Indicative status assessment of the Velika Morava River based on aquatic macroinvertebrates

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Abstract

The objective of this study is to provide an indicative ecological status assessment of the Velika Morava River, based on aquatic macroinvertebrates. Eight metrics were used for this evaluation – Saprobic Index (SI), Biological Monitoring Working Party (BMWP) score, Average Score Per Taxon (ASPT), Number of Ephemeroptera, Plecotera, Trichoptera (EPT) taxa, percentage participation of Oligochaeta in the total macroinvertebrate community (%-Oligochaeta), total number of taxa, number of genera, and number of families. A total of 84 taxa have been identified. Based on analyses of the selected metrics, the indicative status of the Velika Morava River could be assessed as moderate to poor (Class III-IV), which corresponds to the water quality assessment based on the evaluation provided by national water quality monitoring for the 1999-2008 period. There is still a need for system improvement, which will be the topic of further research.

Keywords: aquatic macroinvertebrates, ecological status, community structure metrics, large rivers

Introduction

The aim of this paper is to test a system of ecological status assessment, in particular a component based on aquatic macroinvertebrates as a quality element, proposed to be used for running waters in Serbia. The system was designed according to the recommendations provided by the EU Water Framework Directive (WFD 2000). The objective of the study is to provide an indicative ecological status assessment, since it is based on a limited number of samples, as well as on one quality element only. To provide a comprehensive ecological status assessment, as required by the WFD (2000), systematic monitoring is needed, covering all relevant biological quality elements, as well as parameters supporting biological assessment (selected physico-chemical and hydromorphological parameters).

The WFD (2000) regulates all water management issues and provides a new approach to water status monitoring. The surface water status has to be evaluated based on the ecological and chemical status of the surface water body. It is the general expression of the status of a body of surface water, determined by the poorer of its ecological and chemical status. Ecological status is an expression of the quality of the structure and functioning of aquatic ecosystems. It is assessed based on the deviation of selected biological (community) parameters from the reference situation (conditions recorded within the surface water bodies that are "natural", or "near natural", more precisely those that are not under the influence of anthropogenic pressures).

Implementation of the WFD (2000) in Serbia began in 2003 (Ninković et al., 2010), and the basis for an effective system for surface water status evaluation has been established (Paunović et al. 2007, Ninković et al., 2010).

The Velika Morava River is 175 km long and it originates from the Zapadna Morava and the Južna Morava rivers. According to the catchment area (38,000 km²) and the mean annual flow (230 m³

UDK: 592-152.41(282.243.744)(497.11)

s-1, gauge station Ljubičevo, near the confluence with the Danube - Annual Water Quality Report (1999-2008)), the Velika Morava is one of the major tributaries of the Danube. Over 95% of the basin is located within the territory of the Republic of Serbia.

The basin area is densely populated and the river is under the influence of various types of pollution (organic, nutrient, and pressure from various other substances originating from industry), as well as hydromorphological pressures (cutting off of meanders, shortening, channelling, and gravel and sand extraction).

The aquatic life in the Velika Morava River has hardly been explored. According to available data, the river has been studied only as part of broader research (Simić, 1996, Paunović, 2007), covering the wider area.

Materials and Methods

Sampling was performed in July, August, October and November of 2010, at five sampling sites: VM1 (Varvarin), VM2 (Ćuprija), VM3 (Bagrdan), VM4 (Markovac Bridge) and VM5 (Ljubičevo Bridge) (Table 1, Figure 1). Semi-quantitative sampling was conducted using a hand net (25x25 cm, 500 µm mesh size). A multi-habitat sampling procedure (Hering, 2004) was applied.

