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Development and structure of phytoplankton in the middle part of Kremenchug reservoir

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An analysis of quantitative and qualitative composition of phytoplankton in the middle part of the Kremenchug reservoir in the water area near the village of Chervona Sloboda, the village of Lesky and the village of Khudyaki in August 2016 is presented. The peculiarities of its formation in this period are established, and the changes that took place in the structure of its grouping are determined. The phytoplankton values of the Kremenchug reservoir were at the level of the total number of 16.8–54.0 million cells/dm^3, the total biomass of 2.3–4.9 mg/dm^3 and tended to develop in previous years. The basis of phytoplankton was formed by three groups of algae: *Chlorophyta, Bacillariophyta, Cyanophyta*. Green algae (class *Chlorophyta*) developed the least: their share was 3.1–28.8% of the total. The most represented species were *Volvox aureus* Ehr., *Micractinium pusillum* Fresen., *Pandorina morum* (O. Müll.) Bory and *Chlamydomonas reinchardtii* Dang. Diatoms algae (class *Bacillariophyta*) accounted for 19.2–62.4% of the total biomass, which was quite important in the formation of phytoplankton. Our data shows that *Melosira granulata* (Ehr.) Ralfs, *M. angustissima* Neizvestnova-Zhadina, *Nitzschia acicularis* (Kütz.) W. SmITH. prevailed among diatoms in all three studied areas. Blue-green algae (class *Cyanophyta*) predominated at all sampling stations No 1, 2, and 3, amounting to 26.0–93.7% and formed the basis of the phytoplankton community. In this group of algae the most represented species were: *Aphanizomenon flos-aquae* (L.) Ralfs ex Bornet & Flahault, *Anabaena flos-aquae* (L.) Bory, *Microcystis aeruginosa* Kützing, (station No 1 and 2), *An. flos-aquae, M. aeruginosa* (station No 3). Calculation of the Berger-Parker dominance index showed that at all sampling stations the highest rates had only alga *M. aeruginosa*. Its dominant role gradually decreased along the Dnieper: D_{BP} = 0.83, 0.53, and 0.41 at sampling stations No 1, 2, and 3, respectively. As a result of intensive development of colonial alga *M. aeruginosa,* it acquired the status of absolute dominant and subdominant species in the structure of this phytoplanktocenosis. Thus, cyanobacteria have become the dominant group of photosynthetic organisms of this phytoplanktocenosis. In such a way occurs the succession of diffuse nature of regressive type towards the monodominance of the community, which threatens the balance of this hydroecosystem in general.

Keywords: phytoplankton, cyanobacteria, aquatic organisms, Kremenchug reservoir.

Introduction

We studied the part of the Kremenchug reservoir, which differs in the considerable area of shallow water, had insignificant water exchange due to the slow current and warming up in spring and summer. The water here is enriched with nutrients from the catchment area and bottom sediments, this provides intensive development of natural feed base for feeding young fish and elder age groups of various fish. The reservoir is characterized by high species diversity of young fish - up to 16 species in summer. Some authors noted the uniqueness of yearlings ichthyofauna in this part of the reservoir (Kotovska, Khristenko, 2010). Thus, the development of a natural feed base that meets the nutritional fish needs is very important.

A detailed analysis of the literature data for 1961-1984 and own research for 1981-2007 of phytoplankton development of this reservoir is presented by S.V. Kruzhilina (2010). Every year, the conditions of aquatic environment change depending on changes in ambient temperature, rainfall, quality and quantity of soil and sewage, and the regime of flooding the river by locks. It is established that in different years a change in the dominant algae complexes depends on the environmental conditions. Blue-green algae in phytoplankton community were mostly represented by *Microcystis aeruginosa* Kützing*, Aphanizomenon flos-aquae* (L.) Ralfs ex Bornet & Flahault in 1981-1983, 1985, and 1996-2000; *M. aeruginosa, Anabaena spiroides* Klebahn predominated in

1984 and 1986-1991; *A. spiroides, A. flos-aquae* (L.) Bory predominated in 1992–1995; *M. wesenbergii* (Komárek) Komárek in N. V. Kondrat, *M. aeruginosa* – in 2001; *An. flos-aquae, M. wesenbergii* – in 2004; algae *A. flos-aquae, M. aeruginosa,* and *Oscillatoria* sp. Vaucher ex Gomont dominated in 2005-2006. Among the diatoms, *Melosira granulata* (Ehr.) Ralfs, *M. italica* (Ehr.) Kütz. dominated in 2003; *M. granulate* and *M. varians* C.A. Agardh. – in 2002 and 2007 (Kruzhilina, 2010).

