



Representativeness of Monitoring Sites for Ecological Status Evaluation of Water Bodies: Case Study of Chetirka (Logodashka) River and its Tributaries, SW Bulgaria

Emilia D. Varadinova^{1, 2} & Radka P. Fikova¹

¹ Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia, Bulgaria; E-mail: radkafikova@gmail.com

² Department of Geography, Ecology and Environmental Protection, Faculty of Mathematics and Natural Sciences, Neofit Rilski South-West University, 66 Ivan Mihailov Street, 2700 Blagoevgrad, Bulgaria; E-mail: emily.varadinova@gmail.com

Abstract: The study aimed to analyse the representativeness of the monitoring sites for the ecological status assessment of running water bodies through an example of a model systems: Chetirka (Logodashka) River and its tributaries Gabrovska and Leshtinska River as well as the section of the Struma River after the Chetirka inflow. Hydrobiological (benthological and physical-chemical) studies were conducted in the summer of 2016 at six selected representative sites affected by different types of anthropogenic pressures (habitat change, over-exploitation, contamination with nutrients, etc.). The data were compared to the ecological status assessment performed by the Bulgarian West-Aegean Basin Directorate during 2011–2018. The analysis of the associated physical-chemical parameters showed good–high status for all studied rivers and stretches. According to the Biotic Index, the Gabrovska River was determined in a high–good status whereas the Leshtinska, Chetirka and the section of the Struma River after the Chetirka inflow were characterised by moderate ecological status. The results obtained for the polluted sites demonstrate the need for more frequent monitoring observations at vulnerable sites exposed to adverse influences and droughts in order to prevent potential negative impacts on the main river basin.

Key words: rivers, macrozoobenthos, ecological status assessment

Introduction

To ensure the conservation, maintenance and restoration of water resources in Bulgaria, River Basin Management Plans (RBMP) have been developed. An important role in the second planning period (2016-2021) was played by the Program of Measures. It paid special attention to those water bodies, which, due to anthropogenic pressure, did not meet the criteria of the EU Water Framework Directive (2000/60/EC) for the “good” status of surface running water. Benthic macroinvertebrates as

obligatory biological quality element were defined as the most frequently used organisms in the ecological assessment of different water bodies and sensitive to water status alteration (ROSENBERG & RESH 1993).

According to the national water typology, the Chetirka River (also known as Logodashka River), being an important tributary of the Struma River, has been included in the water body *Struma River from the inflow of the Blagoevgradska Bistritza River with tributaries of the Chetirka River and the Aydarovsko Dere to the influx of the Stara Reka River*, Code BG4ST500R1049. It has been defined as

*Corresponding author: emily.varadinova@gmail.com

River type R5: Semi-mountain type in Ecoregion 7. The Chetirka River is one of the tributaries, which is frequently considered as a source of polluted waters joining the transboundary Struma River. Thus, in 2011, the data of hydrobiological monitoring by WABD (2016) showed a bad ecological status of the lotic water body. Although an improvement in status of the Chetirka River was observed in 2012, a deterioration of status of the Struma waters, defined as “moderate” was recorded again in 2014. This was due to the negative human impact on both main river basin and tributaries. These trends characterised the aquatic ecosystem as being in unstable ecological condition, which necessitates additional attention and prevention of the unfavourable influences on the Struma River. Therefore, periodical studies for the assessment of the conditions in both the main river and its tributaries are needed. Different sampling approaches and a variety of methods of analysis and evaluation were used in these surveys. At an earlier stage, the study by SOUFI et al. (2002) covered the trends of the changes in the saprobiological state of Struma River for a 20-years period. On this base, a link between the classical saprobiological assessment methods and biotic indices was established (SOUFI et al. 2006, STOYANOVA et al. 2010). SAKELARIEVA & VARADINOVA (2013) analysed the water quality and assessed the status of the left tributary of the Struma River, i.e. Blagoevgradska Bistritsa River. VIDINOVA et al. (2006) analysed the taxonomical status of the members of the orders Ephemeroptera and Plecoptera regarding the saprobiological situation in the Bulgarian part of the Struma River. STOYANOVA et al. (2014) presented ecological evaluation of the Luda Reka River (left tributary of the Struma River) based on the Ephemeroptera/Plecoptera/Trichoptera (EPT) index.

