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MACROZOOBENTHOS OF THREE BROOKS IN THE SOUTHERN PART OF THE PANNONIAN PLAIN: COMPARATIVE ANALYSIS OF SECONDARY PRODUCTION

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Abstract. Production of macrozoobenthos was investigated at 18 localities on the Kudoski, Jelenacki, and Borkovacki brooks during April, July, and October of 2000 and in January of 2001. 16 groups of macroinvertebrates were recorded in the course of the investigation. The dominant groups in the biomass of macrozoobenthos were Hirudinea (Annelida), Mollusca, Gammaridae (Crustacea), and Trichoptera (Insecta). The greatest biomass of the bottom fauna in all months of investigation was recorded in the Kudoski brook, where it ranged from 41.3248 g/m^2 in July to 133.2384 g/m^2 in October, the next greatest one in the Jelenacki brook, and the least in the Borkovacki brook (from 23.7432 g/m^2 in July to 90.3328 g/m^2 in January).

Key words: macrozoobenthos; secondary production; Kudoski, Jelenacki, and Borkovacki brooks.

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Introduction

On the territory of the Pannonian Plain, macrozoobenthos has been investigated for the most part in the large flatland rivers (the Danube, Tisza, Sava, Begej, and Tamis) and in irrigation canals (Pujin *et al.* 1974, Djukic and Stanojevic 1979, Miljanovic and Djukic 1989, Elexova 1998, Mihaljevic *et al.* 1998, Sporka and Nagy 1998, Graf and Kovács 2002, Nosek 2002, Oertel 2002, Schmidt-Kloiber *et al.* 2002), while considerably less attention has been paid to investigation of the bottom fauna of small streams. This is understandable, since the major part of the hydrological network of the Pannonian Plain is made up of large rivers and canals, and small streams participate more significantly in it only around the rim of the Plain.

Of particularly great significance in the hydrological network are small streams in the Srem region, which occupies the southern rim of the Pannonian Plain. This follows from the fact that the indicated region is completely cut off from the rest of the Plain by the Fruska Gora mountain in the north and separated by the Danube in the east. A large number of streams arise on the Fruska Gora mountain. Of these, ones that flow down the southern slope and empty into the Sava are fairly long and build a branching hydrological network. These aquatic ecosystems are exposed to human influence of varying intensity along their entire course. Except in source regions, the streams flow through agricultural fields and are used as irrigation canals, but they are also recipients of drainage waters from farm land and communal and industrial waste waters. In view of the fact that these are small streams with zoocenoses characterized by dominance of macrozoobenthos — whose organisms on account of their way of life are good indicators of water quality (Hynes 1959) — we felt that it would be interesting to study the influence of anthropogenic pollution on abundance and biomass of their bottom fauna in comparison with mountain streams having similar hydrological characteristics.

The watershed of the Kudoski brook was selected for our investigations, the indicated watershed being composed of the Kudoski, Jelenacki, and Borkovacki brooks. These brooks flow parallel to each other from north to south and are close together (their distances are about 2-3 km). They are characterized by similar physical characteristics (water temperature, substrate type, slope, etc.), so that their differences in regard to biomass and abundance of the bottom fauna are primarily a consequence of specific human influence.

In the present work, the biomass of the macrozoobenthos was selected as the main index for monitoring changes in quantitative composition of the bottom fauna, inasmuch as it is one of the basic parameters for quantification of the level of secondary production (Mason *et al.* 1985). This makes it very important for understanding the functioning of freshwater ecosystems, since zoobenthic organisms are an essential link in the food webs of aquatic biocenoses (Cummins 1973). In spite of this, investigations of biomass of the macrozoobenthos have been rare in aquatic habitats in the southern part of the Pannonian Plain (Mitrovic 1969, Djukic 1980, Djukic *et al.* 1991, Markovic and Mitrovic-Tutundzic 1998, 1999, 2000).

Material and methods

Secondary production of the bottom fauna in the Kudoski, Jelenacki, and Borkovacki brooks was investigated at 18 localities (Fig. 1) during April, July, and October of 2000 and in January of 2001. Sampling was conducted with a quantitative net according to Surber on sectors measuring 300 cm^2 in area. Raw mass of macroinvertebrates was measured with a precision of 0.0001 g. Biomass of organisms was expressed in g/m^2.

The Kudoski, Jelenacki, and Borkovacki brooks arise on the Fruska Gora mountain at 480, 460, and 160 m a.s.l., respectively. Fruska Gora is the greatest mountain in Vojvodina, its highest point (Crveni Cot) lying at an elevation of 534 m a.s.l. The mountain extends in an east—west direction along the southern rim of the Pannonian Plain. The 32 km long Kudoski brook is a left-hand tributary of the Sava river. Its most important left-hand tributary is the Jelenacki brook, of which the Borkovacki brook is a right-hand tributary.