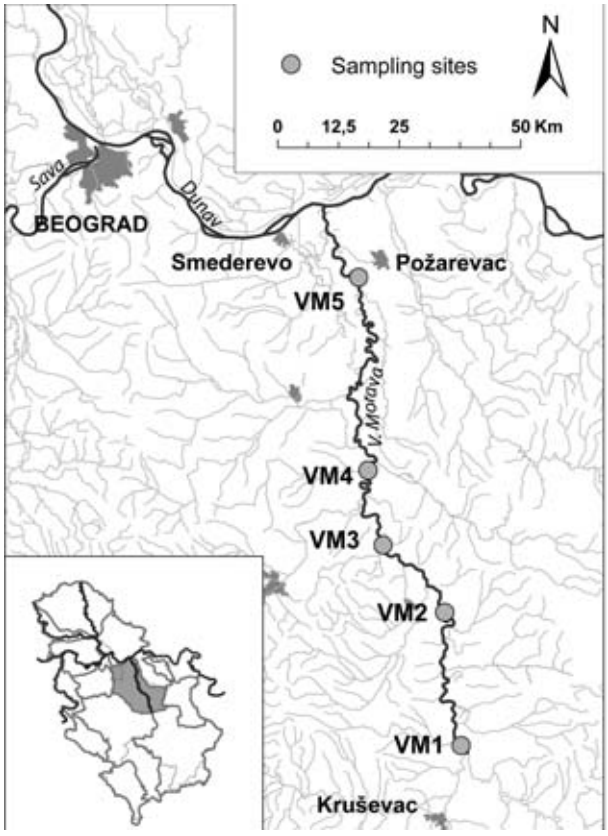

Figure 1: The position of sampling sites.

Table 1: Sampling sites on the Velika Morava River.

Sampling site	*VM1*	*VM2*	*VM3*	*VM4*	*VM5*
Latitude, N	43 43.022	43 56.921	44 05.099	44 13.485	44 35.182
Longitude, E	21 23.053	21 21.873	21 11.377	21 09.215	21 7.748
Altitude (m)	130	115	102	95	72
River length (km)	169.83	135.2	108.81	82.27	21.52
River bed width (m)	120	110	95	85	135

The samples were preserved using a 4% formaldehyde solution and were further processed in the laboratory. Identification was carried out in accordance with the recommendation on the required taxonomic level (Schmidt-Kloiber and Nijboer, 2004). The following metrics were used to evaluate the ecological status: Zelinka and Marvan Saprobic Index (SI, Zelinka and Marvan, 1961), BMWP and ASPT scores (Armitage et al., 1983), EPT taxa, and %-Oligochaeta. The taxa richness parameters (total number of species, number of genera and number of families) were also considered as metrics for ecological status assessment. Saprobiological analysis was performed using the list of bioindicator organisms according to Moog (Moog, 1995). Metrics calculations were performed using AQEM software (AQEM, 2002).

Indicative status assessment was performed according to the procedure proposed by Paunović et al. (2009, 2010), based on the class boundaries shown in Table 2. The system presented in Table 2 is relevant to all Serbian large rivers with medium grain-size mineral substrates belonging to Ecoregions 5 and 10 (Illies, 1978, revised after Paunović et al. 2007).

Results and Discussion

A total of 84 macroinvertebrate taxa were recorded (Table 3). Insecta were found to be the most dominant component of the community with 42 taxa, followed by Oligochaeta and Mollusca, both with 15 recorded species. Diversity of other taxa groups was significantly lower: Hirudinea 5 and Crustacea 4, while the groups Nematoda, Turbellaria and Hydrachnidia were represented by only one species each. Among Insecta, the dominant group was found to be Ephemeroptera (16 species), while subdominant were Trichoptera and Diptera (eight species each), and Odonata (5 species). Among Oligochaeta, Tubificidae and Naididae were found to be the most diverse families

Table 2: Class boundaries of used indices (Paunovic et al. 2010, adapted)

	No. Taxa	*No. Genera*	*No. Families*	*SI*	*BMWP*	*ASPT*	*EPT*	*Oligochaeta (%)*
Class I	>17	>14	>10	<2.00	>60.00	>6.00	>7	<10.00
Class II	17	14	10	2.00	60.00	5.00	5	10.00
Class III	10	9	5	2.50	45.00	4.00	4	25.00
Class IV	8	5	3	3.00	30.00	3.00	2	40.00
Class V	5	3	2	3.20	10.00	3	1	70.00

(6 taxa each). Keeping in mind that Chironomidae (Insecta: Diptera) were not identified to the species level due to the complex identification process and the possibility of identifying only fourth instars larvae with a high level of confidence, the taxa richness is certainly higher.

