Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2020, 10(3), 102-105, doi: 10.15421/2020_140

ORIGINAL ARTICLE

Influence of temperature on the aquatic biota

N.Ya. Rudyk-Leuska[1], N.Yu. Yevtushenko[1], M.I. Khyzhniak[1], M.V. Leuskyi[1], R.V. Kononenko[1], N.I. Tson[2], O.Y. Dumych[3]

[1] National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
[2] Lviv Research Station of the Institute of Fisheries NAAS, Lviv, Ukraine
[3] Ivan Franko National University of Lviv, Ukraine

**Corresponding author E-mail: rudyk-leuska@ukr.net*

Received: 13.06.2020. Accepted: 23.07.2020

Detailed analysis of temperature indicators of Kremenchug reservoir in August showed a tendency to increase the coefficient of their variation (Cv=10.69–13.97%). This is indicated the unstability and stress of the temperature conditions of the aquatic environment for the living organisms. First of all, it affected the organisms of near-flood layers of water which are in direct contact with unstable air masses (Cv=28.45–31.45%). Blue-green algae species which were the most resistant to temperature fluctuations were *Microcystis aeruginosa Kutz. emend. Elenkin* and *Anabaena flos-aquae sp.* Their maximum values were recorded in the water area near the village Chervona Sloboda. An impact of a temperature factor and a number of other abiotic factors leads to intensive water "bloom" and subsequent mass extinction of algae *Cyanophyta*. Hot sunny days with the air temperature up to 18-32 °C and water temperature of 21.0–25.8 °C are the most dangerous to aquatic biota. As a result of lethal consequences, significant amounts of the most sensitive species of aquatic living organisms fall out of the ecosystem: Noble crayfish (*Astacus astacus*) and Zander (*Sander lucioperca*). The obtained results could be partially explained by the global warming.

Keywords: tmperature; ecological conditions; aquatic organisms; Kremenchug Reservoir

Introduction

The changes in air temperature we are witnessing become more and more noticeable every year and are constantly pointing us to climate change (UN Framework Convention, 2000). They are also reflected in changes in the temperature conditions of inland water bodies. One of such sensitive water bodies is the Kremenchug Reservoir, the largest reservoir in Ukraine. A detailed analysis of the literary studies the development of phytoplankton of this reservoir in 1961-1984 and is presented in the works of S.V. Kruzhilina (Kruzhilina, 2010) and we did our own research in 1981-2007.

The development of phytoplankton is constantly influenced by a number of biotic and abiotic conditions. A statistically significant direct correlation between phytoplankton development parameters and amount of solar radiation, water temperature, and content of oxygen dissolved in water has been established. There is a direct correlation between the total solar radiation (Q) and such indicators as the number of phytoplankton species, biomass and water temperature. Spring maximum of total solar radiation (Q) reaches 293 MJ/m^2 when is observed an intense develpoment of *Bacillariophytae* family *(Asterionella Hassal, Cyclotella Kütz. Navicula Bory, Nitzschia Hassal, Stephanodiscus Ehrenb., and Synedra Ehrenb.*). In June-August the quantity of sunny days and water temperature rise to 16-24°C, and registered maximum of solar radiation was in the range of 530-605 MJ/m^2. At that period the amount and biomass of phytoplankton increased but the amount of phytoplankton species decreased (Zadorozhnaya & Shcherbak, 2016).

The main source of water supply, as well as additional ones (this may be permanent, periodic rain and underground sources) are of great importance in these processes. Permanent sources of aboveground and underground water, sewages, periodic rainwater, filtrates with soil minerals, water with agrochemicals of agricultural fields, wastewater with organic matter from pastures and other that fall into the reservoirs with rain. After that the content of dissolved nutrients increases in the reservoir and this often causes an increase in the intensity of phytoplankton development until the water "bloom".