Sampling of macrozoobenthos in the Kudoski brook was carried out at seven localities from rocky and pebbly substrates. Twenty-one quantitative samples were taken in the course of the investigation.

Macrozoobenthos was collected at six localities in the Jelenacki brook (which is 20 km long). Material was collected from muddy and rocky substrates. Altogether, twenty-three quantitative samples were taken in the course of the investigation.

Samples of the bottom fauna in the Borkovacki brook (which is 10 km long) were collected at five localities from rocky and muddy substrates. Eighteen quantitative samples were taken.

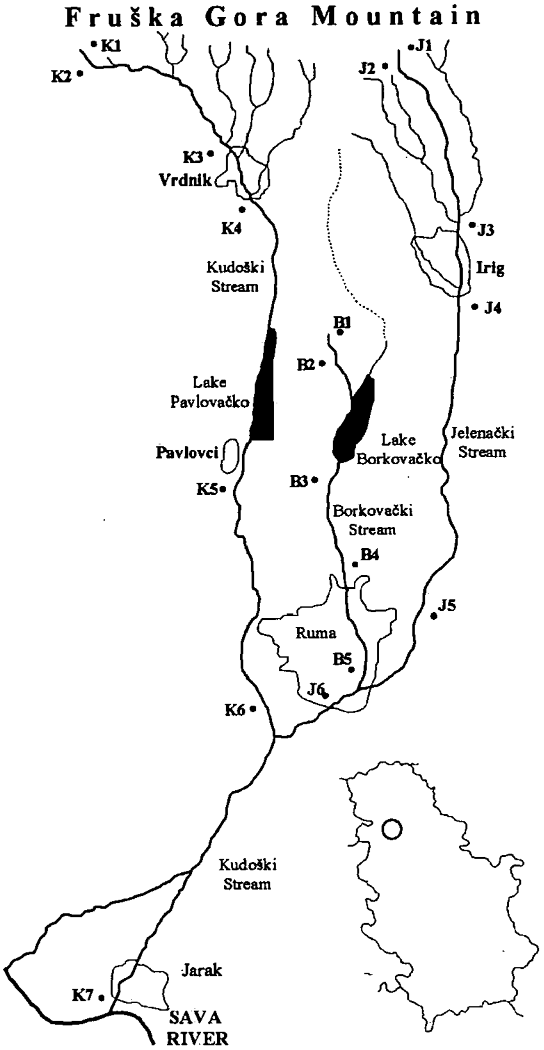

Fig. 1. Investigated localities on three brooks in the southern part of the Pannonian Plain. Location of the three brooks in Serbia is indicated by the circle in the upper right-hand corner of the figure.

Results

Fourteen animal taxa (two phyla, three classes, nine orders, and three families) were recorded in quantitative sampling of the macrozoobenthos in the Kudoski brook. Biomass in the Kudoski brook varied annually in the interval from 41.3248 g/m^2 (in July) to 133.2384 g/m^2 (in October). At the investigated localities in this brook, no macrozoobenthos (0 g/m^2) was found at locality K7 in June and January, while the greatest biomass (518.1593 g/m^2) was recorded at locality K3 in October (Fig. 2). The greatest biomass was recorded at locality K3 in the other months of investigation as well, due to increased abundance of

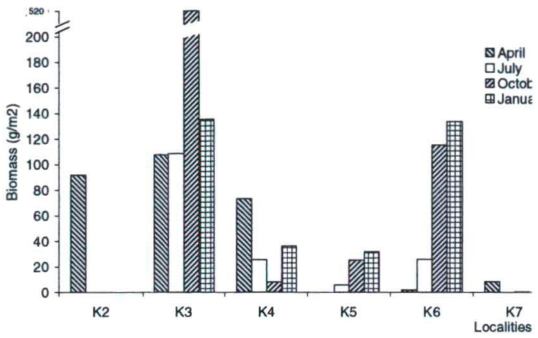

Fig. 2. Secondary production of macrozoobenthos in the Kudoski brook.

Hirudinea and Mollusca there (Figs. 3a and 3b). Not only at the third locality, but at the others also (except locality K2, where Gammaridae are dominant), the abundance of Mollusca (Fig. 3a), Hirudinea (localities K4 and K5, Fig. 3b), and Chironomidae (localities K5, K6, and K7, Fig. 3d) almost completely determined the measured biomass of macrozoobenthos. In regard to seasonal dynamics of biomass in the Kudoski brook, its high values during the winter period stand out clearly. To be specific, the greatest biomass values were recorded in January at localities K5 and K6, while the second greatest values occurred in January at localities K3 and K4.