According to the analysis of recent studies, blue-green algae (*Cyanobacteria synonyms Cyanophyceae, Cyanophyta*) are most often mass-produced. They belong to the oldest forms of life on the Earth. They are known since 3.5 billion years from the late Precambrian. All cyanobacteria are the photosynthetic organisms and their pigments capture light with a wavelength of 550 to 650 nm. About a third of all types of cyanobacteria are able to fix nitrogen that occurs in specialized cells called heterocysts (Oberholster, 2004).

Cyanobacteria are the dominant group of phytoplankton in eutrophic freshwater bodies worldwide. They are developing especially massively in shallow, warm water bodies or in polluted water with low oxygen content (Stotts et al., 1993; Oberholster, 2004). Such outbreaks of development of certain groups of organisms undermine the basis for the sustainable existence of the aquatic ecosystem. Biodiversity is violated as an integral concept that describes the variability inherent in all types of hydroecosystems. To be protected at the legislative level, the International Convention for the Conservation of Biological Diversity on Earth (1992, 1995) and the Concept of national biodiversity conservation program for 2005-2025 in Ukraine (2004) were adopted.

The aim of our work was to analyze the phytoplankton development in the middle part of the Kremenchug reservoir.

Materials and Methods

We focused on three sections of the Kremenchug Reservoir: near the village of Chervona Sloboda (station No 1), the village of Lesky (station No 2) and the village of Khudyaky (station No 3), which are located in the middle section of the Kremenchug Reservoir. The peculiarity of this water area is the predominance of floodplains with mostly sandy, occasionally stony soil, they are overgrown and shaded with floating potamogeton (*Potamogeton natans* L.) and common reed (*Phragmites australis* (Cav.) Trin. Ex Steud.). There is a lot of shallow water with a depth of 0.5-4.0 m, which is well warmed up.

Algological samples were taking with Rutner bathometer. Fixation, concentration, processing of phytoplankton samples were performing in accordance with well-known hydrobiological methods (Romanenko, 2006). The water temperature was measuring daily. Such indicators were fixed t_{max}, t_{min}, and t_{med} (Fig. 1).

Results

The temperature conditions of the aquatic environment were unstable (Cv = 10.69–13.97 %) and stressful for living organisms that inhabited it. The most dangerous were hot sunny days, when the air temperature rose up to 18-32 °C, and water up to 21.0–25.8 °C (Fig. 1).

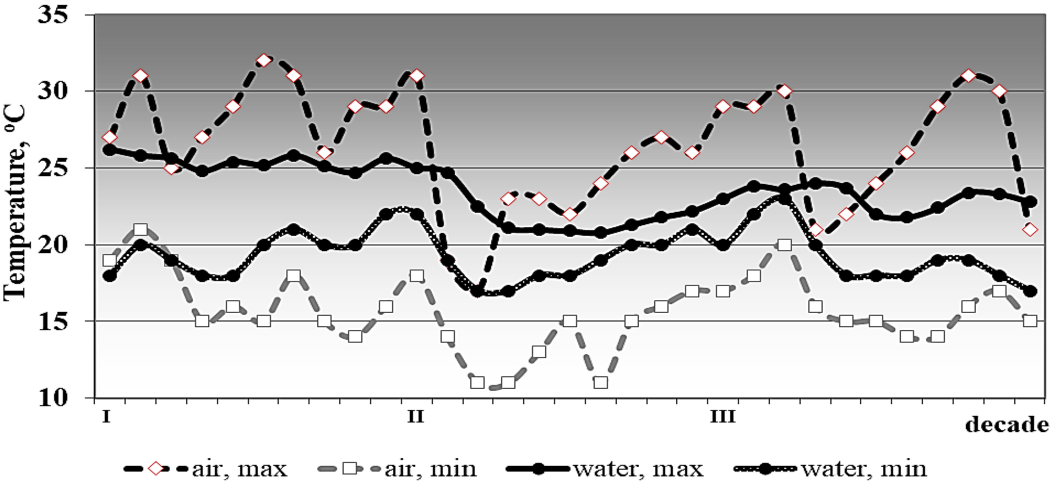

Fig. 1. Dynamics of temperature fluctuations of air and water values by decades in Kremenchug reservoir, °C.

