Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ECOLOGICAL ASSESSMENT OF THE BOROVITSA RIVER, EAST AEGEAN SEA BASIN

Diana KIRIN[1, 2], Petya ZAHARIEVA[1, 2], Radoslava ZAHARIEVA[1, 2], Georgi PATRONOV[3], Marian VARBANOV[1], Gergana METODIEVA[1], Dimitrinka KUZMANOVA[2]

[1]National Institute of Geophysics, Geodesy and Geography (NIGGG), Hydrology and Water Management Research Center, Bulgarian Academy of Sciences, 3 Acad. G. Bonchev Street, 1113, Sofia, Bulgaria
[2]Agricultural University-Plovdiv, Department of Chemistry, Phytopharmacy and Ecology, and Environmental Protection, 12 Mendeleev Blvd., Plovdiv, 4000, Bulgaria
[3]University of Plovdiv "Paissii Hilendarski", Department of Chemical Technology, 24 Tsar Assen Street, Plovdiv, 4000, Bulgaria

Corresponding author email: dianaatanasovakirin@gmail.com

Abstract

This study assesses the ecological state of the Borovitsa River, a tributary of the Arda River sub-basin, and the Maritsa River basin using a methodology approved for the European Union and Bulgaria. For the purpose of the study, in the spring of 2024, macroinvertebrates samples were collected from the Borovitsa River near the village of Nenkovo (in the section between Borovitsa Reservoir and Kardzhali Reservoir, according to Bulgarian river typology, this section is classified as R14:"Sub-Mediterranean small and medium-sized rivers" according to the typology of rivers in Bulgaria. The collected macrozoobenthos were taxonomically identified. Fourteen taxa were identified, based on which key ecological metrics were calculated - EPT taxa, Margalef species richness index (Dmg), Shannon-Weaver species diversity index (H'), Pielou's evenness index (E), Simpson's dominance index (C) and biotic index (BI). The findings provide valuable insights into the biodiversity and ecological status of the Borovitsa River, contributing to regional water quality assessments and conservation efforts.

Key words: *biotic index, chemical status, ecological state, macrozoobenthos, Maritsa River basin.*

INTRODUCTION

The Arda River originates from the northeastern foothills of Ardin Peak, located in the Western Rhodopes, and flows for 241 km before reachingthe Bulgarian-Greek border. It then joins the Maritsa River in Turkey. The Arda River is one of the largest tributaries of the Maritsa River. Major tributaries of the Arda River include the Varbitsa River (98.1 km), Krumovitsa River (58.5 km), Cherna River (48.1 km), Perperek River (44 km), and Borovitsa River (42.1 km). Its highest water levels occur between December and April. The Borovitsa River originates in the Rhodopes and flows into the Arda River, eventually draining into the Kardzhali Reservoir. The Borovitsa River catchment area is 301 km^2 (Kiradzhiev, 2013; East Aegean River Basin Directorate, 2018). The Borovitsa Reservoir supplies drinking and domestic water. The surrounding area is lightly inhabited (Kiradzhiev, 2013; Integrated Development Plan of Municipality of Kardzhali, 2021-2027). The European Water Framework Directive (Directive 2000/60/EU) mandates that all surface waters achieve a "good ecological status".

The Borovitsa River falls into Ecoregion 7 and belongs to type R14 "Sub-Mediterranean small and medium-sized rivers" (Belkinova et al., 2013). A key role in the assessment of the ecological state of surface water is played by biological quality elements (BQEs) includingphytoplankton, macrophytes, phytobenthos, macrozoobenthos and fish. Additionally, physicochemical and hydromorphological parameters contribute to the evaluation. The final assessment of the ecological state is determined on the principle of "one out – all out" (Cheshmedjiev & Marinov, 2008; Belkinova et al., 2013). Despite extensive research on the Arda River and its sub-basin, no previous studies have assessed the Borovitsa River's ecological state using macrozoobenthos as a BQE. Such studies exist for the Arda River (Kirin et al., 2002; Kuzmanov et al., 2002; Kirin et al., 2003; Kirin, 2006) and for the Arda River sub-basin - from the Borovitsa Reservoir (Varadinova et al., 2019). Vidinova (2006) studied mayflies (Ephemeroptera, Insecta) from the Rhodopes Mountains, including from the Arda River, the Malka Arda River, the Varbitsa River, the Krumovitsa River, the Borovitsa River and others. Vidinova et al. (2016) presented a taxonomic list of macroinvertebrates from various standing water bodies in Bulgaria, including the Borovitsa Reservoir.

This study aims to evaluate the ecological state of the Borovitsa River, a tributary of the Arda River sub-basin and the Maritsa River basin, using macrozoobenthos - based bioindicators. The results contribute to regional water quality assessments and environmental management strategies.

MATERIALS AND METHODS

Macrozoobenthos samples were collected from the Borovitsa River in the spring of 2024. The selected biotope (designated as the Nenkovo biotope) is located between the Borovitsa Reservoir and Kardzhali Reservoir, next to the Roman Bridge (41°43'59.8"N 25°13'11.7" E) (Figures 1-2), south of the village of Nenkovo, at an altitude of 420 m. In this section, the river bed is represented by stones and sand.