Organisms of 14 animal taxa (two phyla, two classes, eight orders, and three families) were found in zoobenthos of the Jelenacki brook. Average biomass of macroinvertebrates varied annually in the interval from 23.6254 g/m^2 (in January) to 49.8653 g/m^2 (in April). The lowest zoobenthos biomass (4.4458 g/m^2) was recorded at locality J1 in July, the highest (113.0552 g/m^2) at locality J4, also in July (Fig. 4). In contrast to the picture observed in the Kudoski and (especially) the Borkovacki brooks, it is impossible to isolate groups whose abundance determined the biomass at the majority of localities: instead, these groups varied from locality to locality (Fig. 5). At locality J3, in addition to the indicated groups (Gammaridae, Chironomidae, Oligochaeta, and Diptera, Figs. 5a, 5b, 5c, and 5d), Trichoptera

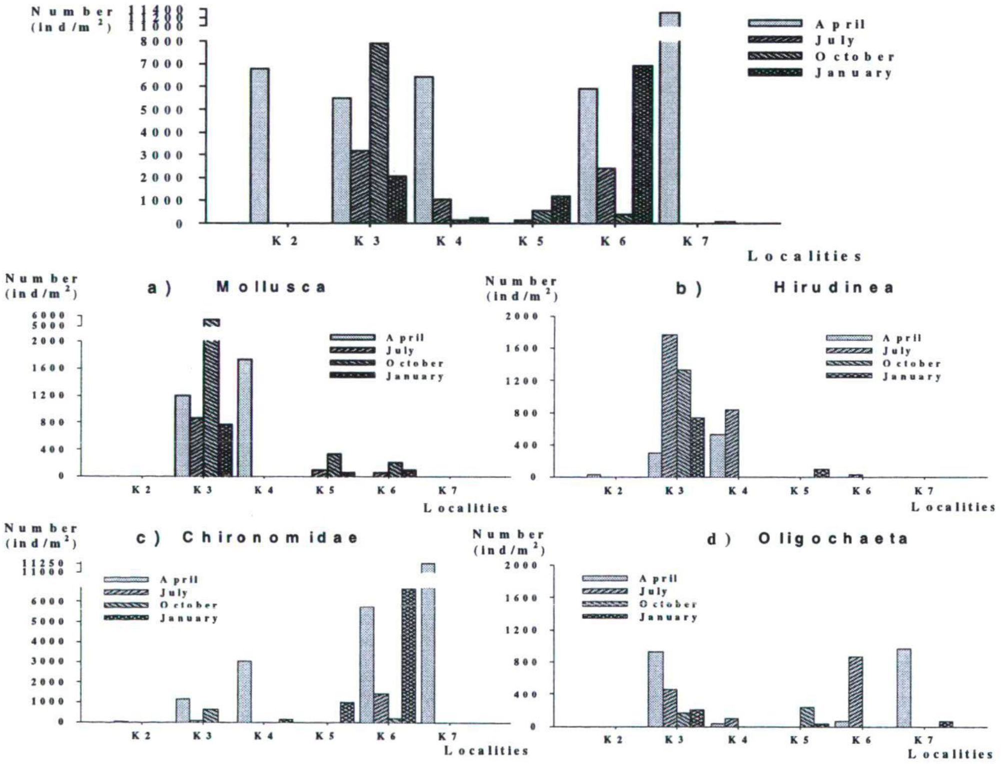

Fig. 3. Abundance of macrozoobenthos at the investigated localities in the Kudoski brook.

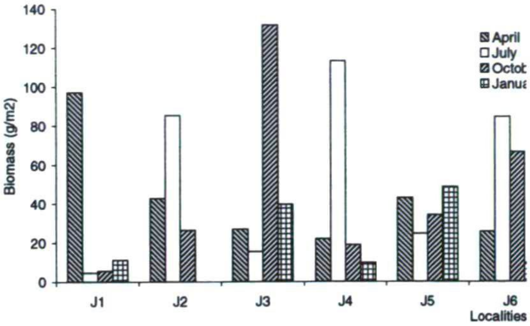

Fig. 4. Secondary production of macrozoobenthos in the Jelenacki brook.

(433 ind/m^2 in April) and Mollusca (133 ind/m^2 in October) were also numerous; at locality J4, Mollusca were abundant in April, June, and October (333, 1033, and 166 ind/m^2, respectively); and at locality J5, Hirudinea were numerous in all months of investigation, with average participation of 71.7% in abundance. Seasonal dynamics of biomass also exhibited few regularities. As in the Borkovacki brook, the greatest biomass in the source region (localities J1 and J2) occurred in spring. Localities J3 and J4 were characterized by fairly equal biomass values by seasons, with the maximum in January (Fig. 4). The other localities (especially J4 and J6) were characterized by significant seasonal oscillations of biomass (Fig. 4).