Table 3: List of taxa recorded at the Velika Morava River

Nematoda
Turbellaria
Dugesia lugubris (Schmidt, 1861)
Oligochaeta
Nais sp.
Nais behningi (Michaelsen, 1923)
Nais bretscheri (Michaelsen,1899)
Nais elinguis (Müller, 1773)
Stylaria lacustris (Linnaeus, 1767)
Branchyura sowerby (Beddard, 1892)
Limnodrilus claparedeanus (Ratzel 1868)
Limnodrilus hoffmeisteri (Claparede, 1862)
Limnodrilus udekemianus (Claparede, 1862)
Potamothrix hammoniensis (Michaelsen, 1901)
Psammoryctides albicola (Michaelsen, 1901)
Tubifex tubifex (Muller 1774)
Propappus volki (Michaelsen, 1916)
Rhynchelmis limosella (Hoffmeister, 1843)
Stylodrilus heringianus (Claparede, 1862)
Hirudinea
Erpobdella octoculata (Linnaeus, 1758)
Erpobdella lineata (Müller, 1774)
Glossiphonia complanata (Linnaeus, 1758)
Helobdella stagnalis (Linnaeus, 1758)
Piscicola geometra (Linnaeus, 1761)
Gastropoda
Lymnaea sp
Lymnaea peregra (Müller, 1774)
Bythinia tentaculata (Linnaeus, 1758)
Holandriana holandrii (Pfeiffer 1828)
Theodoxus transversalis (Pfeiffer, 1828)
Theodoxus danubialis (Pfeiffer, 1828)
Viviparus sp.
Viviparus acerosus (Bourguignat, 1862)
Lithoglyphus naticoides (Pfeiffer 1828)
Mollusca
Sinanodonta woodiana (Lea, 1834)
Corbicula fluminea (Müller, 1774)
Corbicula sp. juv.
Unio sp.
Physa acuta (Draparnaud, 1805)
Physa fontinalis (Linnaeus, 1758)
Crustacea
Asellus aquaticus (Linnaeus, 1758)
Corophium curvispinum (Latreille, 1806)
Gammarus sp.
Dikerogammarus vilossus (Sowinsky, 1894)
Insecta
Gomphus vulgatissimus (Linaeus, 1758)
Calopteryx splendens (Harris, 1782)
Platycnemis pennipes (Pallas, 1771)
Ophiogomphus cecilia (Charpentier, 1825)
Onycogomphus forcipatus ssp. (Linnaeus, 1758)
Baetis rhodani (Pictet, 1843)
Baetis fuscatus (Linnaeus, 1761)
Baetis scambus (Eaton, 1870)
Baetis sp.
Caenis sp.
Caenis horaria (Linnaeus, 1758)
Caenis luctuosa (Burmeister, 1839)
Caenis macrura (Stephens, 1836)
Ephemerella ignita (Poda, 1761)
Ephemerella sp.
Heptagenia coerulans (Rostock, 1877)
Heptagenia (Kageronia) fuscogrisea (Retzius, 1783)
Heptagenia sulfurea (Muller, 1776)
Heptagenia sp.
Oligonuriella rhenana
Potamanthus luteus (Linnaeus, 1758)
Aphelocheirus aestivalis (Fabricius, 1794)
Hydropsyche sp.
Hydropsyche angustipennis (Curtis, 1834)
Hydropsyche contubernalis McLachlan, 1865
Hydropsyche incognita (Pitsch, 1993)
Hydropsyche pellucidulla (Curtis, 1834)
Hydropsyche exocellata (Dufour, 1841)
Mystacides sp.
Leptocerus sp.
Eloeophila sp.
Hexatoma sp.
Tipulidae
Simulidae Gen. sp.
Ceratopogonidae
Chironomidae
Empididae
Limoniidae gen. sp.
Elmidae
Elmis sp.
Limnius volckmari (Panzer, 1793)
Potamophilus acuminatus (Fabricius, 1792)
Hydrachnidia