Nevertheless, data on the ecological status evaluation of the one of the significant tributaries of the Struma, i.e. Chetirka River, and its tributaries (Gabrovska and Leshtinska) are still scarce. Some investigations on abiotic conditions in this area such as debris flow natural hazards, incl. erosion, landslides, flash floods (KENDEROVA et al. 2013) have been published. Concerning the biotic component, especially the taxonomic composition of the macrozoobenthos, only the study by KOTSAKOVA (2016) has been reported. Detailed and systematic ecological research in this area will lead to the enrichment of hydrobiological knowledge and a more complete and updated assessment of the ecological situation of the Gabrovska – Leshtinska – Chetirka River system.

The study aims to analyse the representativeness of the assessment of the ecological status of

surface water bodies through the example of the model lotic systems – Chetirka (Logodashka) River, its tributaries Gabrovska and Leshtinska River and the section of the Struma River, after the Chetirka inflow. We compare data obtained from six monitoring sites at this water body and consider their values as representative points for assessing the ecological status of the river ecosystem.

Materials and Methods

Study area

Benthological and water samples were taken in the summer of 2016 at six selected representative sites of the water body *Chetirka River, with its right inflow Leshtinska River from the springs to the inflow into the Struma River*, Code BG4ST500R049 (Fig. 1). The Gabrovska River catchment area, respectively Site 1 (S1), Site 2 (S2) and part of the Site 6 (S6), were located in the Natura 2000 Protected Zone *Oranovski Prolom – Leshko* (DIRECTIVE 92/43/EEC). The sites S5 and S6 were part of the area classified as sites of high risk by floods (FRMP

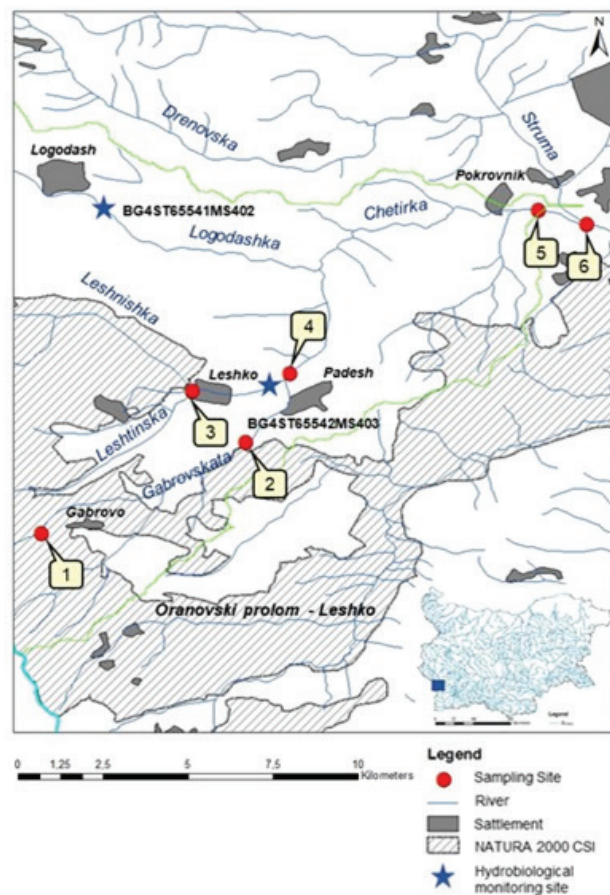


Fig. 1. Sampling sites along the Chetirka (Logodashka) River, Gabrovska and Leshtinska River and the section of the Struma River, after the Chetirka inflow.

Table 1. Sampling sites description.