Total number of phytoplankton ranged from 13.72 to 67.29 million cells/dm^3. Maximum values of 53.97 ± 3.76 million cells/dm^3 were registrated in the water area near Chervona Sloboda village, which is located at the top of the study area (Fig. 2). Probably, this is occurred due to the inflow of domestic sewage from Cherkasy (On Pollution, 2019). A significant decrease in the quantitative values of phytoplankton development was observed downstream. In particular, the area near the village of Lesky was characterized by three times lower numbers as 16.75 ± 1.33 million cells/dm^3. Further downstream, in the area near the village of Khudyaki, the total number of phytoplankton was twice lower than at Chervona Sloboda top station and amounted to 26.15 ± 2.09 million cells/dm^3.

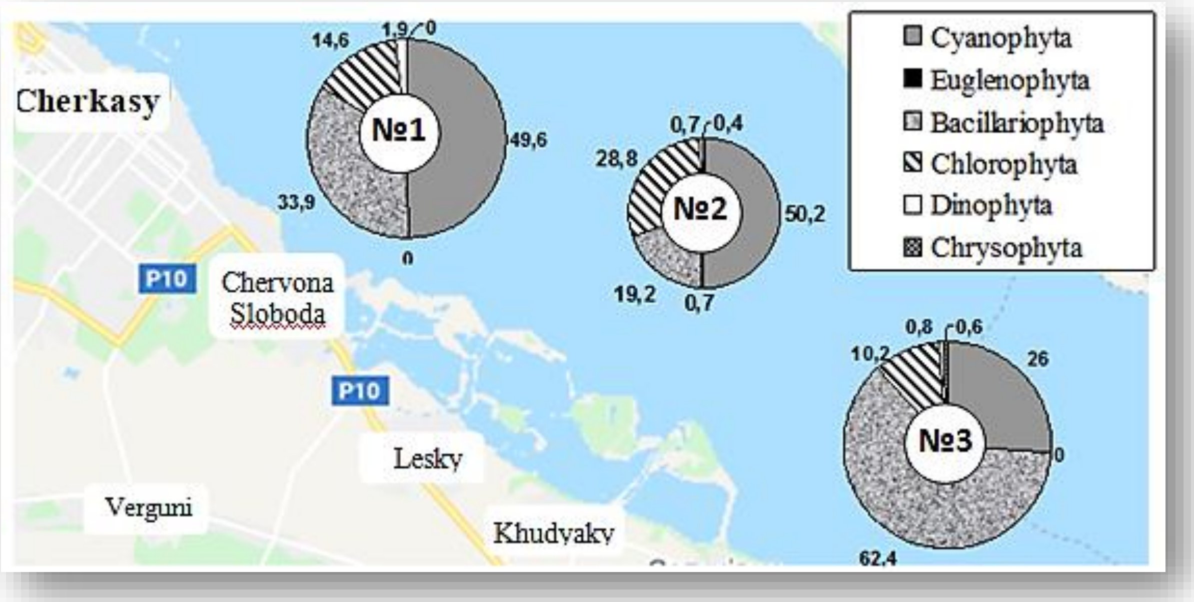

Fig. 2. Distribution of the total number of phytoplankton between its main groups in Kremenchug reservoir (%), in the lower part of Cherkasy.