Aquatic worms (Tubificidae and Naididae), especially L. hoffmeisteri, were the principal component of the community with respect to percentage participation in most of the samples. The percentage participation of Oligochaeta was the highest at sampling sites VM3 and VM5 (77.6% and 59.3 %, respectively). Although not as apparent on a monthly scale, Oligochaeta were also found to be a dominant group (25.6-44.4%). Chironomidae (Insecta: Diptera) were abundant in the processed samples, especially in material from sampling sites VM1 and VM2 (29% and 46%, respectively), while snails and bivalves (Gastropoda and Bivalvia) were the principal component of the community at sampling site VM4 (29%). In July and August, a significant share of EPT taxa was recorded (33% and 27%, respectively).

Average values of the parameters used for the investigated months and sampling sites are shown in Tables 4 and 5.

Table 4: Values of examined parameters - temporal overview

Metrics	*July*	*August*	*October*	*November*	*Average*
Number of taxa	19.20	18.80	18.40	18.40	18.70
Number of genera	13.80	14.60	15.80	15.60	15.00
Number of families	12.20	12.00	13.80	13.00	12.80
SI (Zelinka&Marvan)	2.78	2.64	2.98	2.82	2.80
BMWP score	56.60	49.60	50.20	49.00	51.10
ASPT score	5.31	5.04	4.30	4.67	4.83
EPT taxa	9.80	5.80	3.00	2.20	5.20
% Oligochaeta	25.60	43.00	44.40	44.30	39.30

Table 5: Values of examined parameters – spatial overview

Metrics	*VM1*	*VM2*	*VM3*	*VM4*	*VM5*	*Average*
Number of taxa	25.50	18.90	17.80	24.50	7.20	18.80
Number of genera	20.20	16.00	14.50	18.00	6.00	14.90
Number of families	16.50	14.20	12.50	16.00	4.50	12.80
SI (Zelinka&Marvan)	2.81	2.78	3.09	2.46	2.87	2.80
BMWP score	68.50	49.80	52.50	71.00	13.80	51.10
ASPT score	5.42	5.14	4.60	5.39	3.60	4.83
EPT taxa	7.50	4.50	3.50	9.50	1.00	5.20
% Oligochaeta	24.50	21.30	77.60	13.90	59.30	39.30