Site	Description	Coordinates Elevation	River type	Pressures/impacts	Specifics
S 1	Gabrovska River, village Gabrovo, Chandreva neighbourhood	N 41°53'44.1" E 22°55'54.3" 825 m a.s.l.	R 5	Water extraction, hydromorphological alterations	Protected Zone "Oranovski prolom – Leshko" (Natura 2000 code BG0001022)
S 2	Gabrovska – River before village Padesh	N 41° 55'11.7" E 22° 59'08.7" 581 m a.s.l.	R 5	Hydromorphological alterations, diffuse pollution by farms	Protected Zone "Oranovski prolom – Leshko" (Natura 2000 code BG0001022)
S 3	Leshtinska River, village Leshko	N 41° 56'00.8" E 22° 58'18.3" 583 m a.s.l.	R 5	Construction of migration barriers - weirs, etc., diffuse pollution from agricultural activities, farms	Before WARBD monitoring site BG4ST65542MS403
S 4	Leshtinska River after village Padesh	N 41° 56'17.2" E 22° 59'50.8" 539 m a.s.l.	R 5	Arable land, pollution from point sources (waste water discharge in the Gabrovska River by the "Sewerage System – Padesh")	After WARBD monitoring site BG4ST65542MS403
S 5	Chetirka (Logodashka) River after village Pokrovnik	N 41° 58'51.4" E 23°04'07.2" 336 m a.s.l.	R 5	River bed uncleaned from fallen timber, hydromorphological alterations (disturbed normal conductivity during high water)	Area classified as "high risk" by floods, code BG4_APSFR_ST_05 after WARBD site BG4ST65541MS402
S 6	Struma River after village Moshanets	N 41° 58'40.5" E 23°4'33.9" 323 m a.s.l.	R 5	Hydromorphological alterations (migration barrier – sill, partially damaged)	Area classified with "high risk" by floods, code BG4_APSFR_ST_05

2016). The sites S3, S4 and S5 were situated close to the hydrobiological monitoring points BG4ST65542MS403 (Leshtinska River after village Leshko) and BG4ST65541MS402 (Chetirka River before estuary, bridge to village Moshanets). For detailed descriptions of the sites affected by various type of anthropogenic pressures (water abstraction, morphological alteration, channelization, pollution from point and diffuse sources, etc., after MAES et al. 2018), see Table 1.

Sampling techniques: water quality parameters and biology

Standard measurements of basic water parameters such as temperature, pH, dissolved oxygen (DO), oxygen saturation and electrical conductivity (EC) were taken from all studied sites. An assessment based on supporting physical-chemical elements was applied according to the requirements of the national legislation (REGULATION H-4, 2013). The benthic macroinvertebrate collection was in accordance with an adapted version of the multi-habitat sampling methodology developed on European AQEM/STAR projects (CHESHMEDJIEV et al. 2011) and with the standard BDS EN ISO 10870:2012. The method was regulated by the applicable water legislation (REGULATION H-4, 2013). Two standard biological metrics were applied, with corresponding

scales for assessment of the ecological status: Total Number of Taxa (TNT) and Adapted Biotic index (ABI) (CHESHMEDJIEV & VARADINOVA 2013). The cluster analysis (Bray-Curtis Similarity Matrix) was performed by the statistical package Primer 6 (CLARKE & WARWICK 2001).

Results

Environmental conditions

Characteristics of the studied sites (specific substrate, alternation of rapids and pools, relatively high slope and high flow rate) created favourable conditions for rich physical aeration of the water environment. Regardless of the registered anthropogenic influences (Table 1), environmental conditions provided high values of oxygen concentration. The pH values range from neutral to slightly alkaline environment. The DO and EC values showed a high status for all studied sites. However, higher EC values were recorded at sites from S3 to S6 (Table 2). The monitoring data by the National Executive Environmental Agency reported similar results for 2016 at the controlling monitoring site BG4ST65541MS402, situated between S3 and S4 for these physical-chemical parameters, with an average annual value of a similar scale (DO 8.36 mgO₂/l, pH 7.93 and EC 567.33 µS/cm).

Table 2. Classification of ecological status of the studied sites.

