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# BIOINDICATION POTENTIAL OF PHYTOPLANKTON FOR SEASONAL DYNAMICS EVALUATION IN THE SASYK RESERVOIR, UKRAINE

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**Abstract**

Sasyk is an anthropogenically altered brackish-water reservoir that may serve as an example of desalination treatment of estuary and presents itself as an interesting research object for scientific investigations. Thus, the main aim of the present research composed in tracking ecological condition of Sasyk reservoir with the help of phytoplankton composition and bioindication methods. The sampling was carried out on 17 observation stations, most adequately representing the territory of the reservoir Seasons for it were chosen as summer (August) and autumn (November) 2013, in spring (May) and summer (July, August) 2014. For the investigation, 136 samples of plankton algae were analysed. The total list of all plankton algae found in the Sasyk reservoir through all seasons equalled 207 species and 215 infraspecific taxa. Chlorophyta and Bacillariophyta divisions were prevailing groups over all seasons of the investigated years, which is common for season dynamics in that region. Quantitative characteristics of phytoplankton varied from 12.28 x $10^6$ cells $L^{-1}$ up to 360.645 x $10^6$ cells $L^{-1}$ (average amount varied from minimum value 27.476 x $10^6$ cells $L^{-1}$ to maximum 171.468 x $10^6$ cells $L^{-1}$) as for abundance over all seasons of investigated years and from 1.82 mg $L^{-1}$ to 8.2 mg $L^{-1}$ (minimum average – 3.23 mg $L^{-1}$ and maximum – 4.59 mg $L^{-1}$). The dominant complex species was formed by *Dolichospermum flosaquae* (Brébisson ex Bornet et Flahault) P.Wacklin, L.Hoffmann et J.Komárek, *Aphanocapsa planctonica* (G.M. Sm.) Komárek et Anagn., *Limnothrix planctonica* (Wołosz.) Meffert, *Merismopedia punctata* Meyen, *Merismopedia tenuissima* Lemmerm., and *Oscillatoria amphibia* J. Agardh ex Gomont. With the help of bioindicational analysis, it were revealed major variables based on algal species distributions over the seasons. The indicators reflected the response of aquatic ecosystem to temperature, salinity, acidity, water mass dynamics and oxygenation, organic pollution along with other habitat conditions. According to observations of the dynamics of bioindicators in 2013-2014, it can be concluded that Sasyk reservoir acquires features of a lake freshwater reservoir.
**Keywords:** Bioindication, algae, reservoir, seasonal dynamics, phytoplankton, Sasyk (Kunduk) reservoir, Ukraine

## 1 INTRODUCTION

The example of the Sasyk (Kunduk) reservoir is of great value as a prime pattern of human intervention in waterbodies all over the world. Its history begins as an estuary of the Black Sea and up to a fresh water lake separated from the sea with a dam construction. The concept was to stock a water for irrigation purposes and later failed in achieving it. The main problem laid in natural saline underground waters in that region. Nowadays Sasyk is a huge (210 – 215 $km^2$) waterbody, that is often called reservoir or lake. It lays in Southern part of Ukraine, near the Danube Delta and has connection with Danube River by channel. In turn, Sasyk has inputs of the Sarata and the Kogylnik rivers. In consequence of shallow depths (the maximum being 3.6 m), this waterbody is characterized by wind agitation and as a result lack of temperature stratification. Currently, its salinity equals approximately 2 ppt thus previous aims of management to make Sasyk a freshwater reservoir have not been achieved.

Along with our previous experience in estimation of ecological condition of this water body, Cyanophyta blooming were distinctive for summer period. The defining factor of those changes lied in temperature dynamics (Bilous et al., 2016). Based on published data we assume the process of water quality forming largely depend on development intensity and species composition of algae (Klochenko et al., 2014) and in a same way they serve a good indicator for water quality assessment (Belous et al., 2013; Bilous et al., 2014). Abovementioned factors can help us to assess the Sasyk reservoir ecosystem variables dynamic. So, the aim of present study is revealing of ecological condition of the Sasyk reservoir with the help of phytoplankton composition and bioindication methods.