Organisms belonging to 12 animal groups (one phylum, two classes, eight orders, and three families) were found in the bottom fauna of the Borkovacki brook. The average biomass of macroinvertebrates varied annually in the interval from 23.7432 g/m^2 (in July) to 90.3328 g/m^2 (in January) (Fig. 6). The minimal biomass of zoobenthos (6.3760 g/m^2) was recorded at locality B5, while its maximal value (181.7432 g/m^2) occurred at locality B4 in January. At all localities except B5 — where Chironomidae and Oligochaeta were dominant (Figs 7b and 7d) — biomass was completely determined by the abundance of Gammaridae (Fig. 7a). Deviations from this were observed only at locality B1 in the fall and locality B2 in the spring, where Mollusca participated significantly in the biomass, with 367

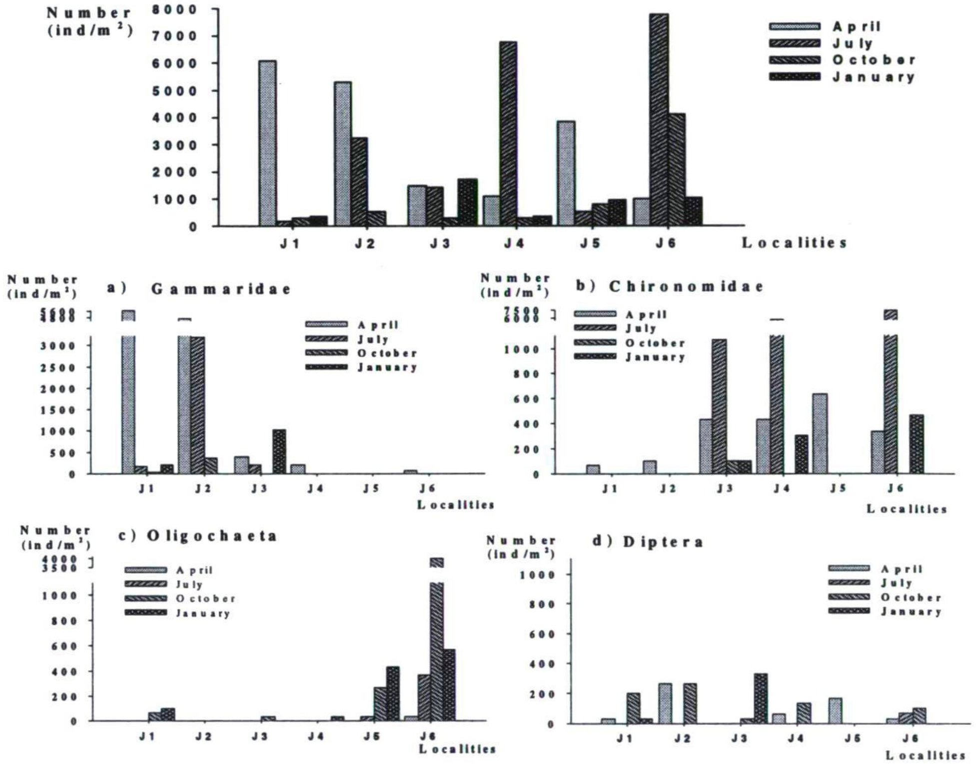

Fig. 5. Abundance of macrozoobenthos at the investigated localities in the Jelenacki brook.

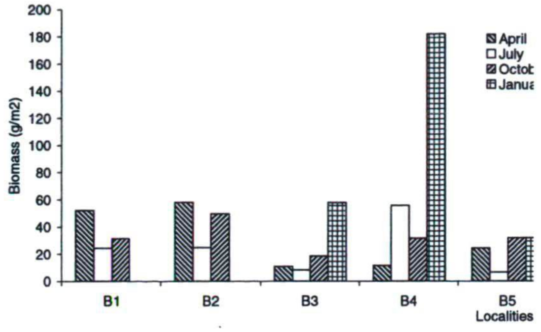

Fig. 6. Secondary production of macrozoobenthos in the Borkovacki brook

and 1666 ind/m^2, respectively (Fig. 7c). Seasonal dynamics of biomass exhibited significant regularities. In the source region (at localities B1 and B2), biomass values were the greatest in the spring, declined in the summer, and rose again in the fall (Fig. 6). At localities B3 and B4, pronounced biomass peaks were achieved in January (Fig. 6). Locality B5 was characterized by slight seasonal changes of biomass apart from its very low values in July (Fig. 6).