Studied sites	Physical-chemical parameter					Biological Indices		Ecological status
	T°C	pH	Dissolved oxygen [mgO /l]	Oxygen saturation [%]	Electrical conductivity [µS/cm]	TNT	Biological Indices	
S 1	10.8	7.49	10.2	108.2	400	25	4.5	High
S 2	14.6	7.36	10.79	118.2	350	22	5	High
S 3	18.0	7.40	8.88	106.7	643	10	3.5	Good
S 4	18.8	7.73	9.96	116.2	639	13	3	Moderate
S 5	17.4	7.34	10.7	114.3	693	12	3	Moderate
S 6	14.8	7.33	9.39	97.8	548	6	2.5	Moderate

Biological (benthological) assessment

Totally, 45 benthic taxa containing 663 individuals were found in the studied sites along the Gabrovska–Leshtinska–Chetirka River system. The highest taxonomic richness and number of individuals were established for S1 and S2 (Fig. 2). These points were characterised by the most favourable environmental conditions and the least anthropogenic pressure.

The macrozoobenthos taxonomic composition in the Gabrovska River was presented predominantly by stenobiotic taxa, typical for clean, unpolluted waters (Fig. 3). They belonged mainly to the groups of mayflies, caddisflies and stoneflies. It should be noted that there were no previous systematic observations in the catchment area of the Gabrovska River. The conducted study was the first from hydrobiological/ecological point of view for this river. The remaining surveyed water sites were more or less affected by various anthropogenic pressures (Table 1) and characterised mostly by the presence of tolerant benthic taxa of chironomids and oligochaetes (Fig. 3).

The analysis of the similarity in the macrozoobenthos taxonomic composition, divided the studied sites into two main groups (Fig. 4). The first group included S1, S2 and S4, which characterised as clean, unaffected (S1) or less affected by anthropogenic impact (S2 and S4). The second group was formed from sites that could be identified as more significantly influenced by human activity (S3, S5 and S6).

According to the leading ABI (Table 2), the Gabrovska River was determined in a high ecological status, whereas the Leshtinska, Chetirka and the section of the Struma River after the Chetirka inflow were characterised by moderate ecological status. Results reported by WERBMP showed similar values for ABI during 2011–2014 for Leshtinska and Chetirka Rivers. Later studies in the pointed rivers have not been carried out.

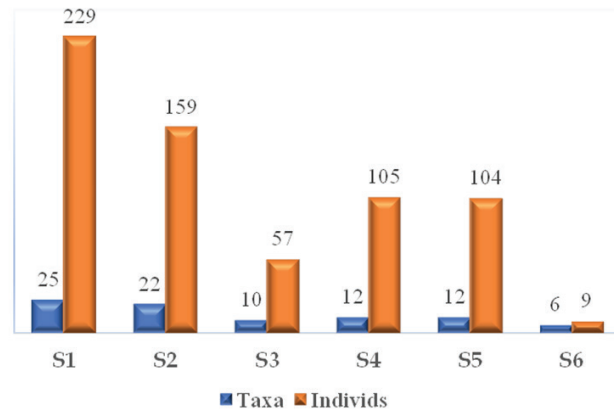


Fig. 2. Number of taxa and individuals at sampling sites.

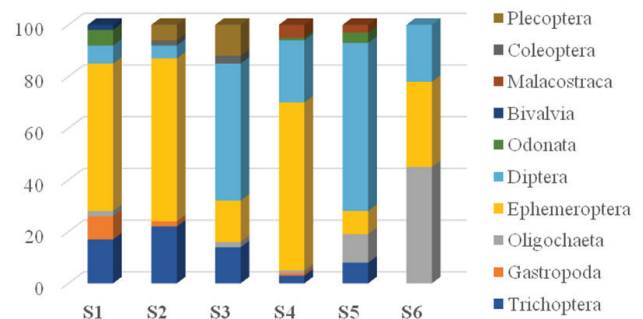


Fig. 3. Distribution of the main macrozoobenthic groups [%].

Discussion

The assessment based on the physical-chemical parameters showed a balanced water environment characterised with undisturbed conditions (Table 2). However, physical water characteristics are highly variable, reflecting a snapshot of the ecological situation in the aquatic environment and describing water conditions in short terms (JUNSHUM et al. 2008). Representative bottom invertebrates are the key communities in the lotic ecosystems and demonstrate lasting changes in rivers due to the human impact. Macroinvertebrates as bioindicators of environmental impacts in

