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Role of natural and climatic factors in formation of autochthonic organic substance streams in small lakes of the south of Western Siberia

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ABSTRACT. The main objectives of this study are to identify the role of external physical and chemical factors in productivity formation of small lakes ecosystems in the south of Western Siberia as well as to assess the impact of these factors on some ecosystem elements (phyto- and zooplankton, macrophytes, benthos) in the light of climate change. The explored lakes are along a 700 km south-north transect latitude from 51°15'N for 56°45'N in the territory within Altai Krai and the Novosibirsk region, in four broadly defined vegetation zones: dry-steppe, steppe, forest-steppe and subtaiga. The lakes have different mineralization (from 0.01 to 67.88 g/dm^3), pH value (from 6.3 to 9.96), dissolved oxygen content (3 – 13 mg/dm^3), BOD_5 (0.28 – 8.32 mgO_2/dm^3), hydrocarbonates, chlorides, sulphates, nitrates, phosphates and calcium. The determining factors in the formation of total production of aquatic ecosystems in the dry steppe zone (primary phytoplankton production, primary production formation in submerged plants, zooplankton and zoobenthos production) are pH and mineralization (94% of explained dispersion) and in the steppe zone – also pH and salinity, but to a lesser degree (65%). In the north, the role of mineralization and strong response of the medium decreases, whereas the sum of temperatures and ion balance of water increases.

Keywords: Key words: lakes, phytoplankton, zooplankton, macrophytes, zoobenthos, abiotic factors

1. Introduction

Aquatic ecosystems, especially small lakes, are influenced by numerous global and regional factors, which provide and regulate the production at all levels of any aquatic ecosystem thus affecting them overall. These factors can vary both in parallel and independently creating new combinations and changing the degree of their impact on any ecosystem component. Particular attention should be paid to the risks of climate change-induced transformations of small lake ecosystems. Fluctuations in temperature, precipitation amount, water exchange with the catchment area, including ionic composition variations caused by changes in evaporation conditions can irreversibly transform ecosystems as a whole, and their production characteristics, in particular.

In biochemistry terms, Western Siberia is a complicated region consisting of vast areas with low and high natural content of macro-and microelements in the environment. Such sites are located in different natural areas and geomorphological structures; they differ in composition and a number of elements in the food chain. Lakes with different types of hydroecosystems and different chemical composition of water and bottom sediments can be found in the same catchment area. The main objectives of this study are to identify the role of external physical and chemical factors in productivity formation of small lakes ecosystems in the south of Western Siberia as well as to assess the impact of these factors on some ecosystem elements (phyto- and zooplankton, macrophytes, benthos) in the light of climate change.

2. Material and methods

The explored lakes are along a 700 km south-north transect latitude from 51°15'N for 56°45'N in the territory of the South of Western Siberia within Altai Krai and the Novosibirsk region. The lakes were

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situated in four broadly defined vegetation zones: dry-steppe, steppe, forest-steppe and subtaiga. The lakes were saucer-like, small- to medium-sized (2.5–1600 ha) basins that were rounded in shape and about 1-3 m in depth.

Samples were collected from the lakes between 15 July and 24 August 2012-2017 years. We explored and analysed 70 lakes. Morphometric and geographical-environmental variables recorded for each site. Field measurements were made of water transparency, conductivity, water temperature, dissolved oxygen content (by titrimetry), biochemical oxygen demand over five days (BOD_5) and pH.. At a research of lakes studied productional characteristics of phytoplankton, zooplankton, zoobenthos and macrophytes. Phytoplankton samples were taken from surface water layer, fixed by 2–3% formalin solution, and concentrated by direct filtration through Vladipor membrane filter, grade MFAS-MA no. 6 with pore diameter of 0.3 μm. The abundance of phytoplankton was evaluated by counting–volumetric method (Guide…, 1992). Zooplankton samples were taken by filtering 100 L of water through Apshtein net with a mesh diameter of 64 μm. The zooplankton samples were fixed and treated in the office by standard methods (Guide…, 1992). The production was evaluated following the accepted methodological recommendations (Vinberg, 1984) for each zooplankton group separately. Organic matter primary production and destruction were determined by light-and-dark-bottle method in oxygen modification. Macrophyte production was examined by standard methods (Guide…, 1992) on test grounds located in phytocenoses dominating in the examined areas. To determine the composition and abundance of the sedimenting lake suspension and the quantitative parameters (matter flux per unit bed area), experiments with sediment traps were carried out (Yermolaeva et al., 2016).