## 2 METHODS

The sampling was carried out in summer (August) and autumn (November) 2013, in spring (May) and summer (July, August) 2014. In total, 17 observation stations, most adequately representing the territory of the reservoir were selected (Figure 1).

Water samples were taken by a Ruthner's bathometer at a depth of 0.5 m in 2-3 replicates, and fixed with 3-4% formaldehyde solution (Romanenko, 2006). In total, 136 samples of plankton algae were taken during the studied period. Parallel with phytoplankton sampling, water and air temperature were measured using thermometer. Later, algological samples were concentrated by sedimentation method in the laboratory and analysed using Zeiss and PZO microscopes.

For morphological species identification, a number of manuals were used (Asaul 1975, Komárek & Fott 1983, Starmach 1983, Starmach 1985, Tsarenko 1990, Krammer & Lange-Bertalot 1991a, b, Krammer & Lange-Bertalot 1997a, b, Komárek & Anagnostidis 1998, Krammer 2000, Lange-Bertalot 2001, Krammer 2002, Krammer 2003, Komárek & Anagnostidis 2005, Komárek, 2013, Palamar'-Mordvintseva 2003, Palamar'-Mordvintseva 2005, Levkov 2009). Phytoplankton cells of each species were calculated in the Nageotte Chamber (0.2 $cm^3$).

