FACTORS WHICH DETERMINE PRODUCTIVITY OF PHYTOPLANKTON OF THE DNESTER RIVER

Ungureanu Laurentia, Zubcov Elena, Tumanova Daria, Borodin Natalia, Bagrin Nina, Ungureanu Grigore

Institute of Zoology

Rezumat

Lucrarea include rezultatele cercetărilor influenţei factorilor ecologici asupra productivităţii fitoplanctonului din ecosistemele fluviului Nistru şi lacului de acumulare Dubăsari pe parcursul anului 2017. S-a constatat că varietatea condiţiilor ecologice contribuie la dezvoltarea unor comunităţi de alge planctonice cu diferite preferinţe faţă de mediul acvatic şi modificarea complexului dominant în decursul perioadei de vegetaţie. Au fost atestate variaţii sezoniere ale valorilor producţiei primare a fitoplanctonului în limitele 0,42-6,9 gO^2/m-2/24 ore în fl. Nistru şi între 0,6-4,87 gO^2/m-2/24 ore în lacul Dubăsari. S-a stabilit că prezenţa elementelor nutritive în anumite concentraţii în ecosistemele acvatice influenţează parametrii cantitativi ai fitoplanctonului, starea fiziologică a celulelor algale şi activitatea lor fotosintetică, astfel influenţând direct sau indirect productivitatea acestora.

Cuvinte cheie: Fluviul Nistru, lacul de acumulare Dubăsari, factori biotici şi abiotici, productivitatea fitoplanctonului, elemente nutritive, azot, fosfor, particule în suspensie, materie organică

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Adresa pentru corespondenţă: Ungureanu Laurenţia, Institutul de Zoologie al MECC, str. Academiei, 1, MD-2028 Chişinău, Republica Moldova; e-mail: ungur02laura@yahoo.com

Introduction

Determinant factors of phytoplankton productivity can be classified into two main categories: abiotic and biotic. While biotic factors (seasonal changes in the algal cell physiological state, their trophic relationships with other hydrobionts, nutritional competition, etc.) are subject to fundamental biological laws and change quite slowly, then the abiotic factors dependent on changes in the hydrological and hydrochemical regime and are characterized by pronounced seasonal variability. The combination of abiotic factors, favoring the propagation and growth of algal cells, leads to the intense development of some species of phytoplankton, which sometimes can cause the flowering of water.

Environmental factors cannot be separated from each other, and research on each factor separately can only be addressed on the methodological level. Physical, chemical and biological properties interpenetrate and the physico-chemical processes of an aquatic biotope cannot be separated in time and space from the functions of a biocenosis. The intensity of impact of anthropogenic factors is manifested by an additional nutrient load on both the aquatic ecosystem and the water catchment area. The dynamics of the chemical composition of aquatic ecosystems is determined by the flow of nutrients from the water capture area, which in turn depends on a number of natural and anthropogenic factors such as the use of water capture for agricultural purposes. The chemical contribution is quite predictable and, under certain conditions, it can even be regulated. There are approximate methods for calculating nutrient loads, which serve as a basis for planning water protection measures. An important element of the anthropogenic impact in recent years is the use of the hydrographic basin for recreational purposes.

With the discharge of toxic substances with domestic and industrial wastewater in freshwater ecosystems, there is a reduction in the development of phytoplankton. The large forms of diatoms algae are those that react firstly to the introduced concentrations of toxic substances. The algae forms with small cell are relatively resistant to the effects of toxic contamination, these forming high density populations of cells. Rapid growth of biomass contributes to accelerated elimination of toxic substances from dead-cell in water [11]. The toxic effect of chemicals on phytoplankton in different areas of the ecosystem is naturally determined by the physicochemical and biological conditions of the environment.

An important aspect of anthropogenic impact should be considered to regulate the water course, during which it is possible to guide the processes of water exchange in the ecosystem. This inevitably leads to the occurrence of a complex of hydrodynamic phenomena in the ecosystem, which includes the modification of the hydrological structure of the masses of water.

Materials and methods of research

Hydrochemical and hydrobiological samples from Dniester River and reservoir lake Dubasari were collected seasonally during the year 2017, in the framework of the research carried out by the Laboratory of Hydrobiology and Ecotoxicology of the Institute of Zoology of MECC.