Discussion

Freshwater ecosystems of the temperate zone are characterized by relatively constant biomass of macrozoobenthic organisms, in which aquatic insects are dominant, together with molluscs, annelids, and crustaceans (Cummins 1973). However, it is still possible to discern certain seasonal variations in their biomass (Hynes 1970) resulting from different adaptations of the life cycle of aquatic insects (egg laying—eclosure times) to environmental factors, primarily water temperature. A large number of aquatic insects survive high summer temperatures (often accompanied by the drying up of smaller streams) in the form of eggs, pupae, or very small non-growing nymphs, the greater part of their growth and development occurring in late fall, winter, and spring (Pleskot 1961). Aquatic insects of this group are called cold water species. Apart from them, there also exists a warm water group of insects, which survive the winter period in the egg and pupa stage

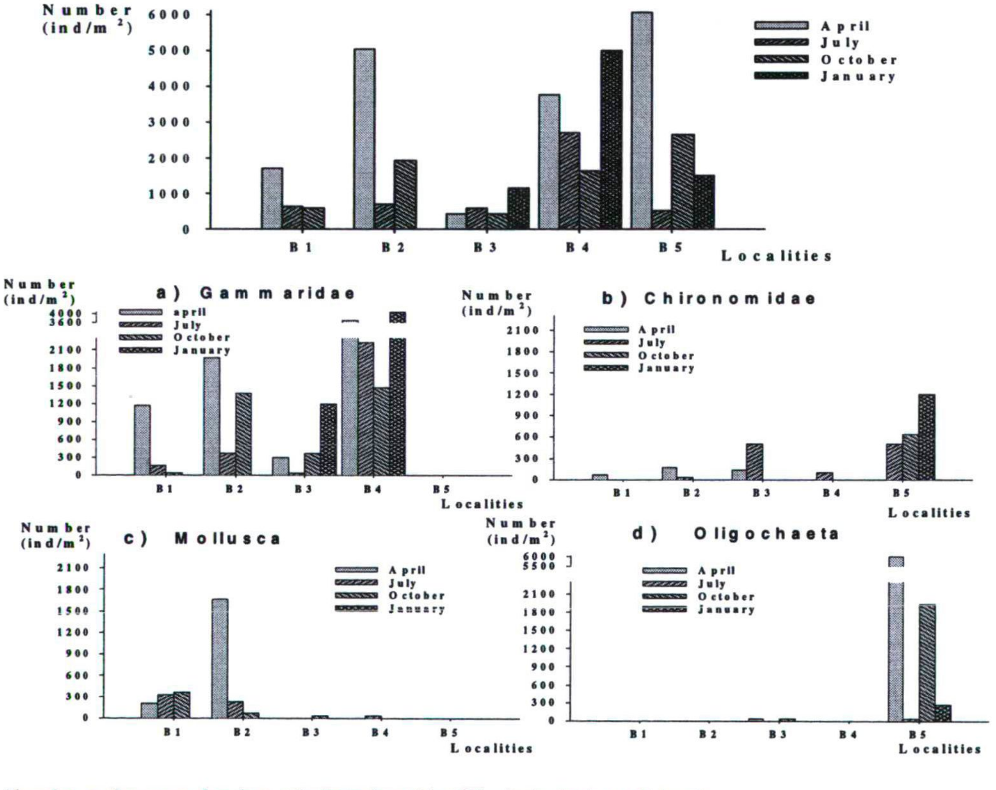

Fig.7. Abundance of macrozoobenthos at the investigated localities in the Borkovacki brook.

and attain their maximal growth and development during the summer. This group is less numerous and mostly made up of Simulidae (Anderson and Dicke 1960, Carlsson 1967), but also some Ephemeroptera (Pleskot 1961) and Trichoptera (Ulfstrand 1968). Greater representation of cold water species and the fact that some cold water species are larger than closely related warm water ones (Steffan 1963, Khoo 1964, 1968) often cause maximal biomass of the macrozoobenthos to occur in the spring, when the period of growth of cold water species is completed (Egglishaw and Mackay 1967). These considerations apply to relatively unpolluted mountain streams, in which larvae of aquatic insects constitute the dominant group of macrozoobenthos. However, it must be asked whether the same can be said about small streams of the highland type exposed to strong human influence along their entire course, such as the brooks investigated in the present study.

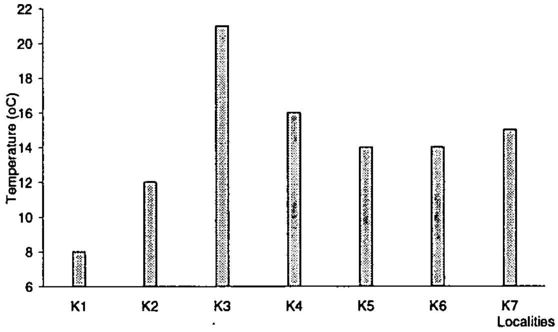

Fig. 8. Mean annual water temperatures in the Kudoski brook.

The greatest biomass of zoobenthos in all periods of investigation was recorded in the Kudoski brook at locality K3. This locality is characterized by high water temperature (Fig. 8) due to inflow of a thermal stream from the spa of Vrdnik several kilometers upstream and a high degree of organic pollution, with a biotic index value according to Plafkin *et al.* (1989) of 7.09, indicating a class of water with very significant organic pollution (unpublished data of the authors). Since Hirudinea and the determined species of the phylum Mollusca are eurythermal (Pennak 1953, Elliot and Mann 1979) and tolerant to organic pollution (Hilsenhoff 1988), and whereas it is known that temperature is positively correlated with biomass in these groups (Cummins 1973), it can be assumed that precisely the combination of these two factors brought about the high biomass at locality K3.