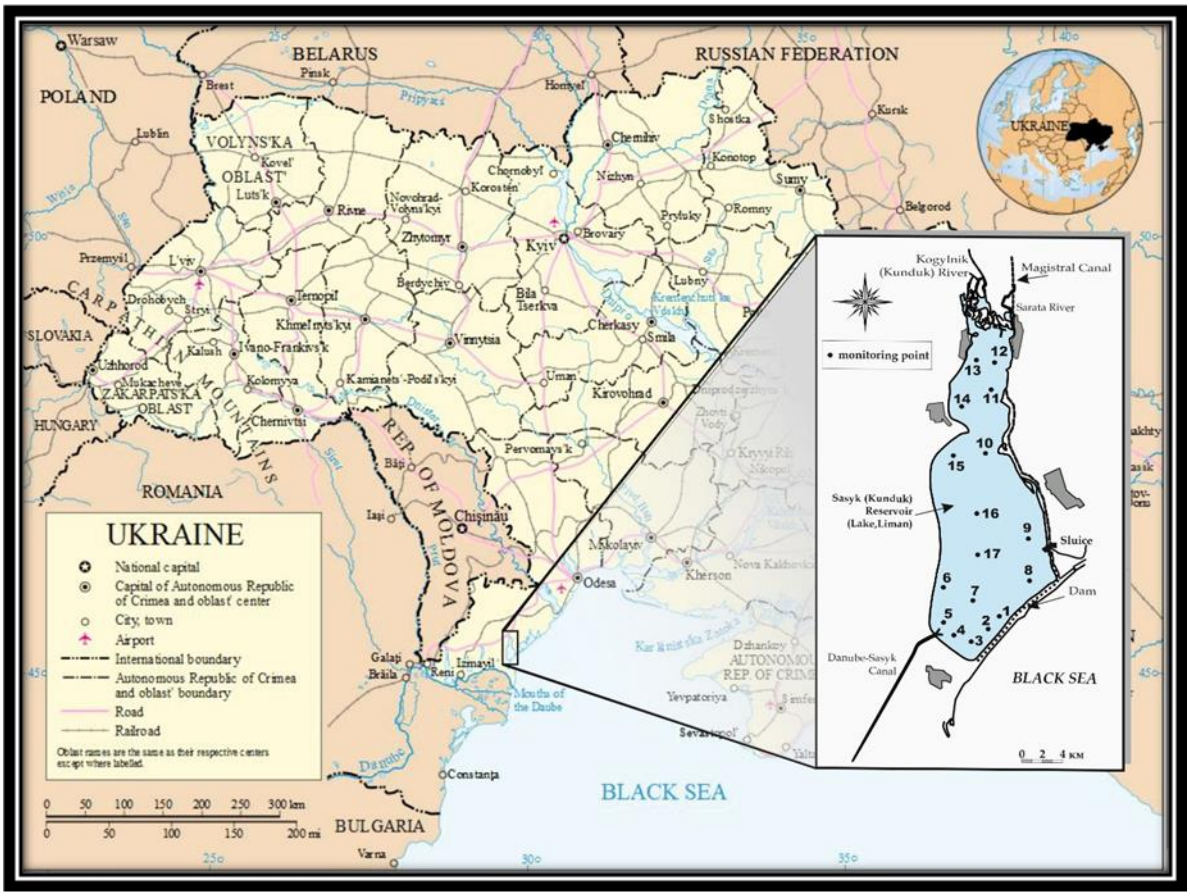


**Figure 1.** Scheme of the Sasyk Reservoir with the sampling stations

Algae indicators reflect the response of aquatic ecosystem to temperature, salinity, acidity, water mass dynamics and oxygenation, organic pollution along with other habitat conditions (Barinova et al., 2006; Barinova, 2011; Barinova et al., 2015). Each group of indicators can be divided into subgroups. As for indicator species of habitat preference (Hab) are distinguished: benthic (B), plankto-benthic (P-B), planktonic (P), epiphyte (Ep) and soil (S). Salinity indicator groups (Hal) may be grouped according Hustedt (1938–1939): halophiles (hl) polyhalobes (ph), oligo-halobes-indifferent (i), oligohalobes-halophobes (hb), mesohalobes (mh). The water mass dynamics and oxygenation (Oxy) are divided: streaming water (str), standing water (st), low streaming water (st-str) and aerophiles (ae). Temperature preferences (Temp) indicators are: warm-water (warm), temperate (temp), eurythermic (eterm) and cool-water (cool). Acidity indicator (pH) species (Hustedt, 1957) are: alkalibiontes (alb); alkaliphiles (alf), indifferents (ind); acidophiles (acf); acidobiontes (acb) and neutrophiles as a part of indifferents (neu). Trophic state indicators (Tro, Van Dam et al., 1994) are: eutraphentic (e), oligotraphentic (ot), oligo- to eutraphentic (hypereutraphentic) (o-e), oligo-mesotraphentic (o-m), meso-traphentic (m), meso-eutraphentic (me) and hypereutraphentic (he). Nitrogen uptake metabolism (Aut-Het) indicators (Van Dam et al., 1994) are divided: nitrogen-autotrophic taxa (ate), tolerating elevated concentrations of organically bound nitrogen; nitrogen-autotrophic taxa (ats), tolerating very small concentrations of organically bound nitrogen; facultative nitrogen-heterotrophic taxa (hne), needing periodically elevated concentrations of organically bound nitrogen; obligatory nitrogen-hetero-trophic taxa (hce), needing continuously elevated concentrations of organically bound nitrogen.

Indices of saprobity (S, Sládeček, 1973, 1986) were calculated based on identified species for each community and quantitative assessment of phytoplankton was performed by known quantitative estimation (Romanenko, 2006). Indicators of Saprobity (Sap) are distinguished regarding to self-purification zone: i – i-eusaprob, m – m-eusaprob, p – polysaprob, b-p – beta-polysaprob; b-a – beta-alpha-mesosaprob; a-b – alpha-beta-mesosaprob, a – alpha-mesosaprob; a-p – alpha-polysaprob, x-b – xeno-beta-mesosaprob; x – xenosaprob; x-o – xeno-oligosaprob; o-x – oligo-xenosaprob; o – oligosaprob; o-b – oligo-beta-mesosaprob; b-o – beta-oligosaprob; o-a – oligo-alpha-mesosaprob; b – beta-mesosaprob.