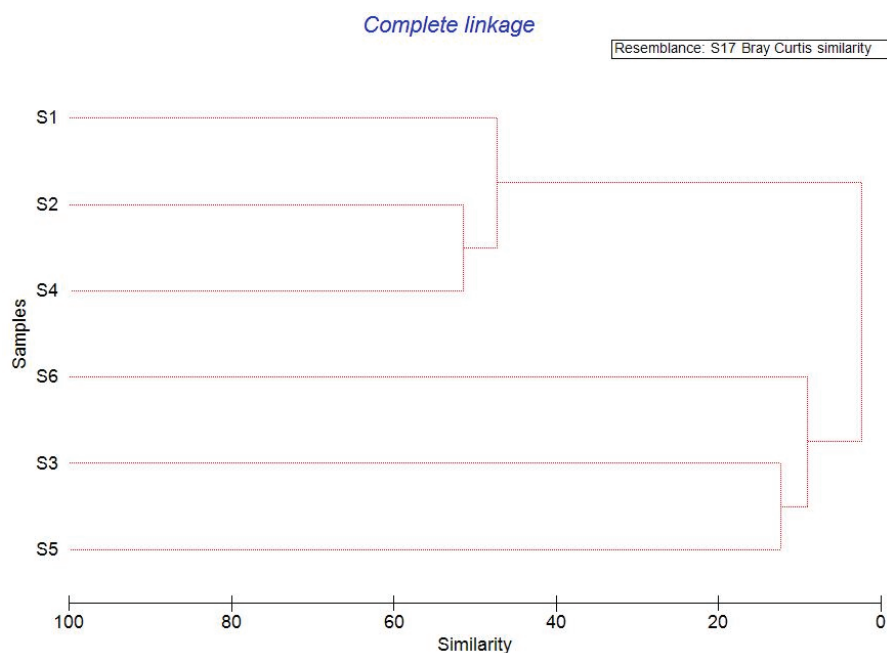


Fig. 4. Comparative analysis of the macrozoobenthos taxonomic composition similarity between studied sites.

rivers (BENNETTI et al. 2012) can be utilised to identify impaired waters, determine aquatic life stressors, set pollutant load reductions and indicate improvement (KENNEY et al. 2009). Therefore, the evaluation by macrozoobenthos with support of the underlying physical-chemical quality elements can be considered representative in determining the ecological status of the lotic ecosystems.

However, can the derived ecological status assessment based on the study of one or two sites only be representative of all river sections that make up the water body? According to WABMP (2016–2021), the status of the studied water body was assessed only by two monitoring sites declared as “representative” (see Materials and Methods). In our study, these are S3 and S5. The ecological evaluation defined as moderate also coincides with these two sites. The deterioration of the condition initiates a significant impact on the riverine ecosystem due to the pollution, which has been registered after the village of Leshko. In this section, the river has been subjected to activities related to runoff regulation and diffuse local impact of the adjacent agricultural lands and livestock farms. The unfavourable ecological situation continued because of the discharge of the sewage system of the Padesh Village in Gabrovska River. The adverse effect was exacerbated and observed in Chetirka River after the village of Pokrovnik (Table 2). Thus, the aquatic contamination and hydromorphological alterations induced negative effects on the aquatic variables and the bottom communities. In addition, waters

of the Chetirka River are used for irrigation. Water abstraction and the fact that the clean tributaries Gabrovska and Logodashka often dry up in summer periods lead to a significant reduction of the flow. Therefore, changes in quantitative parameters may have a negative impact on river ecosystems and make them highly vulnerable.

According to the national water legislation requirements, the ecological assessment of the water bodies is determined by using data for the worst monitoring site of the assessed body (WABD 2016–2021). However, it cannot always be considered representative because the revealed significant differences between rivers and river sections belonging to the studied water body.

Despite the unfavourable general assessment of the ecological status of the Chetirka River (WABMP 2016–2021), not all river sections and rivers within the water body were characterised by a moderate status. Thus, the Gabrovska River (Table 2) as well as the Logodashka River (unpublished data) are unaffected and determined as rivers with high water quality. These tributaries fed the main river with clean waters, and aquatic ecosystems of both main river and tributaries might be described as balanced. An appropriate example is another major tributary of the Struma River, i.e. Strumeshnitsa River (SMILYANOV 2016). In this water body, the evaluation does not correspond to the ecological status assessment of all river stretches and, especially, the tributaries at higher altitudes. Even in one river, the water quality is frequently

varying when comparing among its sections. The Strumeshnitsa River stream has sections assessed as having moderate and bad ecological status. However, its tributary Luda Mara River, above the town of Petrich, is clean and unaffected, with high water quality. Under the city Petrich, Luda Mara River has been heavily polluted due to sewage inflow into it (SMILYANOV 2016).

