

UDC: 631.427.1.

original scientific paper



Acta Agriculturae Serbica, Vol. III, 6 (1998) 45-54

Dynamics of Oligotrophic and Heterotrophic Bacteria in the Grosnica Reservoir and Interrelations between them

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Abstract: The Grošnica reservoir with its microbiological features belongs to quality class I-II according to Kohl (1975). Oligotrophic bacteria are dominant, except in the spring, when heterotrophic bacteria are present in greater number. Composition of bacterial community, their spatial and time distribution varies during vegetation period in the function of physicochemical features of an environment. The relation of heterotrophic and oligotrophic bacteria (Index FO/H) is changed and depends on the quality and quantity of organic matter, as well as condition of other factors in biocenosis (first of all on phytoplankton and macrovegetation status).

Key words: bacteria, oligotrophs, heterotrophs, FO/H index, Grosnica reservoir

Introduction

Microorganisms occupy an important place in the lake ecosystems, not only as primary reducers, but also as producers of autochthonous organic matter. The status of microorganism populations is a realistic indicator of the course of various general and specific biochemical processes, but being also the first indicator of eutrofication it is of great significance in hydrobiological study.

Contributions to the study of bacterioplankton in lakes of Yugoslavia have

been made by Očevski (1985) for Ohrid Lake, by Stilinović and Futač (1984, 1985a, 1985b) for the Plitvica lakes; Ristanović (1974, 1981) for Skadar Lake, by Gajin *et al.* (1990, 1991) for the reservoirs in the Vojvodina; by Čomić (1989), Čomić and Ranković (1990) and Čomić *et al.* (1993) for the Gruža reservoir and by Čomić *et al.* (1997) and Čurčić and Čomić (1997) for Vlasina Lake.

Complex research on biological characteristic of Grošnica Reservoir has been carried out since its early days (Janković, 1966a, 1966b, 1967; Ranković *et al.*, 1999; Ostojić and Simić, 1999). However, the present study is the first one related to microbiological investigations.

The purpose of the present research was to establish quantitative and qualitative composition of the bacterial community, ascertain their spatial and temporal dynamics in relation to the other factors in the ecosystem, and in this way to make a contribution to a better and more complete recognition of the complex processes of organic matter transformation occurring in the lake. Water quality was established on the basis of microbiological indices, a foundation was laid for further observation and follow-up of eutrofication processes and antropogenic influence.

Characteristics of the Grošnica reservoir

The Grošnica Reservoir was formed by damming of the Grošnica River 10 km south of Kragujevac to supply drinking water for the city and surrounding area (Fig. 1). The reservoir was built from 1931 to 1937. In exploitation since 1938, it is the oldest cumulative artificial lake in Yugoslavia (Jeremić, 1976). The original volume of the lake was $1.7 \times 10^6 \text{ m}^3$ (Stanković, 1969). The dam was raised (to a height of 50 m) and the original volume of the lake enlarged (to $3.5 \times 10^7 \text{ m}^3$) in 1962. The reservoir receives water from the Grošnica River, four smaller tributaries, and atmospheric precipitation. Depth of the lake varies throughout the year depending on the inflow and consumption of water. It has maximal depth of 23 m, surface of 22 ha, length of 1750 m, and width of 130-250 m. The shores of the lake are wooded, with beech on the left side and oak on the right.

In regard to temperature characteristics, the lake belongs to the category of dimictic lakes of the temperate climatic zone. However, as a result of exploitation and movement of water, the expected stratification is not observed in the lake during summer, nor is the existence of a thermocline recorded.

Material and Method

Multiple hydrobiological investigation including microbiological analysis of the Grošnica Reservoir was carried out during the period of May 1997 to September 1998. Sampling was conducted on a monthly basis at three constant sites in the lake:

- by the dam;
- in the central part of the lake; and
- in the shallow part.

Samples were invariably taken from depths of 0.5 m, 5 m, 10 m, 15 m, and maximal depth. Sampling was done from surface to bottom using a Ruttner bottle (Hydrobios) for below-surface sample taking.

Standard microbiological methods were employed to examine the following features:

- the number of psychrophilic heterotrophic bacteria on Beef Peptone Medium from Torlak (Belgrade); colonies were counted after 7 days of incubation at temperature of 22⁰C;
- the number of facultative oligotrophic bacteria on Beef Peptone Medium from Torlak in 1:10 dilution; colonies were counted after 7 days of incubation at temperature of 22⁰C;
- the ratio of facultative oligotrophic and heterotrophic bacteria - FO/H index;
- water quality classification was performed according to Kohl (1975).