Water samples have been collected from the middle sector (Naslavcea, Valcinet, Soroca, Camenca) and inferior sector (Vadul-lui-Voda, Varnita, Sucleia, Palanca) of the Dniester River and reservoir Dubasary (Erjova, Goieni, Cocieri). The sample processing was performed according to unified methods for the collection and processing of hydrochemical and hydrobiological samples in field and experimental, according to ISO standards [3-6].

Results and discussion

Data from the literature on the dependence of production processes on **phytoplankton biomass** are quite numerous and even contradictory. Some authors support that the intensity of photosynthesis in aquatic ecosystems is directly proportional to phytoplankton biomass [10, 13]. Others [8, 14] mention that there is no exact correlation between primary production and phytoplankton biomass. The divergences can be argued, because the production of organic substances by phytoplankton is dependent not only on its quantity, it is influenced by a number of biotic factors: the systematic apartenence the algae species belong to, their age and physiological state, the cell sizes and the concentration pigments with an important role in photosynthesis, as well as abiotics: solar radiation and physico-chemical properties of water.

The temperature variations in water, during the vegetation period, are manifested by well-pronounced seasonal successions of the algal communities' structure both in the reophilic ecosystems, such as Dniester River and limnophilic ecosystems the Dubasari Reservoir. It should be noted that in the middle part of the Dniester River, which was considerably influenced by the state of the water from the Dnestrovsk Reservoir, located upstream, the water temperature was lower than in the lower section of the river. It has been found that both the minimum and maximum temperatures increase with the removal of water from the Dnestrovsk dam and the thermal pollution is more pronounced in the Naslavcea- Vălcineţ sector (Figure 1.).

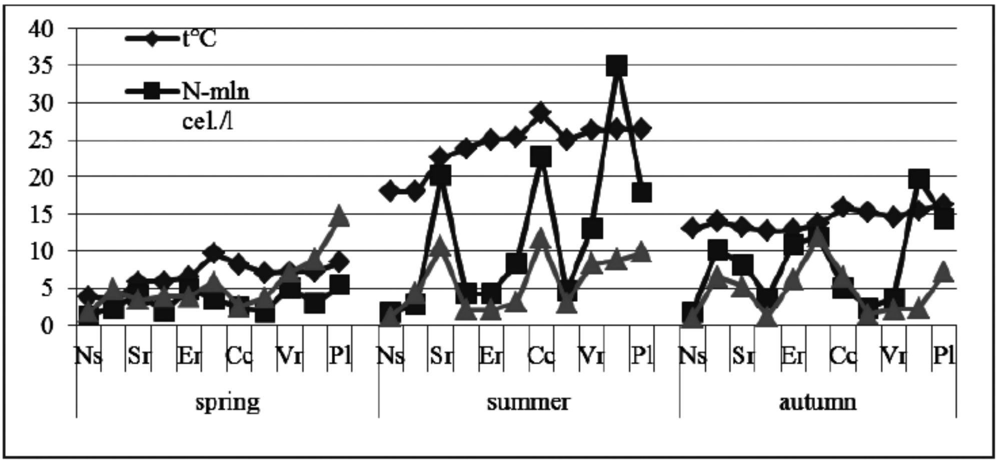

Fig. 1. Seasonal dynamics of water temperature, number and phytoplankton biomass in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasari water Reservoir (Erjova, Goieni, Cocieri) in 2017.

Temperature influences the photosynthetic activity of algae, so that production processes are more intense at higher temperatures, and biomass of algae is directly proportional to solar radiation and temperature. Thus, maximum values of the phytoplankton number and biomass were recorded during the summer period in Dniester River (Figure 1).

The diatom algae are characterized by a very low temperature optimum, while many of them grow intensely in the hot seasons of the year when the water temperature reaches 23-25°C. The green and blue-green algae prefer higher temperatures (20-30°C), but they grow intensely in spring and autumn at much lower temperatures.

Water transparency determines spatial distribution and production peculiarities of planktonic algae communities. The intensity of phytoplankton photosynthesis decreases with diminishing transparency, increased in turbidity and depth of water. In the Dniester River water transparency varies greatly and is decreasing from the middle to the lower sector of the river.