The previous assessment of the ecological status of the Chetirka River system was determined as the worst one based on the study carried out at the two representative national monitoring sites. They are located in the lower sections of the river basin and have a collective character in terms of the impacts registered upstream. However, when analysing the status of aquatic ecosystems for scientific purposes, for a correctness of the evaluation, it is necessary to investigate more sites located within the water body and to include consistently the so-called *hot spots* where local anthropogenic impacts were observed.

Regular monitoring and taking measures to maintain the good ecological status of the waters of the Chetirka River is of particular importance by various reasons, including its function of a tributary of the transboundary Struma River. Inflow into the main valley further strains the already polluted Struma River in the area. The official monitoring data show that the ecological status of the Struma River in 2017 was defined as poor based on biological quality elements and moderate according to the physical-chemical conditions. In 2018, the ecological status of the section of the Struma River after the Chetirka inflow was improved with one degree, i.e. based on biological indicators (biological quality elements phytobenthos and macrozoobenthos) to moderate and based on physical-chemical parameters to good.

The reference to the registers of the WABD has demonstrated that monitoring studies on the status of the Leshtinska and Chetirka Rivers have not been carried out in 2017–2018. This does not allow interpretations of trends in the status of aquatic ecosystems in the study area. Preventive actions and the implementation of appropriate measures are particularly important, especially because shortly after the Chetirka River joins the Struma River, the Natura 2000 Protected Zone “Oranovski Prolom – Leshko” is situated. This is a territory requiring additional restrictions to negative impacts in line with the DIRECTIVE 92/43/EEC (1992) and the BIOLOGICAL DIVERSITY ACT (2002).

Conclusion

The ecological status characterisation of water bodies in Bulgaria revealed a significant problem that concerns the majority of the river catchments in Bulgaria. They have clean and unaffected river sections in the upper parts corresponding to the high water quality and downstream status deterioration, which is a result of human pressures. Pollution prevention is particularly important in the case of the Chetirka River, as it is a tributary of the transboundary Struma River, which is also crossing a Natura 2000 site. This raised the urgent need of taking preventive actions and gradual construction of treatment plants not only in large settlements but also in small villages in the catchment areas of the tributaries. In this context, in parallel with the WARBMP measures, more frequent, periodic monitoring of rivers is required to prevent potential negative impacts on aquatic ecosystems in the big river basins. Another approach to ensure a corresponding assessment is to increase the number of representative sites along the water body; this will guarantee an objective assessment of the environmental situation and accuracy in determining the ecological status of the water body. The results obtained could be a reliable basis for the decision-making process to prevent anthropogenic pressures, the improvement of the conditions in aquatic environment and the achievement of the targeted “good ecological status” of rivers.

References

- BIOLOGICAL DIVERSITY ACT. 2002. Promulgated, State Gazette 77/9.08.2002.
- CHESHMEDJIEV S., SOUFI R., VIDINOVA Y., TYUFEKCHIEVA V., YANEA I., UZUNOV Y. & VARADINOVA E. 2011. Multi-habitat sampling method for benthic macroinvertebrate communities in different river types in Bulgaria. *Water Resources Management* 1 (3): 55–58.
- CHESHMEDJIEV S. & VARADINOVA E. 2013. Domestic macroinvertebrates. In: D. BELKINOVA D., GECHEV G., CHESHMEJHIEV S., DIMITROVA-DULGEROVA I., MLADENOV R., MARINOV M., TENEV I., STOYANOV P., IVANOV P., MIKHOV S., PEHLIVANOV L., VARADINOVA E., KARAGYOZOVA T., VASILEV M., APOSTOLU A., VELKOV B. & PAVLOVA M. Biological analysis and ecological assessment of surface water types in Bulgaria, P. Hilendarski University Publishing House, 978-1954, 147-163 -423-824-7.
- CLARKE K. R. & WARWICK R. M. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd ed. PRIMER-E Ltd, Plymouth.