3. Results

The lakes have different mineralization (from 0.01 to 67.88 g/^{d}m3), pH value (from 6.3 to 9.96), dissolved oxygen content (3 – 13 mg/^{d}m3), concentrations of organic matter (according to B_OD5 0.28 – 8.32 m_gO2/^{d}m3), hydrocarbonates, chlorides, sulphates, nitrates, phosphates and calcium. Primary phytoplankton production in the studied lakes varies widely. The most productive lakes are situated in the forest-steppe and sub-taiga zones, where gross primary production ranges from 1.14 to 1.96 m_gO2/l·h. The lakes in the dry steppe and steppe zones are less productive (0.01 – 0.9 m_gO2/l·h). The annual total production of macrophytes also varies greatly (60.8 5309.0 g/m2·year in air-dry weight). The lakes from the forest-steppe zone are most productive; the main producer of organic matter here is semi-submerged vegetation. Biomass production makes up 1046 3974 g/m2·year in air-dry weight. Submerged vegetation, the production of which ranges from 708 to 1790 g/m2·year in air-dry weight, plays a big role in the formation of organic matter. Zooplankton production also varies significantly (5.54 – 952 g/m3·year). We have not established the explicit dependence on lakes location in one or another natural zone, but mostly the most productive lakes are located in the steppe zone. Often, lakes with high and low rates of total zooplankton production are situated within the same catchment area. Each studied natural area is distinguished by its own ratio of products of different groups. Rotifera in the forest-steppe zone demonstrates the highest rates of production (3.53 g/m3·year on average), and in the steppe and dry steppe – minimum ones (1.54 g/m3·year on average). Cladocera is also most developed in the lakes of the forest-steppe zone (on average, 177 g/m3·year), and its least production is registered in the lakes from the subtaiga zone (on average, 44.5 g/m3·year). As for Copepoda, its highest average production is noted in the steppe and dry steppe zones (58.8 g/m3·year), while the lowest – in the subtaiga ones (28.5 g/m3·year). Maximum biomass of bottom macroinvertebrate communities is typical for lakes of the arid-steppe subzone (6.1–10.5 g/m2). Minimum zoobenthos number (0.7–1.3 th. ind./m2) and biomass (1.0–2.0 g/m2) are recorded in the dry-steppe subzone (low and moderate productivity classes).

4. Discussion

We offer at our own version of the classification of sapropels. Depending on the composition of organic and mineral parts (ash content) sapropels are divided into types*: organogen*ic with ash content up to 30 %*; organominer*al (30-50%)*; mineral-organogen*ic (50-70%) an*d mineraliz*ed (70-85%). Bottom sediments with ash content above 85% are mineral silts. The sapropel composition is determined by the species composition and the degree of biota productivity (Strakhovenko et al., 2016). Phytoplankton actively extracts nitrogen and phosphorus from water thus reducing the amount of organic substances in the water and increasing their content in the bottom sediments. The contribution of phytoplankton to organic flux is particularly significant during blue-green algae blooming. Dispersion analysis suggests that the formation of primary phytoplankton production during the vegetation period in the studied lakes is mainly influenced by such factors as the sum of positive temperatures for the vegetation period and the content of dissolved oxygen in water. Being sensitive to the increased concentration of chlorides (note: only increase in chlorides concentration up to 1 g/l brings to an increase in phytoplankton production), phytoplankton production is practically independent of mineralization. At the same time, with phytoplankton production growth, an increase in nitrogen compound concentrations occurs in water due to the rapid development of nitrogen-fixing cyanobacteria (Strakhovenko et al., 2014).