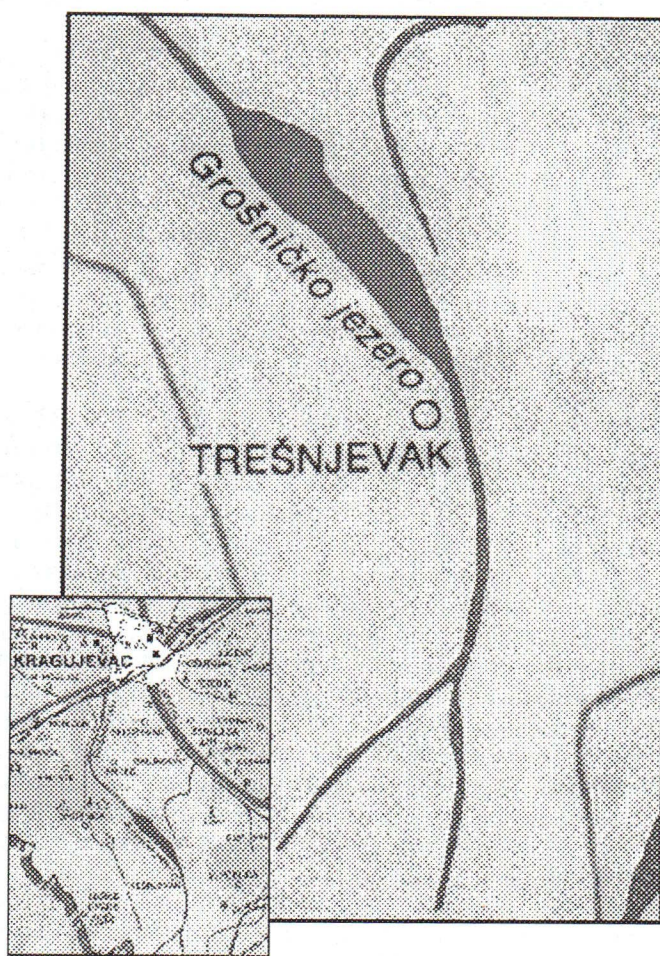


Fig. 1. Morphometric map of Grosnica Reservoir with sampling points

Results and Discussion

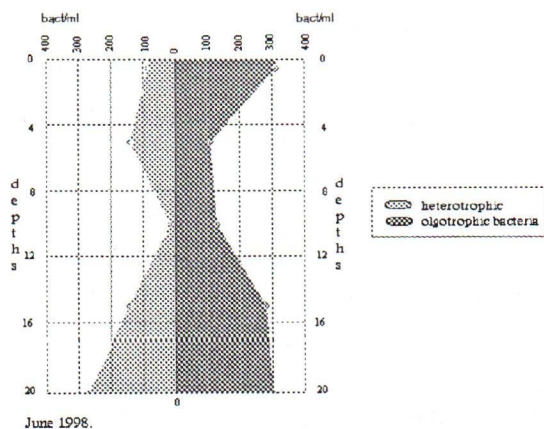
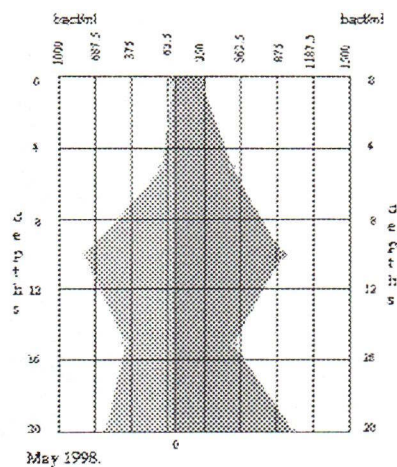
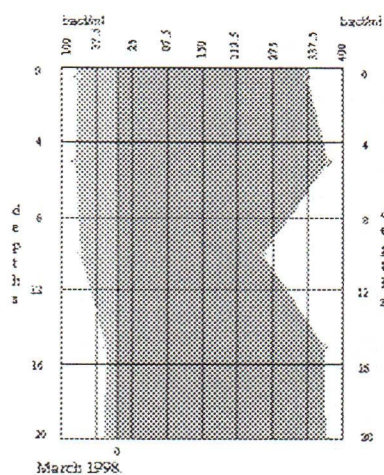
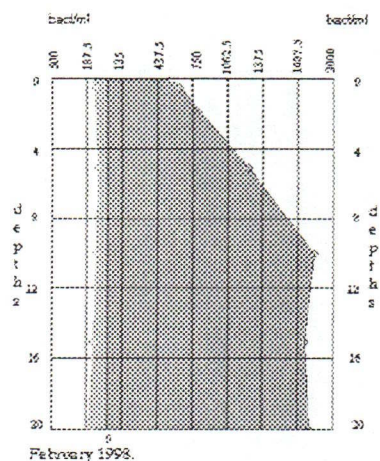
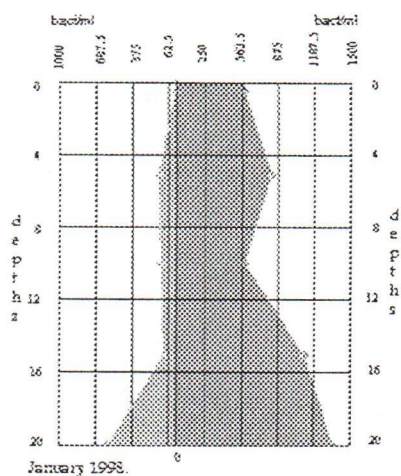
Figure 2 presents a comparative survey of the abundance of oligotrophic and heterotrophic bacteria, spatial and time dynamics of the same, and their interrelationship (the FO/H index) in the Grošnica Reservoir on the example of the deepest part of the lake (in front of the dam).