Statistically generated maps were constructed with the help of Statistica 12.0 program (TIBCO Statistica™) on the base of our data of the Sasyk reservoir in summer 2014.

## 3 RESULTS AND DISCUSSION

The phytoplankton composition characterized each season by taxalists with quite common proportion between divisions and at the same way had some specific features. Chlorophyta and Bacillariophyta divisions were prevailing groups over all seasons of the investigated years, which is common for season dynamics in that region (Belous et al., 2014; Bilous et al., 2015). Regarding proportion of divisions, chlorophytes prevailed in autumn 2013, and diatoms in spring 2014 (Figure 2).The identified algal taxa for Chlorophyta and Cyanophyta were most diverse in summer 2013. The number of diatom species, as well as dinophytes and euglenoids increased over the summer of 2013 until summer of 2014. Overall, the most diverse composition has proved to be in the fall of 2013. The total list of all plankton algae found in the Sasyk reservoir through all seasons of the years of investigations equalled 207 species and 215 infraspecific taxa.

Some of described facts may be explained with the help of temperature changes over the years and for the seasons. According to literary sources from 1981 – 2012 years, levels of water temperature recorded between 10.6 and 13.2 annual average period (Ivanova, 2015). In summer, the water may be soaked to 25 – 30 °C in the reservoir. A the same time our studies have shown that all over the reservoir the water temperature varied from 23 to 24.8 °C in August 2013 and 12–13.5 °C at the beginning of November. Taking into consideration alsochannel and gateway spillway has been working and the homothermal conditions prevailed mainly during observations in the water area in 2014. In the spring, for example, in some areas of the reservoir, weak back stratification was recorded and the temperature has stayed within a variance of 15 – 17.8 °C. The annual summer temperature turned to be higher than the previous year, therefore water warmed up to 24 – 27.6 °C (Ivanova, 2015).

Quantitative characteristics of phytoplankton varied from 12.28 x $10^6$ cells $L^{-1}$ up to 360.645 x $10^6$ cells $L^{-1}$ (average amount varied from minimum value 27.476 x $10^6$ cells $L^{-1}$ to maximum 171.468 x $10^6$ cells $L^{-1}$) as for abundance over all seasons of investigated years and from 1.82 mg $L^{-1}$ to 8.20 mg $L^{-1}$ (minimum average – 3.23 mg $L^{-1}$ and maximum – 4.59 mg $L^{-1}$) (Figure 2). Difference in quantitative characteristics over all investigated water body may be explained by different factors. Some of them should be mentioned as Danube-Sasyk canal, which brings Danube water, also inputs from the Sarata and Kogylnik rivers and one more common fact is the difference in part of the reservoir that has thickets of higher aquatic plants in comparison of open parts of the reservoir (Klochenko et al., 2013; Klochenko et al., 2015). Maximum abundance of plankton algae was in the summer 2014 due to cyanophytes mass development. The dominant complex species was formed by *Dolichospermum flosaquae* (Brébisson ex Bornet et Flahault) P.Wacklin, L.Hoffmann et J.Komárek, *Aphanocapsa planctonica* (G.M. Sm.) Komárek et Anagn., *Limnothrix planctonica* (Wołosz.) Meffert, *Merismopedia punctata* Meyen, *Merismopedia tenuissima* Lemmerm., and *Oscillatoria amphibia* J. Agardh ex Gomont.

Bioindicational analysis helped us to reveal major variables that related to the algal species distributions over the seasons. We demonstrated that earlier with help of statistically generated maps of phytoplankton abundance and biomass as well as bioindicator groups of algae in the Sasyk reservoir distribution (Barinova et al., 2016) and find that it could help to reveal the source of influence to it. Thus, indicators of water temperature were sensitive and distribution of its groups over seasons show increasing of cold water indicators in autumn and spring which has been don't revealed in both summer periods of 2013 and 2014 (Figure 3).