As a result of experiments conducted in natural and model conditions, it was found that during the intensive development of blue-green algae, when "flowering" occurs, specific substances are released metabolites that have a strong influence on the formation of phytoplankton and bacteriocenosis. The toxins produced by blue-green algae are characterized by a wide spectrum of antimicrobial action on saprophytic, pathogenic and potentially pathogenic microorganisms and viruses (Sirenko & Kirpenko, 2000). At the same time, an excessive increase in the numbers of algae during the period of waterbloom, their die-off, and release of large amounts of organic compounds readily soluble in water are favorable for the development of microorganisms accompanying blue-green algae, including representatives of the pathogenic microflora (Sirenko & Kirpenko, 2000). It is established that, freshwater cyanobacteria (blue-green algae) *Microcystis aeruginosa* and *Anabaena flos-aquae* produce hepatotoxic peptides, which cause the signs of poisoning in mice (LD_{50}=50 µg/kg) (Krishnamurthy et al., 2002).

Various toxic compounds are constantly present in the aquatic ecosystem, but this is not manifested because aquatic organisms have a number of specific protection systems. It was found that a sharp increase in the concentration of ammonium nitrogen NH4 + leads to inhibition, and ultimately to the death of the culture of blue-green algae and NH4 + ions have no inhibitory effect on the growth of chlorococcal algae. It was found that in the culture of Chlorococcales algae there are concomitant bacteria associated with them, and due to them the amount of ammonium nitrogen in the environment decreases (Gorbunova et al., 2001).

For example, crustaceans are resistant to the high concentrations of heavy metals in the water at the genetic level (Lopes et al., 2006). The fishes have a detoxification system, removing toxic substances through the gills, kidneys, skin (Birungi et al., 2007).
Under the influence of various environmental factors, the biotopes of the Kremenchug Reservoir undergo constant changes in time and space. Each of its parts is unique from the biological and practical points of view. Changes in environmental conditions, up to extreme values, require constant monitoring of the situation.

Materials and Methods

We focused on three specific sections of the Kremenchug Reservoir: in the area of the village of Chervona Sloboda, the village of Lesky and the village of Khudyaky in August 2016, which are located in the middle part of the Kremenchug Reservoir. The peculiarity of this water area is the predominance of floodplains, shallow water with a depth of 0.5–0.9 m to 2-4 m, well warmed, overgrown mainly with floating and reed. The soil here is mostly sandy, sometimes stony. Sampling was performed with a Rutner bathometer. Fixation, concentration, processing of algological samples were performed in accordance with hydrobiological methods (Romanenko, 2006). The water temperature was recorded daily. The results of temperature observations and hydrochemical analyzes of the Cherkasy meteorological station and the archive of weather conditions from the weather sites vikka.ua and meta.ua (2016) were taken into account. At the same time, we fixed t_{max}, t_{min}, t_{med}.
Statistical processing of the data was performed using Statistica v.10 and Microsoft Excel software.