Thus, at Naslavcea and Valcinet water is in most cases transparent to the bottom of the river and their value are dependent on the water level and varies within the limits of 100-200 cm, ensuring the penetration of the solar rays to the lower layers of the river. At Soroca station the water of the river is heavily polluted with wastewaters, so the transparency is in most cases lower, varying in the limits of 30-70 cm and only sometimes reaching 200 cm. The same situation is also characteristic for the Camenca station. In the lower sector of the Dniester River the water transparency was 100 cm during the vegetation period, except Varnita (70 cm) and Palanca (50 cm) during the summer period.

The degree of illumination at different depths of aquatic ecosystems depends on the transparency of the water. Under natural conditions the **intensity of light** changes during different times of the year and even during different time of the day. The light regime of the aquatic basins is dependent on the degree of absorption and distribution of the solar radiation when passing through the water layer and the degree of reflection of light by the water mirror. Under aquatic ecosystems, algae must adapt not only to variations in light quantity but also to the oscillations of its quality. The ability of water to absorb and disperse light is quite large and this limits the illuminated depth. The different conditions of illumination of aquatic ecosystems determine the different character of the distribution of the phytoplankton photosynthesis intensity and, to a large extent, the values of the primary production at a unit area. During spring and autumn, when the intensity of photosynthesis is highest and illumination conditions are moderate the bacillariophyta algae dominate in the composition of phytoplankton. They possess the ability to photosynthesize under a wide range of illumination and at lower temperatures [1].

Correlation between mineral, organic suspensions and phytoplankton parameters. Following the investigations, a clear negative correlation between the suspension content and phytoplankton biomass in the middle sector of the Dniester River and the Dubasari water reservoir during the spring and in lower sector of the Dniester River during autumn was established (Figure 2). The correlation between the suspension content and phytoplankton biomass was positive in the summer period in most cases, the spring in the lower part of the Dniester River, and autumn in the middle sector of Dniester River and Dubasari Reservoir.

The high content of suspensions considerably diminishes the depth of the euphotic layer and respectively the values of the primary production to below the m^2 of the aquatic surface and often lead to intense destruction processes of organic substances both in the lentic ecosystems and in the investigated reservoir. Throughout the growing season, the concentration of organic suspensions and the values of primary production of phytoplankton undergo changes, reflected in seasonal fluctuations of their values. For some algae species the inclusion of organic substances is accompanied by intensification of photosynthesis, and for others by diminishing this process. A positive correlation has been established between the concentration of organic suspensions and the values of the primary production of phytoplankton during the summer and autumn in the middle sector of Dniester River and the Dubasari Reservoir, while in the lower sector these parameters were inversely correlated (Fig.3).

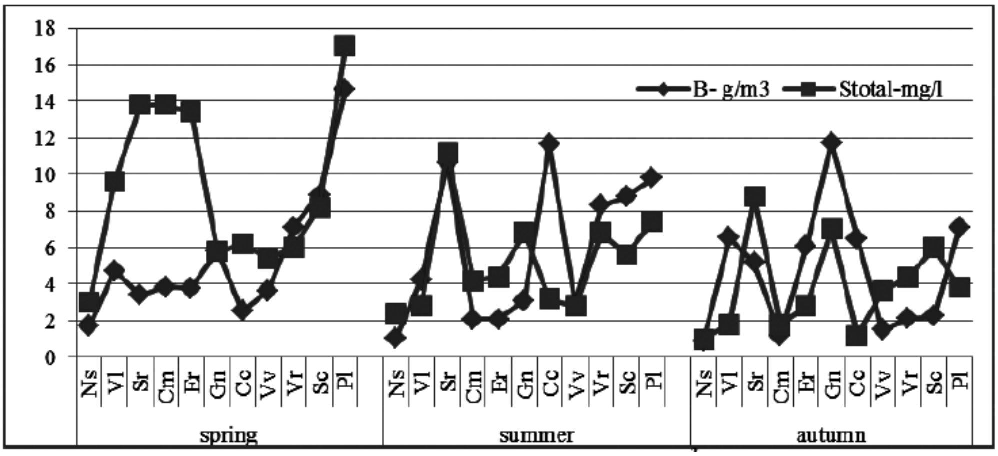

Fig. 2. Correlation between phytoplankton biomass (B – g/m³) and the concentration of organic and inorganic suspensions (Stotal – mg/l) in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasary Reservoir (Erjova, Goieni, Cocieri) in 2017.