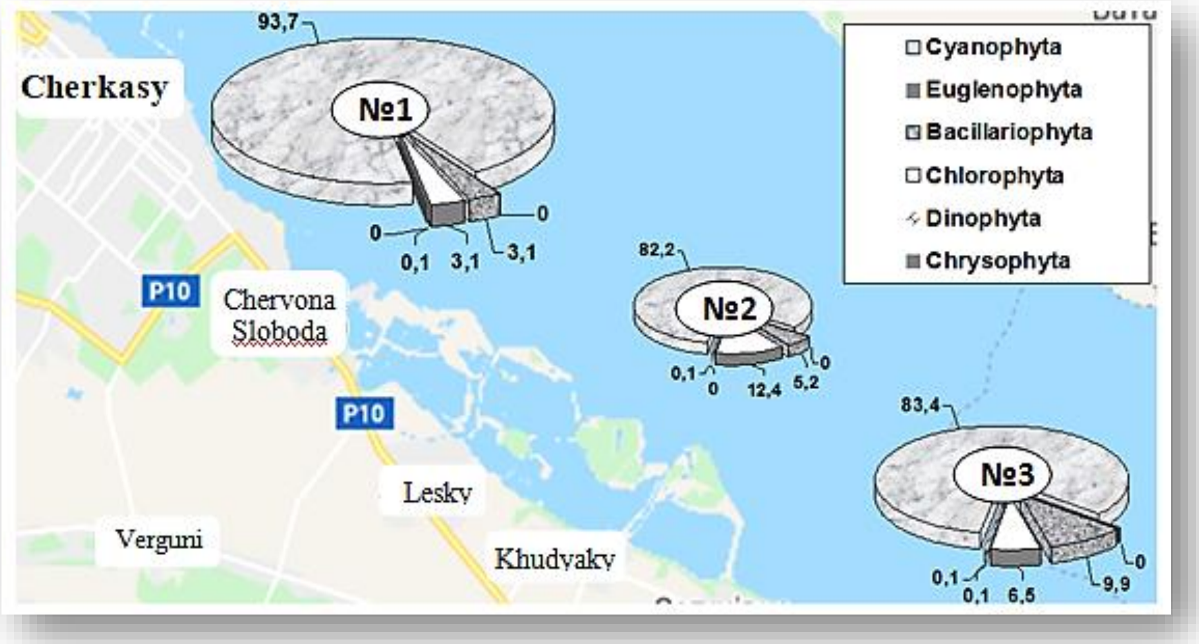

Fig. 3. The structure of phytoplankton groups in terms of biomass in Kremenchug reservoir downstream from Cherkasy, (%).

Values of total phytoplankton biomass were minimal 2.30 ± 0.23 mg/dm^3 at the sampling site No 2 (the village of Leski) and were higher by 1.7 times on the two other stations: 4.86 ± 0.36 mg/dm^3 on the section No 1 of the village of Chervona Sloboda and 4.89±0.39 mg/dm^3 in the area No 3 in the village of Khudyaki (Fig. 3). Such data correspond to the period of decline of algae vegetation of the Kremenchug reservoir – 2.1-3.8 mg/dm^3 – in 2004 (Kruzhilina, 2010).

The samples showed that of diatoms (class *Bacillariophyta*) was represented quantitavely as 1647.00 ± 132.05, 872.00 ± 69.91, 2592.0 ± 207.82 thousand cells/dm^3 at sampling stations No 1, 2, and 3, respectively and in percentage terms it was 3.1, 5.2,; and 9.9 % respectively (Fig. 2). Their biomass values amounted respectively to 1.65 ± 0.13, 0.54 ± 0.04, and 3.05 ± 0.24 mg/dm^3 that made 33.9, 19.2, and 62.4% (Fig. 3) and turned out to be quite important in the formation of phytoplankton. Therefore, in areas No 1 and 3 an increase of role of diatoms in the phytoplankton biomass formation was observed. This trend was noticed by various researchers of phytoplankton of the Kremenchug reservoir from 1981 till 2007, but at that period of time their share ranged from 9 to 59 % (Scherbak, 1998, Kruzhilina, 2010). In this group of algae the most represented were the species *Melosira granulata* (Ehr.) Ralfs, *M. angustissima* Neizvestnova-Zhadina, *M. varians* at all three study sites.

The green algae (class *Chlorophyta*) was amounted to 1698.00 ± 136.14, 2082.00 ± 166.93,amd 1702.0 ± 136.46 thousand cells/dm^3 at sampling stations No 1, 2, and 3, respectively and in percentage terms it was only 3.1, 12.4, and 6.5 % respectively (Fig. 2). Their biomass values respectively were as 0.71 ± 0.06, 0.81 ± 0.06, and 0.50 ± 0.04 mg/dm^3 and in a percentage of 14.6, 28.8, and 10.2 % (Fig. 3). Therefore, a decrease in the proportion of green algae was observed in plots No 1 and 3. In this group of algae the most represented species were *Volvox aureus* Ehr*., Micractinium pusillum* Fresen*., Pandorina morum* (O. Müll.) Bory and *Chlamydomonas reinchardtii* Dang.