Results and Discussion

The air temperature was changed from 19 to 27 °C (Fig. 1), and the water temperature was ranged from 18 to 24 °C (Fig. 2) in August. The temperature contributed to the maximum development of the *Chlorophyta* algae which are the most valuable in nutritional value for invertebrates and fish group. The highest algae quantity we recorded in the water area of the village of Lesky, especially of the following species as *Micractinium pusillum Fresen, Volvox aureus Ehrenb.* and *Pandorina morum (O. Müll.) Bory.*
In the future, the temperature fluctuated, reaching a critical level of air up to 29-32 °C and of water up to 25-26 °C (Fig. 2). At the same time, we observed a slowdown in the development of most groups of algae, except *Cyanophyta*. This process is explained by the fact that the temperature optimum for blue-green algae is shifted towards higher temperatures, namely ≥25°C (Zadorozhnaya, 2016). *Microcystis aeruginosa Kutz. emend. Elenkin* and *Anabaena flos-aquae sp.* stood out in development - their maximum quantitative values were recorded in the water area near the village Chervona Sloboda.
We supposed that the most intensive "blooming" of water occurs on hot sunny days. In this case, the number of photosynthetically active radiation (PAR) will be decisive. PAR is an important input parameter for the increasing of plant productivity. Special studies have been conducted to determine whether a cloudy day and a sunny day have a direct effect on the amount of active photosynthetic radiation. The most informative is the ratio of PAR to the total solar radiation (SR). The highest values were observed in July (0.459). The index PAR/SR has negative correlation with the cloudiness index ($r = -0.36$, $P < 0.001$) and positive correlation with atmospheric water vapor pressure ($r = 0.47$, $P < 0.001$) (Bat-oyun et al., 2012).
We calculated the coefficient of determination (D) which characterizes the level of influence of factors on the resultant trait shows: if $D = r^2 = 0.36^2 = 0.13$, if $D = r^2 = 0.47^2 = 0.22$. Thus, cloudiness and partial pressure have only 13% and 22% influence on the amount of photosynthetically active radiation, respectively, and the remaining 82% and 78% are the influence of other factors. So, in the Kremenchug reservoir addition to the influence of temperature and clouds, a number others of external abiotic factors were imposed. Every year Cherkasy meteorological station signals about deterioration of water quality indicators of the Kremenchug reservoir in the summer. Increased concentrations of nutrients were recorded in the reservoir: the content of ammonium nitrogen was 1.4-1.5 times higher than the maximum permissible concentrations, nitrate nitrogen was 2.2-2.4 times higher than the maximum permissible concentrations SOU (SOU, 2006). It has been revealed that a sharp increase of the NH_4^+ concentration leads to inhibition, and eventually to the death of of blue-green algae culture (Gorbunova et al., 2001).
Further, during hot sunny days of August 6-8 intensive "blooming" of water was observed, the temperature reached its maximum: air 18.0-32.0 °C water 21.0-25.8 °C. During the day a large-scale death of aquatic organisms: mainly algae *Cyanophyta*, Noble crayfish (*Astacus astacus*), Zander (*Sander lucioperca*) was observed (Crayfish, 2016). For both animal species, the temperature exceeded the optimal values of t_{opt}=18-20 °C (Likhareva, 1989) and t_{opt}=6–22 °C (Zander, 2014), so 24 °C and 25 °C were critical for them. During the month, the water temperature varied in the range of 17.0-26.2 °C (Fig. 2). An amplitude of oscillations between the extreme values was 9.2 °C (Fig. 3). That was less than the difference in air temperature, but still indicated a negative impact on the aquatic environment. The daily amplitude of water temperatures was 4.20 ± 0.43 °C (Cv=55.08%) – that was 6 °C less than the air index, due to the large heat capacity of water masses and high temperature inertia.

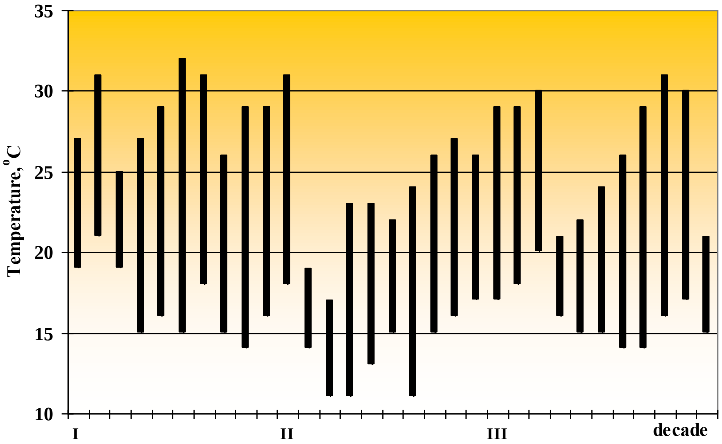

Figure 1. Climatogram of air of Kremenchug reservoir, August 2016 (min–max).