Quantitative Composition and Dynamics of Heterotrophs - As the only biological population capable of transforming organic substances of both biogenic and abiogenic origin, heterotrophic bacteria control the fluctuation of a considerable part of the matter in a lake ecosystem (Munster and Chrost, 1990). A high abundance of heterotrophs indicates water rich in organic substances subject to bacterial decomposition (Petrović *et al.*, 1998).

Heterotrophic bacteria are found in all samples from the Grošnica Reservoir. The number of heterotrophic bacteria varied both by seasons and from one sampling site to another. Values vary from 11.00 bacteria/cm³ of water in October of 1997 at a depth of 0.5 m to 1805.33 bacteria/cm³ of water in September of 1998 at a depth of 5 m, both in the central part of the lake. On the basis of occurrence and abundance of heterotrophic bacteria, water of the Grošnica Reservoir belongs to water quality class I-II (Kohl, 1975). A greater number of the bacteria characteristic of quality class II are found in the hypolimnion during summer. Increase in the abundance of heterotrophs in the hypolimnion and the hypolimnetic oxygen content minimum are the first indicators of change in the quality of water in the lake. With respect to the abundance of saprotrophs--which in exceptional cases exceeds 1000 bacteria/ml--the Grošnica Reservoir is similar to the Vlasina Reservoir (Čomić *et al.*, 1997) and considerably poorer than other oligotrophic lakes in the Balkans (Oceviski, 1985; Ristanović, 1970, 1981; Stilinović and Futač, 1984, 1985a, 1985b).

By comparing the average abundance values of heterotrophs in the water column, we established the seasonal dynamics of these bacteria. A summer maximum of abundance in August (773 bacteria/cm³) and a spring minimum of the community (18.77 bacteria/cm³) were recorded in both growing seasons. The increase of abundance observed during February (1177.86 bacteria/cm³) is a result of hydrometeorological conditions and the presence of allochthonous bacteria that entered the lake from the shore due to rinsing. Throughout the rest of the year, the abundance of these bacteria is determined by changes in physicochemical properties of the water and the status of other factors in the biocenosis. Coordination in the production of bacterio- and zooplankton was established in a previous study (Čomić *et al.*, 1999). It was also found that the maximum of bacterial abundance precedes maximal gross primary production. Evidently, bacteria through their activity ensure a sufficient quantity of adequate mineral nutrients needed by primary producers.

Comparison of the abundance of heterotrophs from different sampling sites in water of the Grošnica Reservoir revealed no significant variations in horizontal distribution, except at times of heavy precipitation. The number of heterotrophs in the shallow part of the lake is then increased due to ingress of allochthonous land-based species.