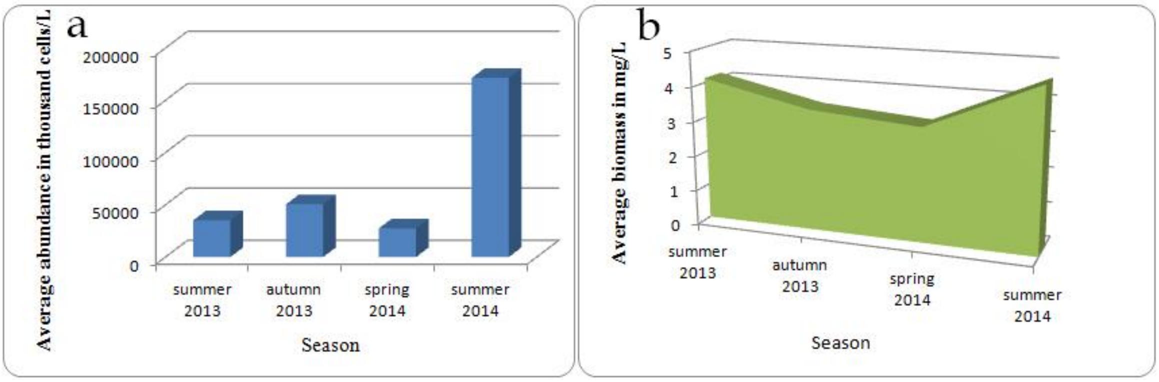


**Figure 2.** Average quantitative characteristics of Sasyk reservoir phytoplankton (a – abundance, b – biomass).

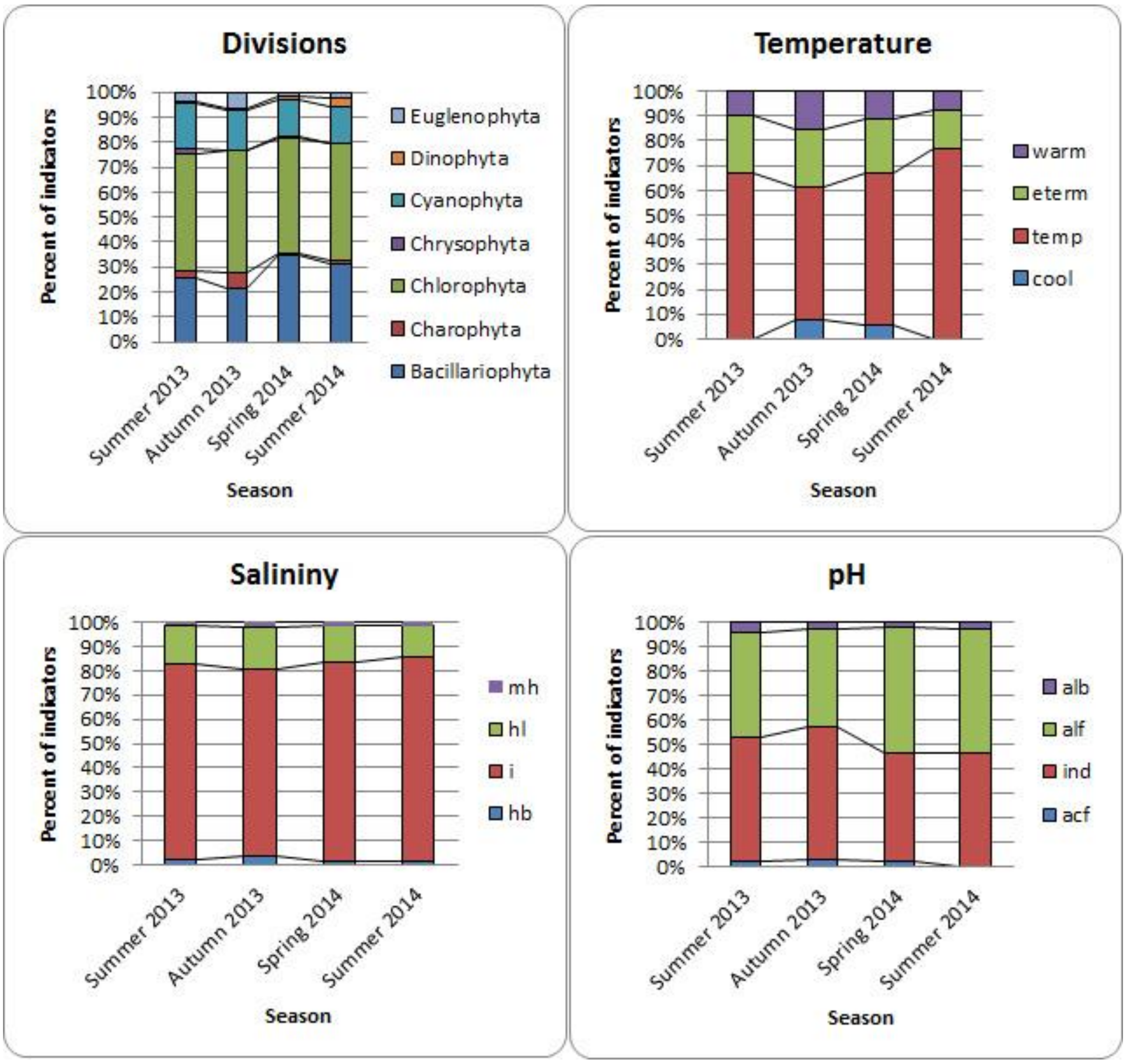


**Figure 3.** Seasonal distribution of the species richness in taxonomic Division, water temperature indicators, salinity indicators, and indicators of water pH in the Sasyk Reservoir, 2013-2014. Abbreviation of indicator groups names as in Methods part.

Salinity indicators show increasing of halophilic group over that investigated period (Figure 3). Indicators of high pH (alkaliphiles and alkalibiontes) were significantly increased in 2014, as can be seen on Figure 3. Important part of the ecosystem state assessment is analysis of the nutrition uptake metabolism of the investigated phytoplanktonic species variety in the reservoir. It can help not only to assess the preferences of revealed species in receiving energy for future protein generation for all trophic pyramid but also can help toxic impact assessment. Thus, the bioindication analysis show (Figure 4) decreasing of facultative heterotrophic species in communities over studied period. It can be peculiarity of the Sasyk reservoir ecosystem as trend of detoxification. As a result of bioindication, of water quality in the Sasyk reservoir can be seen the same tendency for increasing of indicators Class II of water quality during period of investigation 2013-2014 (Figure 4). Therefore, it can be related mostly with trend of ecosystem properties than of seasonal variation in the Sasyk reservoir.

