrients with their droppings.

Moss was found at the bottom of some lakes in Antarctica (Li S.-P. et al., 2009; Korotkevich, 1958; Kurbatova and Andreev, 2015; Simonov, 1971). In the oasis of the Thala Hills, we did not find a single lake with moss content in bottom samples, while in the oases of Schirmacher and Larsemann Hills, moss is found in many lakes. Moss at the bottom of Lake Glubokoe (Schirmacher oasis) has three distinct layers at different column depths. Accumulations of stems indicate favorable conditions for moss growth during certain periods of the lake evolution, which may be associated with the presence or absence of ice cover. In lakes Pomornik (Schirmacher oasis) and Progress (Larsemann Hills oasis) the bottom growth contained the deep-sea moss *Bryum pseudotriquetrum* P.G. Gärtner, B. Meyer and Scherbius, 1802, most common in Antarctica (Li S.-P. et al., 2009; Kurbatova and Andreev, 2015), and in Lake Deep (Schirmacher oasis) – *Plagiothecium orthocarpum* Mitten., 1869, which has not yet been found in other lakes of Antarctica (Li S.-P. et al., 2009).

Conclusions

Low quantitative indicators (chlorophyll *a* content 0.1–0.45 μg/L; phytoplankton biomass 0.02 ± 0.01 mg/L) and species diversity are characteristic features of Antarctic lakes. There is no classical food chain, and the microbial loop predominates, with the energy flow that passes through the benthos community.

The observed climate change trends over the past 50 years in some areas of East Antarctica are mixed. In the oasis of Thala Hills, no noticeable changes were detected, however, there is an increase in the variability of meteorological parameters over a long period. So, now there is an increase in days with strong winds, precipitation and blizzards in the summer period compared to the 1960s. In the Schirmacher oasis, climate warming is observed. Here since the 1970s to date, there has been a change in the configuration of the lakes (snowfields have melted along the shores), some lakes have moved from the category of permanently covered with ice to the category of an opening lake.

The main reaction of the lakes of the Antarctic oases to climate change is manifested in a change in the ice regime. The peculiarity is that freeing from ice does not lead to an increase in the vegetation period, as is typical for lakes in East Fennoscandia (Filatov et al., 2012). After the ice melts, the water mass rapidly cools from the surface to the bottom because of heat spent on thawing, radiation cooling, evaporation under the influence of wind-wave mixing. In this case, an isotherm with a temperature of 0.5 °C is established, which is at least 3 °C lower than in lakes covered with ice.

The optical properties of the water and ice of the studied Antarctic lakes allow a sufficient amount of light to pass to a depth of more than 30 m, which together with a constant water temperature of about 4 °C, provides good conditions for the development of cyanobacterial mats and moss at the bottom of the lakes.

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