Occurrence of the least bottom fauna biomass (in all months) at locality K7 is a consequence of exceptionally high pollution, which is clearly indicated by the complete absence of macrozoobenthos in the summer and fall periods and finding of only two specimens of Oligochaeta in winter. Such a high degree of pollution stems from influence of the town of Ruma, whose sewage and industrial waste water (from leather, shoe, and plastic pipe factories, as well as a fruit and vegetable processing plant) flow into the Kudoski brook directly or with water of the Jelenacki and Borkovacki brooks. It is also a consequence of constant agricultural pollution, since the Kudoski brook flows through agrarian landscapes all the way to its mouth.

The lack of an animal group with dominant influence on biomass in the Jelenacki brook can be explained by the absence of dominant influence of ecological factors such as increased water temperature in the Kudoski brook and shallow depth of the stream bed in the Borkovacki brook (see parts of the discussion pertaining to these brooks) on macrozoobenthos development.

Whereas the Kudoski brook is heavily polluted throughout its entire course (with biotic index values of from 6.92 at locality K5 to 8 at locality K7) and the Borkovacki brook (if we exclude locality B5) is characterized by moderate organic pollution (with biotic index values of from 5.98 at locality B2 to 6.16 at locality B3), biotic index values in the case of the Jelenacki brook varied within a wide range (from 5.68 at locality J3 to 9.24 at locality J5) (unpublished data of the authors).

Variation of the quality of water in the Jelenacki brook results in a significant variation in composition of the bottom community from locality to locality. Thus, at locality J3 (where the water is cleanest), the more sensitive groups Trichoptera and Ephemeroptera were significantly abundant, in addition to Gammaridae and Chironomidae. On the other hand, at locality J5 (where the water is most heavily burdened with organic pollution), the tolerant group Hirudinea was dominant, together with significant participation of Oligochaeta and Chironomidae.

Such changes in the qualitative composition of zoobenthos from one locality to another result in the lack of significant regularities in biomass dynamics, since different groups of macrozoobenthos are characterized by different dynamics of growth and development.

In the Borkovacki brook, a pronounced peak of biomass was achieved in January at localities B3 and B4 (Fig. 6). This can be attributed to reduced human influence due to the absence of agrotechnological measures during the winter period, since the brook at these localities flows through agrarian ecosystems, as in the case of the Jelenacki brook (localities J3 and

J5). The great abundance of specimens of Gammaridae (which determines high biomass values at these localities) is probably a consequence of shallow water depth (0.07-0.10 m) and good aeration, factors that favor the development of species of this family (Wundsch 1922).

The slight oscillations of biomass at locality B5 probably result from consistently poor water quality, as indicated by a biotic index value of 8.04 (unpublished data of the authors), which means that the water is of a class characterized by serious organic pollution. An exception was observed during the summer period, when very low zoobenthos biomass was recorded at this locality (Fig. 6). Here it is pertinent to note that sewage water from the town of Ruma flows into the Borkovacki brook upstream from locality B5, while high summer water temperatures led to enhanced decomposition of organic matter and increased oxygen consumption, as was clearly indicated by the unpleasant odor and great muddiness of the water. Such deterioration of ecological conditions probably led to significant decrease in abundance of the tolerant groups Chironomidae and Oligochaeta, while other animal groups were not recorded.

Comparison of biomass in these three brooks reveals certain similarities. Biomass in source regions has a spring peak determined by occurrence of the greatest Gammaridae abundance in April. At localities where the brooks flow through agrarian ecosystems and intensive farming is the main source of pollution, biomass values peak in the winter, when agrotechnological activity is the lowest.

Nevertheless, in spite of their relative closeness together, parallel courses through similar terrestrial ecosystems, and similar types and levels of human influence (intensive agriculture and receipt of communal water from the settlements of Irig, Vrdnik, and Ruma), significant differences exist between the three brooks studied. These differences are primarily evident in the group of organisms which with their abundance and/or individual mass determine the total biomass. Gammaridae are that group in the Borkovacki brook; Mollusca (with significant participation of Hirudinea and Chironomidae) in greatest measure represent that group in the Kudoski brook; and several categories of organisms (varying from locality to locality and by seasons) constitute it in the Jelenacki brook.

Variation of macarozoobenthos biomass in the three investigated brooks differs in two main ways from the dynamics of seasonal biomass variation in mountain streams (Zivic *et al.* 2000).