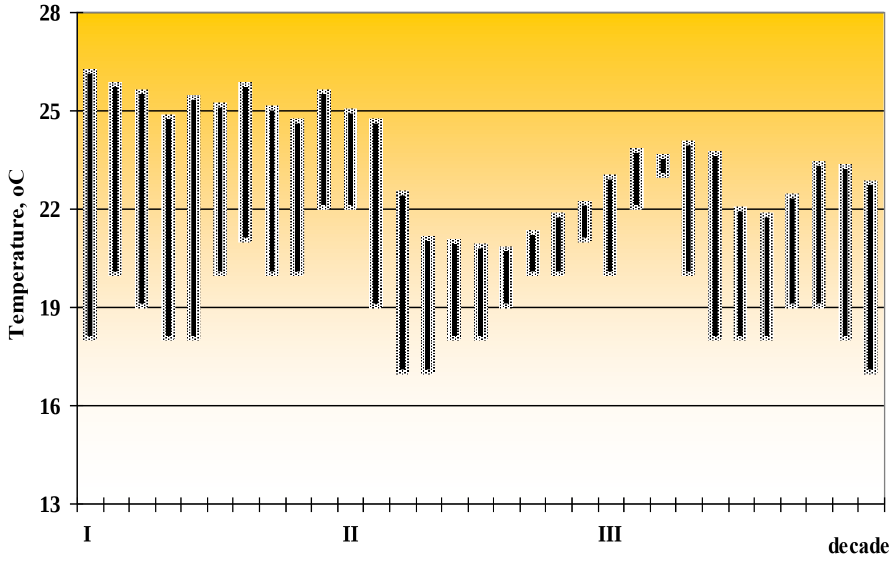

Figure 2. Climatogram of water of Kremenchug reservoir, August 2016 (min–max).

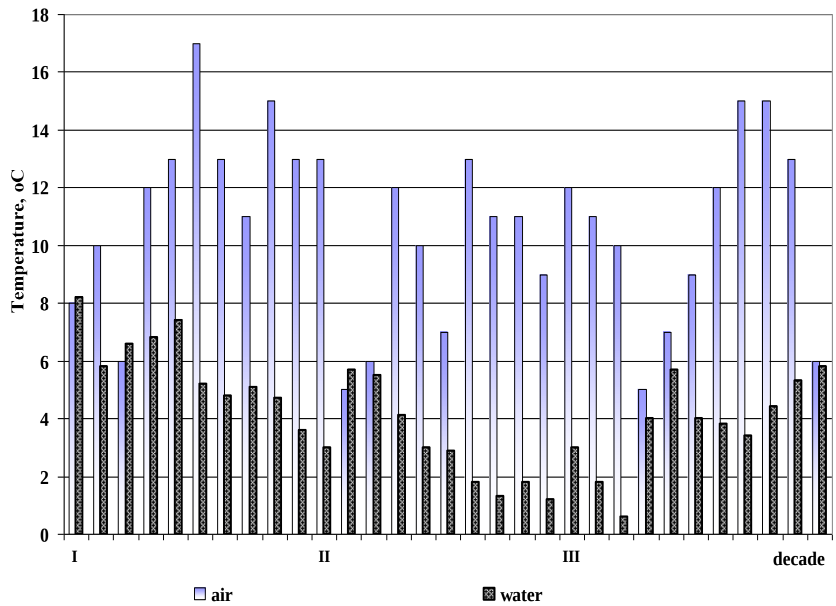

Figure 3. Fluctuation of the daily amplitude of air and water temperatures of Kremenchug reservoir, August 2016, °C.

The air temperature fluctuated within 18.95–22.70 °C, the water temperature was changed from 20.62 to 22.51°C. The first decade of August was the warmest: the average air temperature was 22.70 ± 1.44 °C (Cv=28.45%), the water – 22.51 ± 0.20°C (Cv=13.97%), and in the middle of the month the temperature was the lowest: air temperature was 18.95 ± 1.33°C (Cv=31.45%), water temperatre 20.62 ± 0.49 °C (Cv=10.69%). According to the coefficient of variation, we suggested that the air temperatures were characterized by significant variability, and the water temperatures varied moderately, which indicated unstable environmental conditions. Although the average monthly water temperature of 21.42 ± 0.34 °C (Cv=12.50%) corresponded to the described long-term values, the overall indicators of phytoplankton biomass were quite low (4.19 ± 0.32 mg/dm^3, Cv=29.15%) and demonstrated stressful conditions of the aquatic environment in August 2016.

Conclusion

Detailed analysis of temperature indicators of Kremenchug reservoir in August showed a tendency to increase the coefficient of their variation (Cv=10.69–13.97%). This indicates the unstability and stress of the temperature conditions of the aquatic environment for living organisms. First of all it will affect the organisms of near-flood layers of water which are in direct contact with unstable air masses. (Cv=28.45–31.45%).