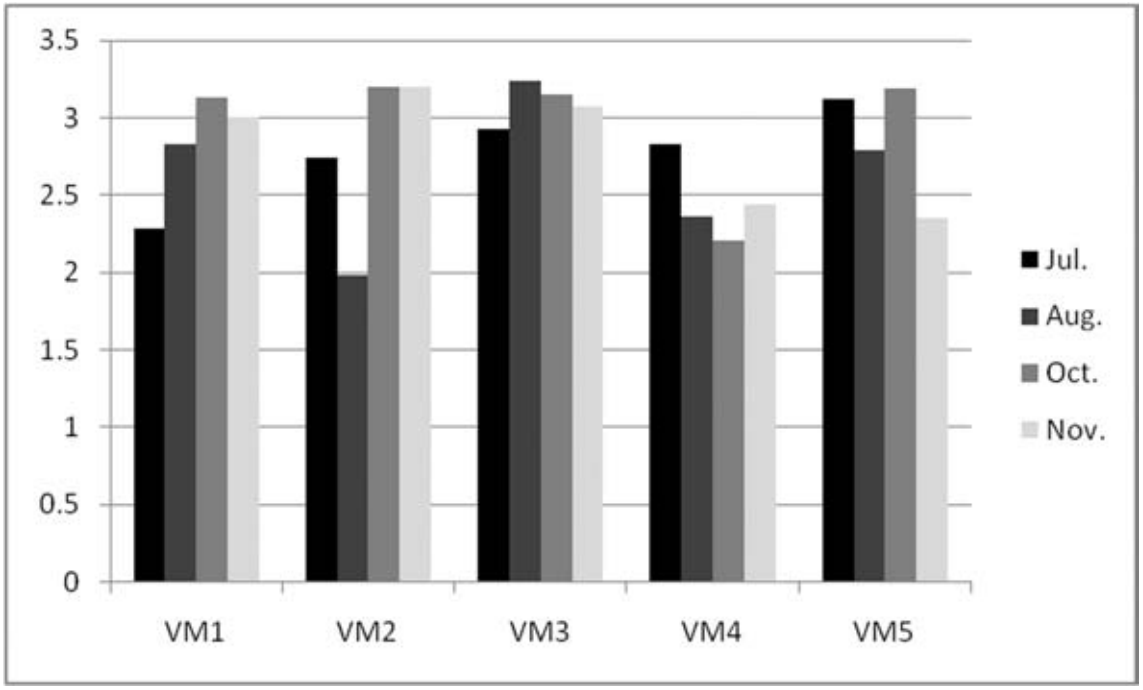

Figure 2: The dynamics of Saprobic Index (SI) values.

The values of SI by investigated period and sampling site are shown in Figure 2.

Estimated ecological status classes, based on processed parameters for the investigated months and sampling sites are presented in Tables 5 and 6.

Table 6: Ecological status classes – temporal overview

Metrics	*July*	*August*	*October*	*November*	*Overall*
Number of taxa	I	I	I	I	I
Number of genera	II	I	I	I	I
Number of families	I	I	I	I	I
SI (Zelinka&Marvan)	III	III	III	III	III
BMWP score	II	II	II	II	II
ASPT score	II	II	III	III	III
EPT taxa	I	II	III	III	II
% Oligochaeta	III	IV	IV	IV	III

The number of taxa per sample varied from 30 (VM4, November) and 29 (VM3, July; VM1, August and VM4, October), to only 5 (VM5, July). The greatest diversity was observed at sites VM1 and VM4 (25.5 and 24.5, respectively), while the lowest diversity was detected at VM5 (7.25 on average), indicating Class III (moderate status). On a monthly scale, values were more uniform and varied, on average, from 18 in October to 19.2 in July. The average number of taxa in the period of investigation was 18.8, which indicates an overall high status of the river (Class I).

The range of the number of families and the number of genera was consistent with the range of the number of taxa. The number of genera varied from 3 (VM5, July) to 26 (VM4, November). Sites VM1 and VM2 were found to be the most diverse (20 and 18.5, respectively). On a monthly scale, values varied from 14.2 (July) to 16.2 (November). The average number of genera was 14.9, which also complies with reference criteria, indicating excellent water quality status.

The number of families ranged from 3 (VM5, July) to 21 (VM4, November and VM1, October). On a monthly scale, this parameter ranged from 12 (July) to 13.8 (October). The average number of families was found to be 12.8, indicating high status.

According to our results, SI significantly varied in the samples from the Velika Morava River, from 1.982 (Class I, high status, VM2, August) to 3.237, (Class V, bad status, VM3, August). Average values per sampling site varied from 2.460 (Class II, good status, VM4) to 3.098 (Class IV, poor status, VM3), while monthly values of SI were found to be within Class III, i.e. they ranged from 2.640 (August) to 2.976 (October). The average value of SI for the Velika Morava during this period was 2.804, which indicates poor water quality (Class III).

According to our study, BMWP ranged from 8 to 98. The highest BMWP scores were recorded in samples from VM3, July (98) and VM4, November (92). High BMWP values (>60) were also recorded at VM4, October (89); VM1, August (80) and VM1, October (79). On the other hand, the lowest BMWP values were recorded at sites VM5 (range 8-20) and VM3, November (20). On average, the highest BMWP value was recorded at site VM4 (71), while the lowest corresponded to site VM5 (13.75, Class IV, poor status). On a monthly scale, BMWP values varied less, with the lowest value recorded in November (46.8), and the highest value in July (53.6). The average BMWP score of the Velika Morava River in the period of investigation was 51.1, indicating Class II (good status).