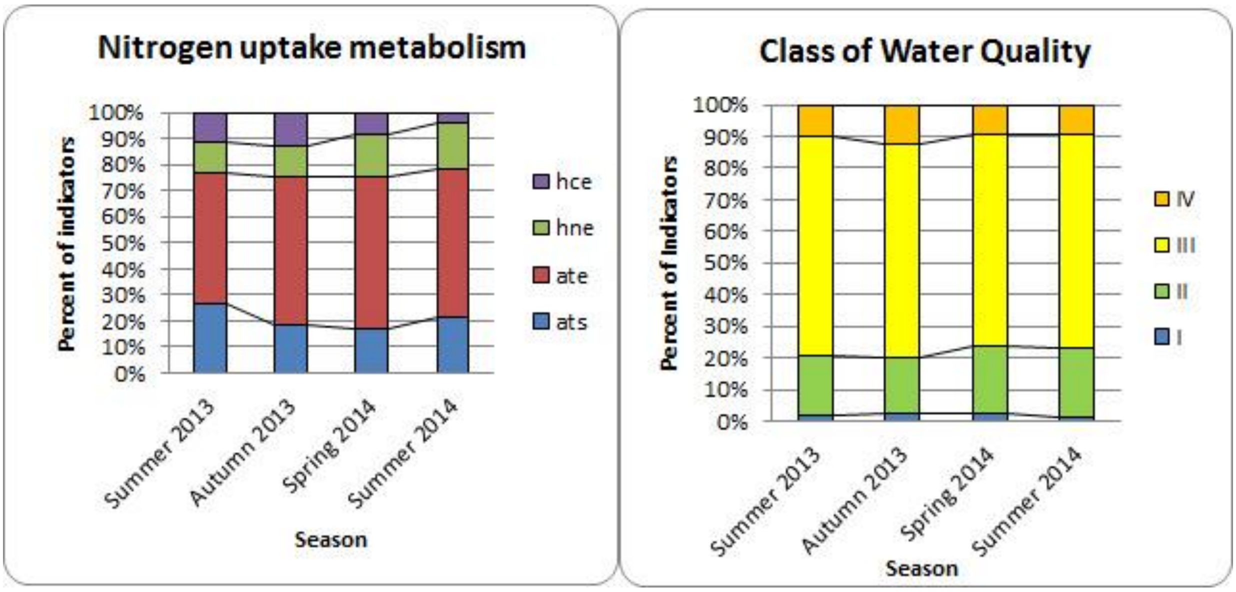


**Figure 4.** Seasonal distribution of the nutrition type indicators and Water Quality Class indicators in the Sasyk Reservoir, 2013-2014. Colour of the Water Quality Class marked according to EU colour codes. Abbreviation of indicator groups names as in Methods part.

All other indicator groups of seasonal dynamics have not sufficiently changed in the Sasyk reservoir phytoplankton. Although, it possible to observe that the phytoplankton in the reservoir ecosystem demonstrates some response to the water temperature dynamics nevertheless this variable is very stable in the surface of shallow waterbody with some seasonal fluctuations.

Statistically generated maps that we has been constructed earlier (Barinova et al., 2016) for the Sasyk reservoir phytoplankton bioindicators and environmental variables in summer 2014 are demonstrated expression of some variables distribution over the sampling stations that related mostly to basic environmental variables on the catchment basin. Thus, Figure 5 reveal distribution of water temperature over the reservoir surface (a) that revealed the Danube water and seawater filtration influence in the lower corner of figure.