Blue-green algae species which were the most resistant to temperature fluctuations are *Microcystis aeruginosa Kutz. emend. Elenkin* and *Anabaena flos-aquae sp.* water "bloom". Their maximum values were recorded in the water area near the village Chervona Sloboda. The impact of temperature value and other abiotic factors leads to intensive water "bloom" and subsequent mass extinction of *Cyanophyta*. Hot sunny days with the air temperatures up to 18-32 °C and water temperatures of 21.0–25.8 °C were the most dangerous. As a result of lethal consequences, the significant amount of the most sensitive species, like Noble crayfish (*Astacus astacus*), Zander (*Sander lucioperca*) fall out in the ecosystem. We assumed that the presented data could prove the global warming to some extent.

References

Bat-oyun Tserenpurev, Masato, S., Mitsuru, T. (2012). Effects of cloud, atmospheric water vapor, and dust on photosynthetically active radiation and total solar radiation in a Mongolian grassland. Journal of Arid Land, 4(4), 349-356. doi: 10.3724/SP.J.1227.2012.00349.
Birungi, Z., Masola, B., Zaranyika, M.F., Naigaga, I. & Marshall, B. (2007). Active biomonitoring of trace heavy metals using fish (Oreochromis niloticus) as bioindicator species. The case of Nakivubo wetland along Lake Victoria. Physics and Chemistry of the Earth, Parts A/B/C, 32(15–18), 1350–1358. doi: http://dx.doi.org/10.1016/j.pce.2007.07.034
Crayfish and fish die en masse in the Dnieper in Cherkasy region. (2016). TV channel VIKKA-news. News archive. 8 August, 16-46.
EU Water Framework Directive (2010). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
Gorbunova, Z.N., Medved', V.A., & Borisova, Ye.V. (2001). Transformation of urea during the growth of some blue-green (Cyanoprocaryota) and green (Chlorophyta, Chlorococcales) algae. International Journal on Algae, 3(4), 89-100, doi: 10.1615/InterJAlgae.v3.i4.80.
Krishnamurthy, T., Carmichael, W.W. & Sarver, E.W. (1986). Toxic peptides from freshwater cyanobacteria (blue-green algae). I. Isolation, purification and characterization of peptides from Microcystis aeruginosa and Anabaena flos-aquae. Toxicon, 24(9), 865-73. doi: 10.1016/0041-0101(86)90087-5.
Kruzhilina, S.V. (2010). Perennial dynamics of quantitative development of phytoplankton of Kremenchug reservoir and its structural indicators. Rybogospodarska nauka Ukrainy, 3, 14-19.
Likhareva, E.I. (1989). Possibilities of restoring crayfish stocks in water bodies of the Leningrad Region 1. Elements of crayfish biology. Collected papaers of the State Research Institute of Lake and River Fisheries, 300, 10 (in Russian).
Lopes, I., Baird, D.J., & Ribeiro, R. (2006). Genetic adaptation to metal stress by natural populations of Daphnia longispina. Ecotoxicology and Environmental Safety, 63(2), 275–285. doi: http://dx.doi.org/10.1016/j.ecoenv.2004.12.015
Results of the analysis of water samples of the Kremenchug reservoir in 3rd quarter of 2012. (2012). Cherkasy. Official portal of the city council. October 26 (in Ukrainian).
Romanenko, V.D. (2006). Methods of hydroecological research of surface waters. Kyiv: Logos (in Ukrainian).
Sirenko, L.A. & Kirpenko, Yu.A., (2000). Biologically Active Metabolites of Blue-Green Algae and Their Role in Epidemiology. Hydrobiological Journal, 36 (5), 14. doi: 10.1615/HydrobJ.v36.i5.110

Citation:
Rudyk-Leuska, N.Ya., Yevtushenko, N.Yu., Khyzhniak, M.I., Leuskyi, M.V., Kononenko, R.V., Tson, N.I., Dumych, O.Y. (2020). Influence of temperature on the aquatic biota. *Ukrainian Journal of Ecology, 10*(3), 102-105.