- EC 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
- EC 1992. Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
- FRMP. 2016. Flood Risk Management Plan in the West Aegean River Basin District for the period 2016-2021.
- JUNSHUM P., CHOONLUCHANON S. & TRAICHAIYAPORN S. 2008. Biological indices for classification of water quality around Mae Moh Power Plant, Thailand. *Maejo International Journal of Science and Technology* 2 (1): 24–36.
- KENDEROVA R., BALTAKOVA A. & RATCHEV G. 2013. Debris flows in the Middle Struma Valley, Southwest Bulgaria. Geomorphological impacts of extreme weather. In: LOCZY D. (Ed.). Dordrecht: Springer Geography. Springer.
- KOTSAKOVA S. 2016. Ecological status of the Chetirka (Logodashka) River and its tributaries assessed by macrozoobenthos. Bachelor's thesis. 72 p. (In Bulgarian).
- MAES J., TELLER A., ERHARD M., GRIZZETTI B., BARREDO J. I., PARACCHINI M. L., CONDÉ S., SOMMA F., ORGIAZZI A., JONES A., ZULIAN A., VALLECILO S., PETERSEN J. E., MARQUARDT D., KOVACEVIC V., MALAK D. A., MARIN A. I., CZÚCZ B., MAURI A., LOFFLER P., BIRK A. B., BIALA K., CHRISTIANSEN T. & WERNER B. 2018. Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Luxembourg: Publications office of the EU.
- REGULATION H-4 for characterization of surface waters. 2013. State Gazette, 22.
- ROSENBERG D. M. & RESH V. H. 1993. Freshwater biomonitoring and benthic macroinvertebrates. New York: Chapman and Hall.
- SAKELARIEVA L. & VARADINOVA E. 2013. Water quality and ecological state assessment of the Blagoevgradska Bistritsa River (South-West Bulgaria) based on macrozoobenthos collected by Two Standardized Sampling Methods. *Bio-technology & Biotechnological Equipment* 27 (3): 3787-3790.
- SMYLYANOV M. 2016. Assessment of the ecological status of the waters in the Bulgarian section of the Strumeshnitsa River and the Luda Mara River. Bachelor's thesis. Blagoevgrad: South-West University, 55 p. (In Bulgarian).
- SOUFI R., VARADINOVA E. & UZUNOV Y. 2002. Recent assessment and long-term changes in the saprobiological state of the Struma River (South-Western Bulgaria). *Journal of Environmental Protection and Ecology* 3 (1): 61–67.
- SOUFI R., VARADINOVA E. & UZUNOV Y. 2006. Relation of the Bulgarian Biotic Index to the standardized indices for water quality assessment in Bulgaria and some biotic indices used in EC countries: investigation for the Struma River (South-Western Bulgaria). *Acta Zoologica Bulgarica* 58 (2): 265–273.
- STOYANOVA T., TRAYKOV I., YANEVA I. & BOGOEV V. 2010. Ecological quality assessment of Luda River, Bulgaria. *Natura Montenegrina* 9 (3): 341–348.
- STOYANOVA T., VIDINOVA Y., YANEVA I., TYUFEKCHIEVA V., PARVANOV D., TRAYKOV I. & BOGOEV V. 2014. Ephemeroptera, Plecoptera and Trichoptera as Indicators for Ecological Quality of Luda River, Bulgaria. *Acta Zoologica Bulgarica* 66 (2): 255–260.
- VIDIDNOVA Y., YANEVA I. & TYUFEKCHIEVA V. 2006. Ephemeroptera and Plecoptera (Insecta) from Bulgarian part of the Struma River. *Acta Zoologica Bulgarica* 58 (1):123–128.
- WABD. 2016. Supplement, Exceedances from Good/ Moderate State Boundary for Basic Physicochemical Parameters and EQS for Specific Pollutants in Surface Waters in the West Aegean Region in 2016.
- WARBMP. 2016. River Basin Management Plan – West Aegean Region for the period 2016-2021.

Received: 19.11.2019
Accepted: 14.07.2020