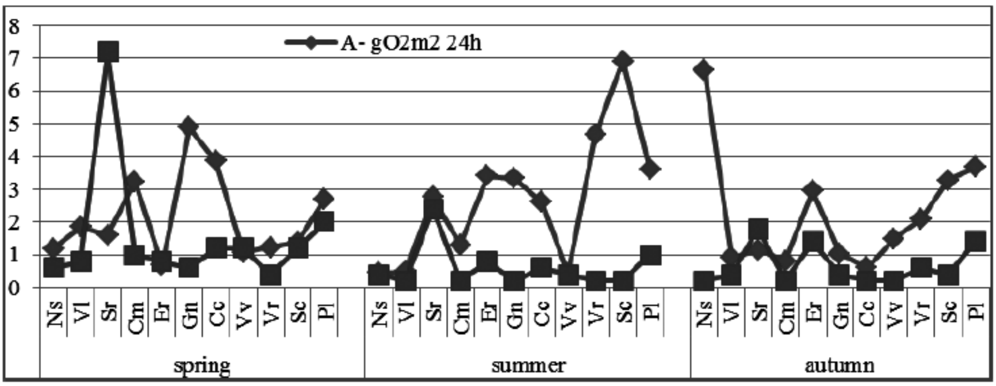

Fig. 3. Correlation between the organic suspension content (Sorg – mg/l) and the values of primary production of phytoplankton (A – gO2/m2) in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasari water Reservoir (Erjova, Goieni, Cocieri) in 2017.

The direct correlation of **phytoplankton biomass values with the values of primary production** and total organic matter content in the middle part of the Dniester River was established in spring and summer (Figure. 4).

It should be noted that the seasonal dynamics of organic substances dissolved in water of Dniester River do not always reflect fully the destructive processes. The positive correlation between the concentration of organic substances and the values of organic matter destruction is more pronounced during spring and summer (Figure 5).

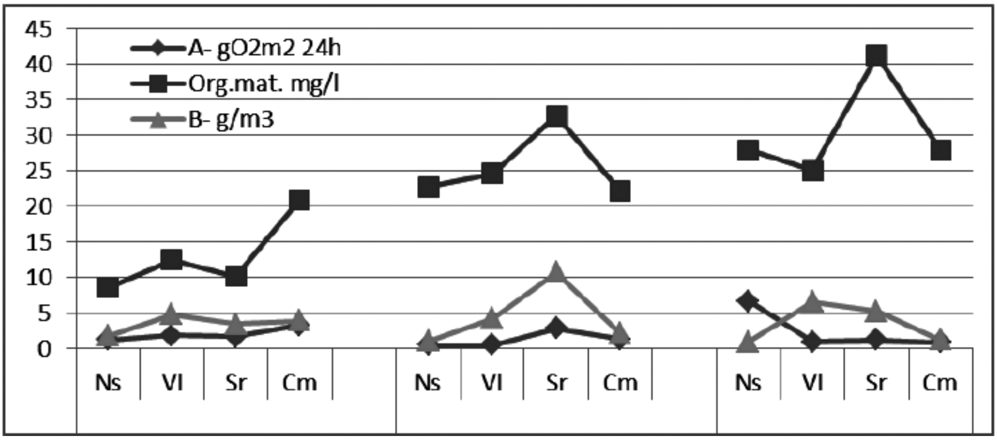

Fig. 4. The correlation of the phytoplankton biomass values (B-g/m³) with the primary production values (A-gO_2m^2 24h) and the total organic matter content (Org.mat. mg/l) in the middle sector of the Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) in 2017.