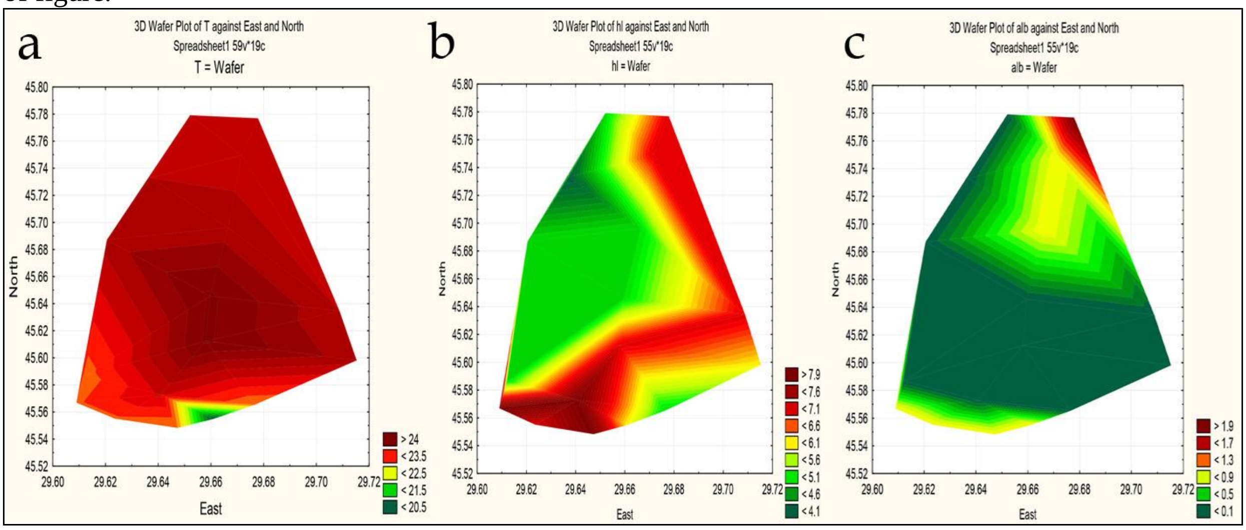


**Figure 5.** Statistically generated surface maps of water temperature (a) – from more than 24 (red) to less than 20.5 (green), halophilic species indicators (b) – from more than average 7.9 (red) to less than 4.1 (green), and alkalibiontic species indicators (c) – from more than average 1.9 (red) to less than 0.1 (green) distribution over the Sasyk reservoir surface in summer 2014.

The halophilic species indicator distribution over the Sasyk surface show relation of it with ground water input from the Kogylnik River basin in the upper part (Figure 5b). It also can be recognized the influence of invisible filtration of the sea waters in the lower part of waterbody. Both these, input of underground waters can be confirmed by surface map of alkalibiontic indicator species distribution over the Sasyk reservoir surface (Figure 5c). At the same way, high pH indicators are mostly comes from the Kogylnik River underground waters that flow across the carbonates (upper part of the map) than with saline and Danube canal waters in the lower part of map. It let us to assume that impact of saline waters is mostly related with seawaters filtration across the Sasyk dam, but high pH waters come with the river runoff even it is not possible to recognize it during the summer period sampling.

## 4 CONCLUSIONS

As a whole, the preference of species regarding substrate choice or as it called ecological types remained constant with the plankton-benthic inhabitants' predominance. With regard to operating temperature tendency, the increase of moderately warm water and the reduction of warm-water (thermophilic) and eurythermic indicator species was observed, in spite of seasonal oscillations of water temperature. Reduction halophilous and increasing of alkaliphilic species indicated the influence of freshening drain. Enriches with oxygen was higher than in autumn season of 2013, and in the summer 2013 the same as in the 2014 it remained identical. Trophic state indicators revealed a slight increase in eutrophication. The largest waters self-purification was fixed in the autumn 2013. The indicators on the classes of water quality showed certain reduction of organic pollution. Nitrogen uptake metabolism or type of nutrition changed towards an increase in of the group of facultative heterotrophic taxa, particularly at the expense of dinophytes and euglenoids. It testifies the weak increase of adverse influence on phytoplankton during the period of investigations.

Bionidication of seasonal fluctuation helped us to divide environmental influencing variables to different clusters. First cluster is included water temperature, pH and salinity, which had not so recognizable changes over season excluding water temperature that helped us to reveal waters coming to reservoir and prevalence of parameter forcing it. Thus, this group of variables can be used as indicator of natural variation of environment and climate change.

Second clusteris included indicator groups that demonstrated visible seasonal fluctuation such as water temperature indicators.

Third clusteris included such indicator groups as taxonomic composition, salinity, water pH, trophic state, and Class of Water Quality that reflected organic pollution. This group of indicators were demonstrated not so changing between seasons but mostly between 2013 and 2014 years. We assume that this group have response to long-term trend of environmental changes. The obtained results demonstrated increasing of diatom species richness, water pH, autotrophic type of nutrition, and water quality with decreasing of numbers of euglenoids, water temperature and salinity, facultative heterotrophes, and indicators of Class IV of water quality. Therefore, third groups of indicators demonstrated trend of the Sasyk reservoir ecosystem to desalination, and increasing of the inputted rivers Sarata and Kogylnik runoff to reservoir. To assume, the Sasyk reservoir acquires features of a lake freshwater reservoir, according to observations of the dynamics of bioindicators in 2013-2014.

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