The oldest group of algae – *Cyanophyta* prevailed in quantitative terms at all sampling stations No 1, 2, and 3 amounting to 50.58 ± 3.51, 13.76 ± 1.10, and 21.80 ± 1.74 million cells/dm^3 respectively. They formed the basis of phytoplankton at all stations 93.72, 82.19 , and 83.36 % respectively (Fig. 2). However, their biomass was insignificant and amounted to only 2.41 ± 0.17, 1.41 ± 0.11, and 1.27 ± 0.10 mg/dm^3, respectively (Fig. 3). These numbers were half of the total biomass of phytoplankton in the section №1 (the village of Chervona Sloboda) – 49,6 % and in the section No 2 (the village of Lesky) – 50.2 %.

On the other hand, in the section № 3 (the village of Khudyaky), the percentage was twice lower than in the previous two and was at the level of 26.0 %. This group of algae mostly was represented by species: *Aph. flos-aquae, Anab. flos-aquae, M. aeruginosa* (station № 1 and № 2), *An. flos-aquae*, *M. aeruginosa* (station No 3). The calculation of the Berger-Parker dominance index, which takes into account the share of the dominant species, showed that at all sampling stations the highest rates had the species *M. aeruginosa,* while its dominant role was gradually reduced at sampling stations No 1, 2, and 3: D_{BP} = 0.83, 0.53, and 0.41 respectively. Thus, as a result of intensive development of colonial algae *M. aeruginosa*, it acquires the status of absolute dominant and subdominant species in the structure of this phytoplanktocenosis.

This was facilitated by optimal temperature conditions, which varied within 20-25 °C, at which, according to observations (Yokoyama & Park, 2003), the maximum growth rate of *M. aeruginosa* cells occurs. According to the literature data (Shcherbak, 1996, Kruzhilina, 2010) a similar situation was observed in the Kremenchug reservoir in the 80-s, namely: in 1981-1983, and 1985, when the species *M. aeruginosa* formed up to 60% of the total biomass of algae. It is known from the literature that algae succession usually follows typical patterns in freshwater resevoirs: from diatoms, through chlorophytes to cyanobacteria (Stotts et al., 1993; Oberholster, 2004). In our case, successional processes occur with a sharp suppression of green algae and the transition from diatoms to blue-green algae.

Note that *Cyanophyta* has specific cytoplasmic inclusions – gas vesicles that promote the buoyancy of their cells (Oberholster, et al., 2004). As a result of intensive development of blue-green algae, up to blooming, there is a further mass uplift of cells to the water surface, which is observed in the change of water colour of the reservoir. The mass development of algae can be seen even from the space. The photos taken from the satellites Terra and Aqua (Fig. 4) gave the opportunity to see that of the entire cascade of Dnieper reservoirs, the most intensive process of water blooms took place between 26-29 August 2016 and was observed in the Kremenchug reservoir (Shevchuk, et al., 2019). An accumulation of cyanobacteria in the surface layer caused shading of the water column and a decrease of photosynthetic processes. Under such conditions, the oxygen regime deteriorates sharply, which is accompanied by suffocation among aquatic organisms. As a result, the water had bad smell.