The investigated brooks were characterized by considerable variation of biomass, which can be attributed to different levels of human influence, the factor that in greatest measure determines the qualitative and quantitative state of the macrozoobenthos in them. Thus, the share of insect groups (apart from Chironomidae) in total abundance was only 6.9%, whereas the tolerant groups Chironomidae (34.5%), Oligochaeta (12.3%), Hirudinea (7.7%), and Mollusca (10.9%) were dominant. The significance of variation of human influence on biomass is seen most distinctly in the case of crop production, whose intensity varies clearly from season to season and is lowest in winter, when biomass achieves maximum values at localities where this influence is prevalent (localities K4, K5, J3, J5, B3, and B4).

The second significant difference is that seasonal biomass dynamics (except in source regions) did not exhibit the regularities observed in mountain streams. The presence of these regularities of seasonal biomass variation in source regions of the investigated brooks is attributable to the fact that human influence is the weakest there, as is indicated by both the biotic index and the index of saprobicity. The reason why the regularities in question are absent on the rest of the stream course should be sought in the fact that they are based on the premise that insect groups are dominant or participate significantly in the quantitative composition of macrozoobenthos, which due to significant human influence is not the case in the investigated brooks.

Reference

Anderson, M.T. and Anderson, H.N. (1995): The Insect Fauna of Spring Habitats in Semiarid Rangelands in Centrol Oregon. — Journal of the Kansas entomological society, 68 (2) supl. 65 - 76.

Anderson, J. R. and Dicke, R. J. (1960): Ecology of the immature stages of some Wisconsin blac flies. — Ann. Entoml. soc. Am., 53, 386-404.

Bode, R.W., Novak, M.A. and Abele, L.E. (1996): Quality Assurance Work Plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Albany, NY. 89p.

Carlsson, G. (1967): Enivironmental factors influencing blckfly populations. — Bull. Wordld Health Organ, 37, 139-150.

Cummins, K. (1973): Trophic relations of aquatic insects. — Ann. Rev. Entomol. 18, 183-206.

Dosdall, L. and Lehmkuhl, D. M. (1979): Stoneflies (Plecoptera) of Saskatchewan. — Quaest. Entomol. 96, 279-309.

Djukic, N. (1980): Dinamika populacija Oligochaeta i njihovo ucesce u bioprodukciji nekih vodenih ekosistema u Vojvodini. Doktorska disertacija, Institut za biologiju, PMF-a, Univerzitet u Novom Sadu, 1-133.

Djukic, N., Maletin, S., Selesi, Dj. and Miljanovic, B. (1991): Relationship between nutritive elements and Oligochaeta biomass in reservoirs of Pannonian basin-Yugoslavia. — Fifth International Symposium on Aquatic Oligochaete Biology, Abstracts: 10 pp.

Djukic, N. and Stanojevic, M. (1979): Fauna Oligochaeta Begeja i Tamisa. Drugi kongres ekologa Jugoslavije, Zagreb.

Egglishaw, H. J. and Mackay, D. W. (1967): A survey of the bottom fauna of streams in the Scottish Highlands. Part III. Seasonal chengs in the fauna of three streams. — Hydrobiologia, 30, 305-334.

Elehova, E. (1998): Interaction of the Danube river and its left side tributaries in Slovak stretch from benthic fauna point of view. — Biologia, Bratislava, 53/5, 621-632.

Elliot, J.M. and Mann, K.H. (1979): A key to the British freshwater leeches, with notes on their life cycles and ecology. — Freshwater biological association Scientific publication, 40, 72 pp.

Graf, W. and Kovács, T. (2002): The aquatic intertebrates of the Lafnitz-Rába river system in Austria and Hungary - a natural heritage of the Central European potamocoen. — Inetmat. Assoc. Danube Res. Limnological Reports,. 34, Proceedings of the 34th Conference, Tulcea, Romania, 295-302.

Harper, P.P. and Hynes, H.B.N. (1970): Diapause in the nymphs of Canadian winter stoneflies. — Ecology, 51, 925-927.

Hilsenhoff, W.L. (1988): Rapid field assessment of organic pollution with a family-level biotic index. — J. N. Am. Benthol. Soc. 7, 65-68.

Hynes, H. B. N. (1970): The ecology of stream insects. — Ann. Rev. Entomol. 15, 25-42.

Hynes, N. (1959): The use of invertebrates as indicators of river pollution. — Simposium on water pollution, 165 - 169.

Khoo, S. G. (1964): Studies on the biology of *Capnia bifrons* (Newman) and notes on the diapause in the nymphs of this species. — Gewäss. Abwäass, 34/35, 23-30.

Khoo, S. G. (1968): Experimental studies on diapause in stoneflies. I. Nymphs of *Capnia bifrons* (Newman): — Proc. Roy. Entomol. Soc. London, Ser., A, 43, 40-48.