The processes of primary production formation in submerged plants are most intensively influenced by the concentration of sulfate ions and dissolved oxygen (64.3 and 59.3% of the explained dispersion, respectively). The sum of effective temperatures (58.8%) and acidity (pH) (69%) are also of great importance.

Zooplankton production is less limited by abiotic factors. With mineralization increase, solely species amount significantly decreases. Cladocera, Rotifera, Copepoda respond to environment gradients changes in a different way. Often, such a response is multidirectional. Zooplankton production mainly depends on Cladocera and the amount of organic substances in water (according to BOD_5). Massive development of Cladocera enriches bottom sediments with phosphorus. With pH increase, production of Rotifera and Copepoda increases reaching its maximum at $8.5 \leq pH \leq 9.5$. Copepoda contribute to the conservation and deposition of nitrogen/

Amphibiont insects contribute to the removal of organic matter from bottom sediments to land. Maximum values of macrozoobenthos biomass are characteristic of oligohaline and subsaline lakes; minimum macrozoobenthos biomass is observed in meso - and hypersaline lakes. Temperature, water transparency and pH suggest a positive significant ($p < 0.05$) correlation with biomass ($r = 0.66$) and density ($r = 0.64$) of macrozoobenthos.

The determining factors in the formation of total production of aquatic ecosystems in the dry steppe zone are pH and mineralization (94% of explained dispersion) and in the steppe zone – also pH and salinity, but to a lesser degree (65%). In the north, the role of mineralization and strong response of the medium decreases, whereas the sum of temperatures and ion balance of water increases.

5. Conclusions

In the south of Western Siberia, local abiotic factors have major impact on the formation of small lakes ecosystems thus determining their species diversity, the quantitative ratio of different components and production characteristics and, in most cases, prevailing over global factors. However, our study shows that there are general dependencies related to climatic characteristics change in different natural zones. One of the main global factors is the sum of positive temperatures during the vegetation period. From south to north, the role of this factor in the formation and functioning of aquatic ecosystems increases. Hence, global warming accompanied by average annual temperature growth, will primarily affect the lakes situated in the forest-steppe and subtaiga zones. At the same time, the rapid development of phytoplankton, including toxic blue-green algae, and the increased productivity of lake ecosystems as a whole are expected. This can lead to the increased in synthesis of autochthonous organic matter and, as a result, to severe eutrophication of lakes, deterioration of oxygen regime and water quality as a whole.

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References

Guide for Hydrobiological Monitoring of Freshwater Ecosystems. 1992. In: Abakumov, V.A. (Ed.). St. Petersburg: Gidrometeoizdat. 318 p. (in Russian)

Strakhovenko V.D., Roslyakov N.A., Syso A.I. et al. 2016. Hydrochemical characteristic of sapropels in Novosibirsk oblast. Water Resources 43(3): 539-545. DOI: 10.1134/S0097807816030167

Strakhovenko V.D., Taran O.P., Ermolaeva N.I. 2014. Geochemical characteristics of the sapropel sediments of small lakes in the Ob-Irtysh interfluves. Russian Geology and Geophysics 55(10): 1160-1169. DOI: 10.1016/j.rgg.2014.09.002

Vinberg G.G. 1984. Zooplankton and its production. In: Methodological Recommendations on the Collection and Processing of Materials in Hydrobiological Studies in Freshwater Bodies, Leningrad: GosNIORKh, ZIN AN SSSR, pp. 1-34. (in Russian)

Yermolaeva N.I., Zarubina E.Y., Puzanov A.V. et al. 2016. Hydrobiological conditions of sapropel formation in lakes in the South of Western Siberia. Water Resources 43(1): 129-140. DOI: 10.1134/S0097807816010073