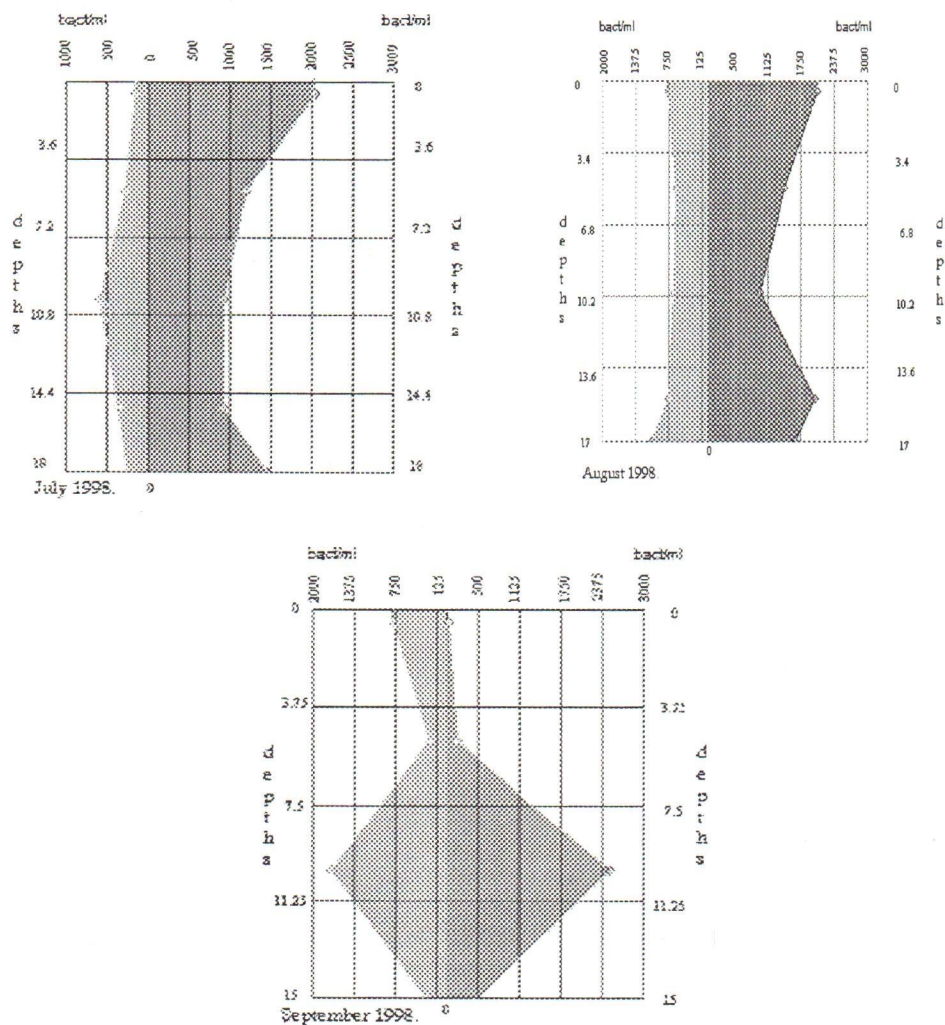


Fig. 2. Spatial and temporal dynamics of oligotrophic and heterotrophic bacteria (locality Dam)

The vertical distribution of heterotrophic bacteria varied throughout the growing season (Fig. 2). The abundance maximum occurred at different depths and invariably depended on the nature and quantity of nutrients. The greatest number of bacteria was most often found in the zone above the lake bottom, where organic matter originating from dead phytoplankton and macrovegetation accumulated.

Abundance of Facultatively Oligotrophic Bacteria in the Grošnica Reservoir - Many authors (Ishida and Katoda 1981; Moaleđ and Overbeck, 1980;

Gajin *et al.*, 1988) have recently emphasizes oligotrophs as dominant, autochthonous bacteria, especially in clean lake and river waters. Oligotrophs present in low concentrations of nutrients, demonstrate a high substrate affinity, and play an important role in transformation of organic matter in lakes. Investigating oligotrophic bacteria in the Plußsee, Moaleđ (1978) stressed that oligotrophic bacteria have a competitive advantage over saprophytes.

Facultatively oligotrophic bacteria are found in all samples of water from the Grošnica Reservoir. The maximal value of abundance (2474.67 bacteria/ml) was recorded in September of 1998 by the dam at a depth of 10 m, the minimal value in May of 1997 at a depth of 0.5 m.