Markovic, Z. and Mitrovic-Tutundzic, V. (1998): Secondary production of zooplankton and bottom fauna in the cyprinid farm "Dubica" at Banatska Dubica. — Ichthyologia,. 30, 15-30.

Markovic, Z. and Mitrovic-Tutundzic, V. (1999): Dynamic of zooplankton and bottom fauna production on the "Sveti Nikola" cyprinid fish farm at Neuzina during the 1999 rearing season. — Ichthyologia,. 31, 21-36.

Markovic, Z. and Mitrovic-Tutundzic, V. (2000): Secondary production of zooplankton and bottom fauna in the Sava lake. — Annul proceedings of the Yugoslav society for water protection, 251-256.

Mason, W. T., Lewis, P.A. and Webwer, C.I. (1985): An evalution of benthic macroinvertebrate biomass methodology. — Environmental Monitoring and Assessment,.5, 399-422.

Mihaljevic, Z., Kerovec, M., Tavcar, V. and Bukvic, I. (1998): Macroinvertebrate community on an artificial substrate in the Sava river: long-term changes in the community structure and water quality. — Biologia, Bratislava, 53/5, 611-620.

Miljanovic, B. and Djukic, N. (1989): Fauna Oligochaeta kao indikator kvaliteta vode reke Tamis. — Zbornik Matice srpske za prirodne nauke, br. 77, 167-179.

Mitrovic, V. (1969): Uticaj nasada sarana na biolosku produkciju ribnjaka. — Zbornik radova poljoprivrednog fakulteta Univerziteta u Beogradu, 1-66.

Nosek, J.N. (2002): Macroinvertebrate studies at the Hungarian Danube section 4. The colonization dynamics of macroinvertebrates on different substrates. — Inetmat. Assoc. Danube Res. Limnological Reports, 34, Proceedings of the 34th Conference, Tulcea, Romania, 317-326.

Oertel, N. (2002): Macroinvertebrate studies at the Hungarian Danube section 3. Artificial substrate as a tool to study macroinvertebrate colonization. — Inetmat. Assoc. Danube Res. Limnological Reports, 34, Proceedings of the 34th Conference, Tulcea, Romania, 327-336.

Pennak, R.W. (1953): Freshwater invertebrates of the United States, chapter 36 Gastropoda. The Ronald Press Company, New York, 681 pp.

Plafkin, JL., Barbour, M.T., Porter, K.D., Gross, S.K. and Hughes, R.M. (1989): Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency. EPA 440/4-89/001. 8 chapters, Appendices A-D.

Pleskot, G. (1961): Die Periodizität der Ephemeropteren-Fauna einiger österreichischer Fliessgewässer. — Verh. Int. Ver. Limnol. 14, 410-416.

Popescu-Marinescu, V. (2002): Evolution of zoobenthic Ponto-Caspian elements populations in the Danube, at the Iron Gates. — Inetmat. Assoc. Danube Res. Limnological Reports, 34, Proceedings of the 34th Conference, Tulcea, Romania, 347-356.

Pujin, V., Ratajac. R. and Djukic, N. (1974): Sastav i dinamika zooplanktona i faune dna na nekim deonicama Hidrosistema DTD. — Letopis naucnih radova Poljopr. fakulteta, Novi Sad, 17-18, 261-268.

Schmidt-Kloiber A., Nesemann H., Moog O., Graf W. and Baumgartner B. (2002): Recovery of the benthic community in a restored section of the Austrian Danube. — Inetmat. Assoc. Danube Res. Limnological Reports, 34, Proceedings of the 34th Conference, Tulcea, Romania, 357-366.

Steffan, A. W. (1963): Bezeihungen zwischen Lebensraum und Körpergrösse bei mitteleuropäischen Elminthidae. — Z. Morphol. Oekol. Tiere, 53, 1-21.

Ulfstrand, S. (1968): Life cycles of benthic insect in Lapland streams (Ephemeroptera, Plecoptera, Trichoptera, Diptera Simullidae): — Oikos, 19, 167-90.

Vincent, E. R. (1967): A comparison in the Gibbon River above and below the geyser basins, Yellowstone National Park. — Limnol. Oceanogr., 12, 18-26.

Ward, J. V. and Stanford, J. A. (1982): Thermal responses in the evolutionary ecology of aquatic insect. — Ann. Rev. Entomol. 27, 97-117.

Wundsch, H. H. (1992): Beitrage zur Biologie von *Gammarus pulex*. — Arch. Hydrobiol. 13, 478-531.

Sporka, F. and Nagy, S. (1998): The macrozoobenthos of parapotamon-type side arms of the Danube river in Slovakia and its response to flowing conditions. — Biologia, Bratislava, 53/5, 633-643.

Zivic, I., Markovic, Z. and Brajkovic, M. (2000): Sekundarna produkcija makrozoobentosa Puste reke. — Godisnjak Jugoslovenskog drustva za zastitu voda, 175-180.