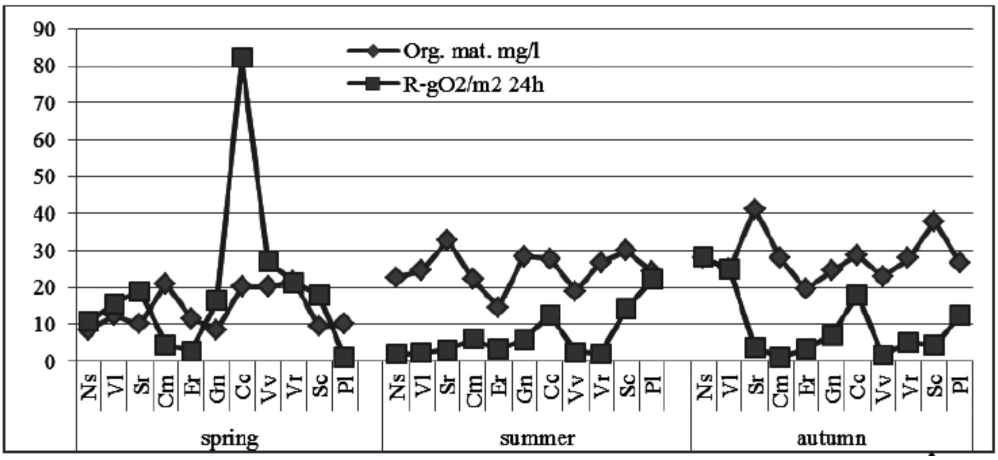

Fig. 5. Correlation of the values of the destruction of organic substances (R-gO_2/ m² 24h) with the total content of organic matter (Org. mat. mg/l) in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasari water Reservoir (Erjova, Goieni, Cocieri) in 2017.

However, the negative correlation between the concentration of organic substances and the values of the destruction of organic matter in Dniester River and in the Dubasari Reservoir the values are consistent during the autumn.

The **main nutrients**, indispensable for the development of phytoplankton, are the nitrogen and phosphorus compounds, and for the diatoms silicon. Planktonic algae, depending on their specific peculiarities, can use nutrients both in the form of mineral and organic compounds.Their presence of these nurients in certain concentrations in aquatic ecosystems influences the quantitative parameters of the phytoplankton, the physiological state of the algal cells and their photosynthetic activity, thus directly or indirectly influencing their productivity. Mineral nitrogen is used by algae in the form of nitrates and ammonium salts. For blue-green algae both forms of nitrogen are equally accessible. Nitrate nitrogen is the predominant component of the mineral nitrogen concentration and organic nitrogen is dominant in the total nitrogen content.

The positive correlation between nitrite concentration, primary production and phytoplankton biomass reveals that the excess of NO_2 - is eliminated in the aquatic environment in the physiological processes that occur in algal cells.This process takes place especially in ecosystems where the diatoms and green algae are predominating. Representatives of these groups possess a high nitrate reduction capacity, which results in nitrates being converted into nitrites, which are eliminated off by the algal cells. In ecosystems dominated by cyanophyta algae, which are characterized by lower nitrate reduction intensity, nitrite assimilation processes predominate. In such cases, there is a negative correlation between phytoplankton biomass and nitrate content. Thus, in the middle and lower sector of the Dniester River during the summer and autumn when the bacillus-shaped algae dominate in the composition of the phytoplankton was registered, a positive correlation of the biomass, the primary production and nitrite nitrogen concentration was revealed (Figure 6.).