Examination of the abundance of facultative oligotrophs in different periods of the year showed that this community is characterized by a summer maximum and a spring minimum of abundance. The observed state of affairs is in keeping with the seasonal distribution of facultative oligotrophs in the Vlasina Reservoir (Curčić and Čomić, 1998). Similar seasonal fluctuations of facultative oligotrophs have also been found in lakes of the mesotrophic type, the Gruža Reservoir for example (Čomić, 1989).

Comparison of the abundance of facultative oligotrophs at different sampling sites in the Grošnica Reservoir revealed no regularity in the distribution.

The abundance of facultative oligotrophs in the water column varied as a function of sampling time, but no regularities were established in their vertical distribution (Fig. 2).

From the wider ecological aspect, the ratio between facultatively oligotrophic and heterotrophic bacteria or FO/H index also represents an indicator of the state and quality of water and implies a greater or lesser capacity for self-purification of an aquatic ecosystem (Petrovic *et al.*, 1998).

Comparative examination of the abundance of heterotrophs and oligotrophs revealed that the autochthonous community of facultative oligotrophs is dominant in Grošnica reservoir. In relation to heterotrophs, the community of oligotrophs were dominant in 68.8% of tested water samples. An exception to this was observed in May-June 1997, when the dominant bacteria in the lake were heterotrophic ones. The dominance of heterotrophs in spring is a consequence of the presence of allochthonous land-based species that enter the lake from the shore as a result of rinsing at times of increased water inflow.

The FO/H index in water of the Grosnica Reservoir varied between 0.28 and 15 (Tab. 1). In most cases, values less than 1 occurred sporadically, at greater depths. Only in January in the middle of the lake was the value of this index throughout the entire water column between 0.28 and 0.81, which indicates poor water quality.

Previous investigations of Gajin *et al.* (1986) showed that the ratio of oligotrophs to heterotrophs in clean water was most often greater than 1, *i.e.*, the oligotroph population was dominant. Examining the ratio of eutrophic to heterotrophic bacteria Ishida and Katoda (1977) noted that the indicated ratio increases in parallel with the concentration of dissolved organic substances in the water of Mergazzo Lake. The autor concluded that eutrophic bacteria are dominant in polluted waters, while oligotrophic bacteria are dominant in unpolluted lake waters.

Conclusion

On the basis of the results obtained by the microbial examinations of water in Grošnica Reservoir in the period of May 1997 to September 1998, the following can be concluded:

- Grošnica Reservoir with its microbiological features belongs to class I-II bonity according to Kohl (1975);
- facultative oligotrophic bacteria are dominant community in the water, except in spring when heterotrophic bacteria are in the larger number;
- spatial and time distribution of bacteria varies during vegetation period in the function of physicochemical features of a environment;
- the relation of heterotrophic and oligotrophic bacteria (Index FO/H) is changed and depends on the quality and quantity of organic matter, as well as condition of other factors in biocoenosis (first of all on phytoplankton and macrovegetation status).

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DINAMIKA OLIGOTROFNIH I HETEROTROFNIH BAKTERIJA U GROŠNIČKOM JEZERU I NJIHOVI MEĐUSOBNI ODNOSI

-originalni naučni rad-

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Rezime

Grošničko jezero kao najstarije akumulaciono jezero u Jugoslaviji jeste specifičan ekosistem od posebnog značaja. Mikrobiološka ispitivanja Grošničkog jezera vršena su u okviru kompleksnih hidrobioloških ispitivanja, u periodu maj 1997. - septembar 1998. Godine sa ciljem da se utvrdi sastav zajednice bakterija, njena prostorna i vremenska dinamika u odnosu na ostale činioce u ekosistemu i time doprinese potpunijem sagledavanju složenih procesa transformacije organske materije u jezeru. Na osnovu mikrobioloških pokazatelja utvrđen je kvalitet vode i stvorena osnova za praćenje procesa eutrofikacije i antropogenog uticaja.

Na bazi rezultata mikrobioloških ispitivanja utvrđeno je da Grošničko jezero pripada I-II klasi boniteta po K o h l-u (1975). U jezeru je dominantna zajednica fakultativnih oligotrofa, izuzev u proleće kada su brojnije heterotrofne bakterije. Prostorna i vremenska distribucija bakterija se menja tokom vegetacione periode u zavisnosti od promene fizičkih i hemijskih svojstava. Odnos fakultativnih oligotrofa i hetrotrofa (Index FO/H) se menja i zavisi od količine i prirode organske materije, kao i od stanja ostalih činioca u biocenozi (od stanja fitoplanktona, zooplanktona ili makrovegetacije).