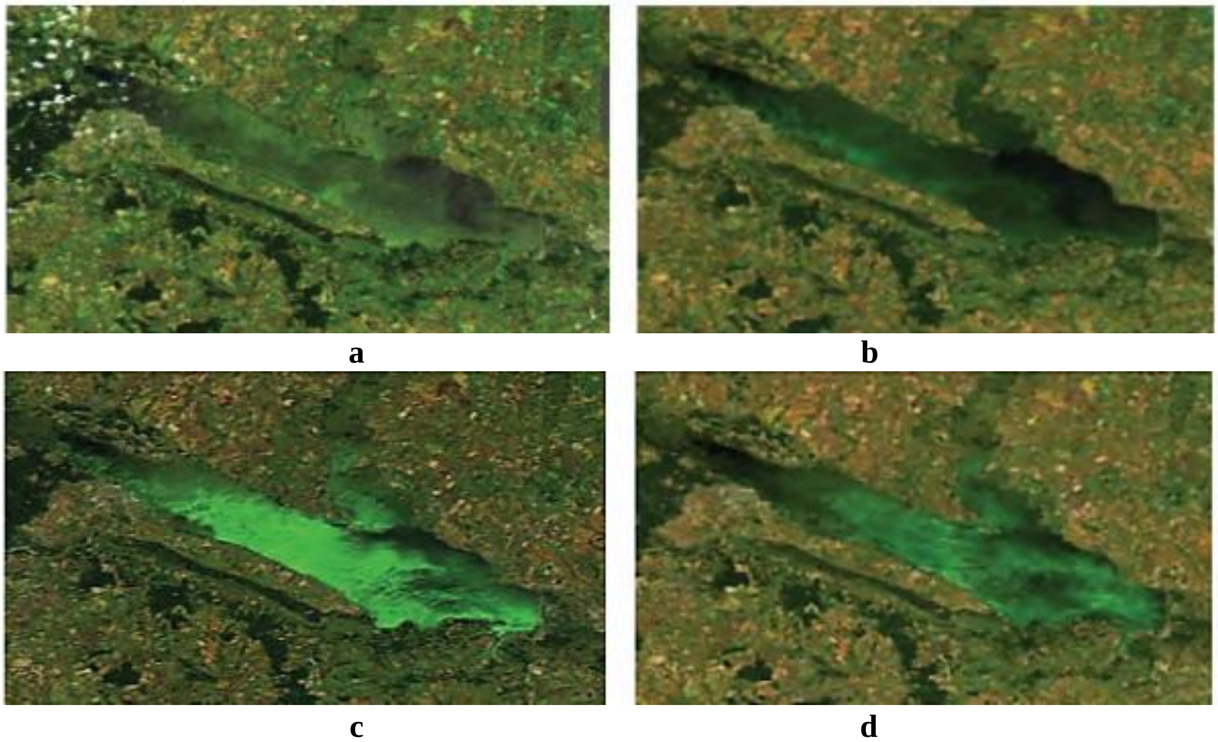

Fig. 4. Satellite photographs of the Kremenchug Reservoir during the water blooming; a – 08.26.2016, b – 08.27.2016, c – 08.28.2016, d – 08.29.2016 (Shevchuk et al., 2019).

Thus, the presented data on the development of phytoplankton of the Kremenchug reservoir clearly shows that there is a real threat to the existence of this hydroecosystem, caused by the violation of biological and ecological balance. Such situation requires immediate action at the local and state levels.

Conclusion

The phytoplankton values of the Kremenchug reservoir were at the level of the total number of 16.8–54.0 million cells/dm^3, the total biomass of 2.3–4.9 mg/dm^3 and tended to develop in previous years. The basis of phytoplankton was formed by three groups of algae: *Chlorophyta, Bacillariophyta, Cyanophyta.*

Green algae (*class Chlorophyta*) developed the least: their share was 3.1–28.8 % of the total. The most represented species were *V. aureus, Micr. pusillum, P. morum* and *Chl. reinchardtii*

Diatoms algae (*class Bacillariophyta*) accounted for 19.2–62.4 % of the total biomass, which was quite important in the formation of phytoplankton. Our data shows that *M. granulata, M. angustissima, Nit. acicularis* prevailed among diatoms in all three studied areas.

Blue-green algae (*class Cyanophyta*) predominated at all sampling stations No 1, 2, and 3, amounting to 26.0–93.7% and formed the basis of the phytoplankton community. In this group of algae the most represented species were: *Aph. flos-aquae, An. flos-aquae, M. aeruginosa* (stations No 1 and 2), *An. flos-aquae*, *M. aeruginosa* (station No 3).

Berger-Parker index value showed the highest rates of only alga *M. aeruginosa*. at all sampling stations. Its dominant role gradually decreased along the Dnieper: D_{BP} = 0.83, 0.53, and 0.41 at sampling stations No 1, 2, and 3, respectively. As a result of intensive development of colonial alga *M. aeruginosa*, it acquired the status of absolute dominant and subdominant species in the structure of this phytoplankton comminity.

Thus, cyanobacteria become the dominant group of photosynthetic organisms in this phytoplankton comminity. In such a way, the succession of regressive type diffuse nature occurs towards the monodominance of the community, which threatens the balance of this hydroecosystem.

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