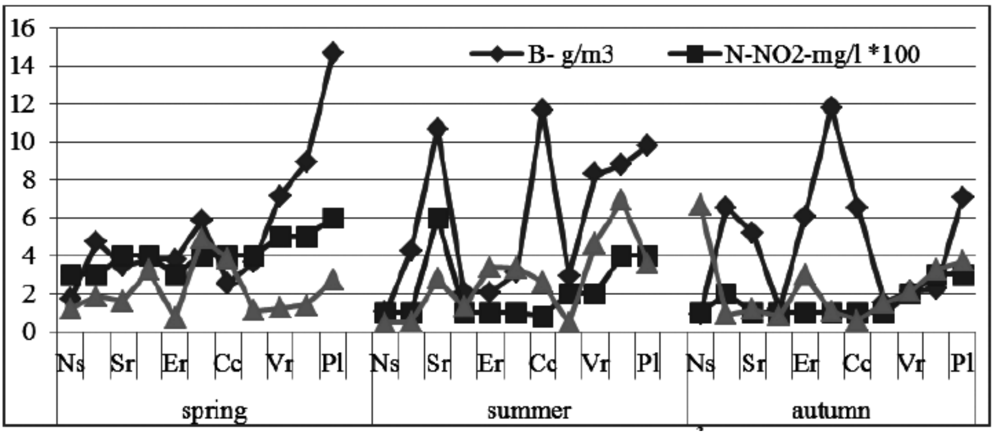

Fig. 6. Correlation between phytoplankton biomass (B – g/m³), primary production (A- gO₂/m-²) and nitrogen nitrate concentration (NO-2, mg/l) in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasari water Reservoir (Erjova, Goieni, Cocieri) in 2017.

After analyzing the seasonal and multiannual dynamics of concentrations of nitrogen compounds and phytoplankton biomass, it has been established that nitrate compounds play a special role in the development of phytoplankton, thus demonstrating a positive correlation between the dynamics of nitrates, nitrite production and phytoplankton biomass.

Thus, the dynamics of the content of organic nitrogen compounds in natural waters is closely related to the functional activity of planktonic algae. The increase in phytoplankton biomass, its functional activity level and the physiological state of the algal cells contribute to an intensification usage of nitrogen compounds. A stabilization of the increase in phytoplankton parameters lead to a decrease in the utilization rate of the nutrients and an increase in their concentrations in the water. Simultaneously with the assimilation of nitrogen compounds, in the natural waters there is also the elimination of nitrites by the algal cells. The way how such processes will occur depends on the dominance of some or other species and the physiological activity of algal cells. These peculiarities of phytoplankton-nitrogen compounds can be used to produce predictions on the changes in the hydrobiological and hydrochemical regime of continental aquatic ecosystems.

The role of phosphorus in the development of planktonic algae consists in its participation in energy accumulation and transformation processes in the cells. Phosphorus regeneration in algal cells occurs very quickly, and the rate of phosphorus circuit in aquatic ecosystems is much higher than nitrogen and silicon [15]. Therefore, the dependence of biomass and primary production of phytoplankton on the phosphorus concentration in water is a feature with profound ecological significance and the most convenient way to estimate the influence of nutrients on hydrobionates. The quantitative assessment of phytoplankton's response intensity to changes in the phosphorus concentration in water is one of the most relevant methods for predicting the changes in the trophicity of aquatic ecosystems. This dependence allows to evaluate of both critical and permissible productivity levels, leading to irreversible changes in the ecosystems.

At the same time, a very wide range of values of biomass and phytoplankton production was observed at the same values of the phosphorus concentration in the water of the Dniester River and the Dubasary reservoir (Figure 7). This shows that, in additionally to the phosphorus concentration in the water, a wide range of ecological factors can influence the process, acting in complex and at different intensitie on the process of photosynthesis and the development of planktonic algae.