The highest ASPT score (6.1) was recorded at VM1, July (corresponding to Class I, high status). The values of ASPT determined for sites VM3, July and VM4, November, were slightly lower (5.76 and 5.75, respectively, Class II, good status). The lowest values were recorded at VM5 (2.67, October, Class V, bad status), VM5, July and VM5, October (4.00, Classes IV and III, poor to moderate status), as well as VM3, November (3.33). The highest average value (5.42, Class II, good status) was recorded at VM1, while the lowest was measured at VM5 (3.6, Class IV, poor status). On the time scale, the ASPT index ranged from 4.4 (Class III, moderate status) in October, to 5.42 (Class II, good status) in July. The average value for the entire river during the examined period was 4.83, which corresponds to Class III, moderate status.

EPT taxa ranged from 0 (VM5, November; VM5, August; VM3, October; VM3, November; and VM2, October) to 18 (VM1, July). The highest value of the EPT index was recorded at site VM4 (9.5), while the lowest was recorded at VM5 (1).

The percentage of Oligochaeta (%-Oligochaeta) ranged from 3.3 at VM4, October, to 93.7 (Class V) at VM5, August. On a temporal scale, %-Oligochaeta values varied in the range from Class III in July (25.9) to Class IV in October (44.5). The average value for the Velika Morava, during our investigation, was 39.3, which indicated moderate water quality (Class III).

Based on the analyses of all parameters, the indicative status of the Velika Morava River could

be assessed as moderate to poor (Class III-IV).

Relations between the community structure and water status have often been discussed in the literature (Washington, 1984; Rosenberg and Resh, 1993; Simić, 1996; Chapman, 1996). For an effective ecological status assessment, with high confidence, several metrics should be used in order to avoid misinterpretation of the community response. Thus, using the SI as a sole parameter could lead to misinterpretation of results, due to trans-saprobial impact(s), for example. Given the intolerance of some organisms used to indicate saprobic status to toxic contamination, some functional groups could become reduced (e.g. groups indicating the presence of organic pollution and/or intensive sedimentation), and thus saprobial analyses could be misinterpreted.

In general, a small number of recorded taxa, with the dominance of one or a few species, indicate the presence of stress. Mass development of aquatic worms (Oligochaeta), followed by a reduced number of other benthic species, indicates the presence of excessive organic matter and poor water status.

In view of the above, ecological status assessment based on aquatic macroinvertebrates requires the use of several metrics. An example of the necessity of using several metrics could be the situation recorded at site VM3. The taxa richness metrics (total number of taxa, number of genera and number of families) at this site indicated high status (Class I), but at the same time Oligochaeta (Tubificidae) were found to be the dominant group, which could point to the presence of organic pollution and intensive sedimentation (as a consequence of hydrological regime changes) and %-Oligochaeta indicates Class V.

The SI values recorded at the Velika Morava show that α-mesosaprobic and β-mesosaprobic bioindicators prevail, which indicates a moderate to high presence of organic pollution and points to moderate ecological status (Class III). Nearly half the samples (9 of 20) exceeded the SI value of 3.00 (Class IV).

A steady increase of the SI along the longitudinal profile in the downstream direction was evident, indicating a decreasing water status (particularly in July).

Based on the analyses of all parameters, the indicative status of the Velika Morava River could be assessed as moderate to poor (Class III-IV), which corresponds to the water quality assessment based on the evaluation provided by national water quality monitoring for the period 1999-2008 (Annual Water Quality Report 1999-2008), which generally assessed the Velika Morava River as belonging to Class III-IV.

With regard to saprobiological analyses, it should be noted that in the list used for calculations (Moog, 1995), indicator values were provided for 54 identified taxa out of 84 (64.3 % of the total number of taxa recorded), meaning that saprobic indication values were not available for 30 taxa (35.7 %). For sites VM1 and VM2, the proportion of the taxa not covered by the saprobic indicator list is even higher (app. 60%). The share of the taxa that are not covered by the list belongs to the taxa found to be frequent in Serbian waters, as well as abundant at some sites. Non-indigenous species were found among them. This fact points out that available saprobic lists need to be modified to enable valid ecological status evaluation of running waters in Serbia.

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