Short communication

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Relationships of hydrochemical and biological indicators in the under ice water of Lake Baikal in the spring period. Analysis using correlation networks

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ABSTRACT. This study demonstrates that phytoplankton remain the dominant controllers of the chemical composition of dissolved matter in the coastal waters of Lake Baikal during its ice period. Massive planktonic blooms from March to May lead to the accumulation of dissolved biogenic elements and carbon dioxide, thereby maintaining the stable chemical composition of littoral waters. As it was before, the pH of Baikalian waters is regulated primarily by the reversible synthesis of hydrocarbonate and carbonate ions, which is induced by phytoplankton development and the accumulation of dissolved carbon dioxide in algal cells. We show that the littoral area of Lake Baikal near Listvennichny Bay is heavily polluted by easily oxidized anthropogenic organic matter. Biogenic elements produced during the bacterial destruction of this matter may explain the changes in bottom phytocenoses.

Keywords: Lake Baikal, phytoplankton, ice cover, chemical composition of water, bacterial communities

1. Introduction

Lake Baikal hosts an extremely complex ecosystem with a plethora of interspecies interactions. The purity of its waters is passively supported by the low mineralization of the river inflow and actively maintained by the orchestrated work of the algal community (phytoplankton) and bacterioplankton in the pelagic zone. The complex biochemical processes happening in this community maintain the balance of dissolved inorganic and organic matter in the water of Lake Baikal. Phytoplankton development leads to the accumulation of dissolved salts that contain biogenic elements as well as the transformation of those salts into insoluble forms. Bacterioplankton, in turn, is responsible for the destruction of organic matter produced by the algae. In this way, dissolved matter is constantly leaving the water column and sinking to the bottom of the lake floor where it forms sediments. During the last few years, there have been significant changes in the lake ecosystem, particularly in coastal and pelagic zone (Kravtsova et al., 2014; Timoshkin et al., 2016; Bondarenko et al., 2019)

The main goal of this work was to study the hydrochemical parameters of water and the functional characteristics of the communities of algae and bacteria in ice water and in ice samples in estuarine zones of rivers with varying degrees of anthropogenic load, and assess the impact of stress factors of eutrophication and acidification on the course of key environmental processes.

2. Material and methods

In March 2018, water was sampled from Lake Baikal's southeastern and southwestern coasts in the river mouths and from the lake waters near the rivers. Samples were also taken from two reference stations in the lake's pelagic zone (51.53875 N, 104.19746 E and 51.86710 N, 104.83247 E) (Fig. 1). The lower reaches of the Solzan (51.49722 N, 104.15836 E), Bolshaya Osinovka (51.50056 N, 104.24403 E) and Malaya Osinovka (51.50056 N, 104.25354 E) rivers pass through the town of Baikalsk and its industrial area. The Pereemnaya River (51.56891 N, 105.16609 E) does not pass through any settlements in its entire course. The lower reaches of the Kamenushka (51.84457 N, 104.87505 E), Krestovka (51.85535 N, 104.85970 E), and Bolshaya Cheremshanaya rivers (51.84429 N, 104.83949 E) pass through the Listvyanka settlement.

This study examined parameter: concentrations of organic carbon (C_{org}) and chlorophyll *a* (Chl_a), total phytoplankton mass (ΣPB), total rate of methane oxidation (ΣMO), count of organotrophic bacteria (OB), count of thermotolerant bacteria cultivated at 22°C

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(TMC22C), count of thermotolerant bacteria cultivated at 37°C (TMC37C), biogenic oxygen depletion (BOD), and total primary production rate (ΣPP), which is the rate of light-dependent CO_2 assimilation, total bacterial count (NB), and total bacterial primary production (ΣBP) which is the rate of *dark-assimilation* CO_2, concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-; concentrations of biogenic elements such as $N(NO_2^-)$, $N(NO_3^-)$, $S(SO_4^{2-})$, $N(NH_4^+)$, $P(PO_4^{3-})$; concentration of dissolved carbon in carbon dioxide $C(CO_2)$ and methane $C(CH_4)$; oxygen concentration (O_2); chemical oxygen depletion (COD); and water pH.

Pairwise correlations between all parameters (either biological or hydrochemical) were estimated with Spearman's *r* correlation coefficient. The correlation matrix was visualized as a network using the «qgraph» and «igraph» packages in R. The network topology was based on the number of links and correlation coefficients between neighboring nodes. The more links the nodes form among themselves, the closer they were placed in the network. To estimate the overall connectedness of the nodes in this network, we used normalized betweenness centrality (Freeman, 1978) and each node's edge count.

3. Results and discussion

Our work is one of the first to apply an integrated approach to studying the mechanisms of functioning of the ecosystem of the water column of Lake Baikal. It allows us to conclude that when developing the standards for acceptable anthropogenic load on oligotrophic and ultra-oligotrophic lakes, it is necessary to take into account not only pollution by dissolved biogenic elements $N(NO_2^-)$, $N(NO_3^-)$, $S(SO_4^{2-})$, $N(NH_4^+)$, $P(PO_4^{3-})$, but also the flow of organic carbon. Large flow of organic matter of anthropogenic origin under conditions of high oxygen concentration will activate organotrophic bacteria producing carbon dioxide (CO_2). Large concentrations of carbon dioxide will activate photosynthesis processes causing undesirable consequences, including mass developments of filamentous algae and cyanobacteria.

Acknowledgments

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References

Bondarenko N.A., Ozersky T., Obolkina L.A. et al. 2019. Recent changes in the spring microplankton of Lake Baikal, Russia. Limnologica 75: 19-29. DOI: 10.1016/j.limno.2019.01.002

Freeman L.C. 1978. Centrality in social networks conceptual clarification. Social Networks 1: 215-239. DOI: 10.1016/0378-8733(78)90021-7

Kravtsova L.S., Izhboldina L.A., Khanaev I.V. et al. 2014. Nearshore benthic blooms of filamentous green algae in Lake Baikal. Journal of Great Lakes Research 40: 441-448. DOI: 10.1016/j.jglr.2014.02.019

Timoshkin O.A., Samsonov D.P., Yamamuro M. et al. 2016. Rapid ecological change in the coastal zone of Lake Baikal (East Siberia): is the site of the world's greatest freshwater biodiversity in danger? Journal of Great Lakes Research 42: 487-497. DOI: 10.1016/j.jglr.2016.02.011