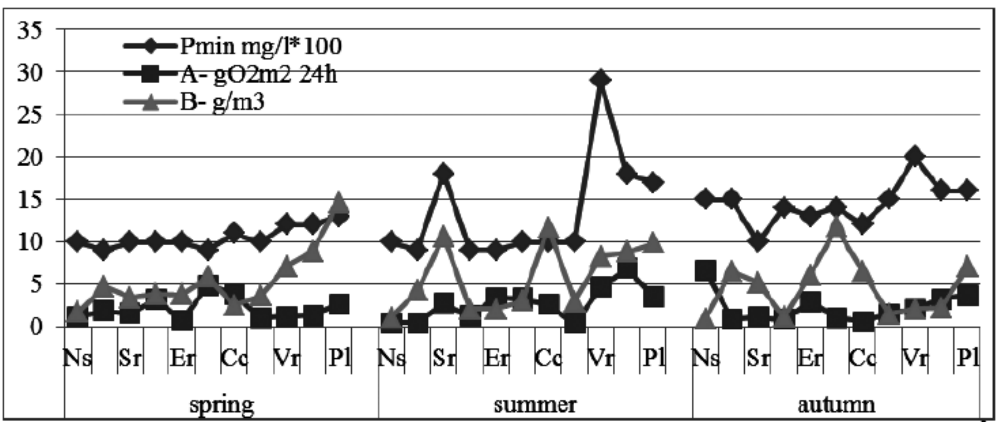

Fig. 7. Seasonal dynamics of mineral phosphorus (Pmin.- Mg/l*100), biomass (B- g/m^3) primary production (A- gO_2/m^{-2}) of phytoplankton in Dniester River (Ns-Naslavcea, Vl-Valcinet, Sr-Soroca, Cm-Camenca, Vv-Vadul-lui-Voda, Vr-Varnita, Sc-Sucleia, Pl-Palanca) and in Dubasari water Reservoir (Erjova, Goieni, Cocieri) in 2017.

Phosphorus, like nitrogen, can be used with planktonic algae in both mineral, phosphate and organic form. It should be noted that organic phosphorus is dominant in the total phosphorus content. In aquatic ecosystems, phosphorus is often the element whose absence limits the development of inferior and superior aquatic plants [7].

The ratio of nutrient content in the environment is recognized as a separate abiotic factor, which limits development of population in communities and influences the structure of phytoplankton. A determined range of N: P ratio can be optimal for particular species. This statement does not negate the separate influence of nutrients on phytoplankton, but complexity is so significant that the ratio of these elements becomes a more significant factor than their absolute concentrations [2, 9, 12].

The stimulatory or inhibitory effect of the nutrient ratio depends also on the peculiarities of the phytoplankton species. The bacillaryophyta algae grows more intense when the nitrate, phosphate and silicon content is higher, in spring and winter; green algae develop on ground during the summer, when nitrite and phosphate concentrations are lower; the golden algae substitute for the diatoms algae when there is little silica in the water and the N: P ratio is increased; cyanophytes develop more strongly when the concentration of nitrates and phosphates is minimal, and the content of organic substances is increased.

Conclusions

Phytoplankton is characterized by high specific diversity, being formed mostly of the diatom and green algae, and in the summer especially of blue-green algae. The variety of ecological conditions and their permanent fluctuations contribute to the development of planktonic algae communities with different preferences to the aquatic environment and the modification of the dominant complex during the vegetation period.

The quantitative parameters of the algae communities are characterized by a vast amplitude of spatial-temporal oscillations of their number and biomass values, which can be observed by comparing such values over time (seasonal and multiannual dynamics) and space (distribution of algal communities in different sectors of aquatic ecosystems) in the investigated ecosystems. Thus, the number of phytoplankton varied within the limits 1,33-35,05 million cells/l in Dniester River and 2,43-22,74 million cells/l in Dubasary Reservoir. Biomass values of phytoplankton varied within the limits 0,88-14,63 g/m^3 in Dniester River and2,07-11,75 g/m^3 in Dubasary Reservoir. In all investigated ecosystems the well-seasoned seasonal dynamics of the phytoplankton quantitative parameters was highlighted: the maximum values of the number and biomass were recorded during the summer and autumn periods in Dniester River and Dubasari Reservoir.

Seasonal and spatial fluctuations of phytoplankton biomass in investigated aquatic ecosystems are not accompanied by corresponding fluctuations in primary production. Seasonal variations in primary production values of phytoplankton have been attested within the limits 0,42-6,9 gO^2/m-2/24h in Dniester River and 0,6-4,87 gO^2/m-2 /24h in Dubasary Reservoir. In the vertical distribution of phytoplankton production, maximum values were recorded in the superficial horizons of the river. With the increase in the water depth, the intensity of photosynthesis decreases, which corresponds to a decrease in transparency and increase in turbidity.

The main biogenic nutrients, indispensable for the development of phytoplankton, are the nitrogen and phosphorus compounds, and for the diatom algae is silicon. Their presence in certain concentrations in aquatic ecosystems influences the quantitative parameters of the phytoplankton, the physiological state of the algal cells and their photosynthetic activity, thus directly or indirectly influencing their productivity. On the structure of phytoplankton communities in aquatic ecosystems, in addition to providing nutrients, many other biotic factors still influence, which are: algae consumption by zooplankton and phytophagous fish, the destruction of algal cells and their sedimentation, competition for nutrients with macrophytes and bacterioplankton.

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