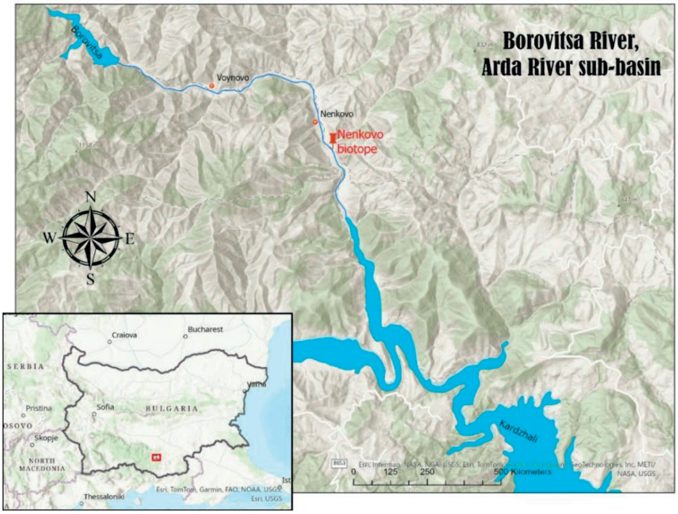

Figure 1. Borovitsa River, Arda River sub-basin, Maritsa River basin

Figure 2. Views from the Borovitsa River, Nenkovo biotope

Macroinvertebrate sampling followed EU and Bulgarian legislative requirements and standards (Cheshmedjiev et al., 2011; EN ISO 10870:2012; EN 16150:2012; Regulation No. H-4 of 14.09.2012; Belkinova et al., 2013). The taxonomic identification and abundance assessment of the collected macroinvertebrates were conducted under laboratory conditions using a stereo zoom microscope, KERN OZL 464T24. According to Regulation No. H-4 of 14.09.2012 and Belkinova et al. (2013), the following metrics were calculated: - total number of taxa; - number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa; - Trichoptera taxa was the dominant group.

Additionally, the following indices were calculated: 1) Margalef species richness index (Dmg) (Margaleff, 1958); 2) Shannon-Weaver species diversity index (H') (Shannon & Weaver, 1963); 3) Pielou's evenness index (E); 4) Simpson's dominance index (C) (Magurran, 1988); 5) Saprobic index (SPUB) and 6) Biotic index (BI) based on Flanagan & Toner (1972), modified by Clabby (1979), Clabby (1982).

The indices were calculated using the following formulas:

1) $$\mathbf{Dmg} = \frac{(\mathbf{S-1})}{\mathbf{log_2 N}},$$

where:
S - number of species in the sample;
N - total number of organisms in the sample.

2) $$\mathbf{H'} = (\mathbf{P})(\mathbf{logP}),$$

where:
H' - index of individual species diversity;
P - the proportion of the taxon (amount of the taxon divided by the total number of organisms in the sample).

3) $$\mathbf{E} = \frac{\mathbf{H'}}{\mathbf{log_2 N}},$$

where:
H' - index of individual species diversity;
N - number of specimens.

4) $$\mathbf{C} = \sum \left(\frac{\mathbf{n_i}}{\mathbf{N}}\right)^2,$$

where:
n_i - number of specimens of each i-species;
N - number of specimens of all species (total abundance)

5) $$\mathbf{SPUB} = \sum(\mathbf{s_i h_i I_i})/\sum(\mathbf{h_i I_i}),$$

where:
s_i - saprobic importance of species/taxon i;
h_i - relative abundance of species/taxon i;
I_i - indicator weight of species/taxon i.

RESULTS AND DISCUSSIONS

In the study of macrozoobenthos from the Borovitsa River, Nenkovo biotope, 14 taxa with 219 specimens belonging to 6 orders were identified. Trichoptera taxa were the most dominant group. The most abundant taxon was *Schmidtea polychroa* (Schmidt, 1861) (order Tricladida; 79 specimens) (Table 1). The number of identified taxa suggests a very good ecological state of the water of the Borovitsa River in the studied biotope.

More than half of the macroinvertebrate taxa in the Nenkovo biotope belong to the EPT taxa (8 taxa). Taxa from these orders are sensitive to anthropogenic pressure, and their presence indicates a good ecological status for the river in the selected biotope. A previous study (Vidinova, 2006) reported four taxa of Ephemeroptera for the Borovitsa River - *Electrogena lateralis* (Curtis, 1834), *Electrogena macedonica* (Ikonomov, 1954), *Electrogena quadrilineata* (Landa, 1970) and *Choroterpes picteti* (Eaton, 1871), but these species were absent in the Nenkovo biotope.

In the Borovitsa Reservoir a total of 14 macrozoobenthos taxa were recorded, including:

- 1 taxon Oligochaeta (*Limnodrilus* sp. juv.),
- 1 taxon Ephemeroptera (*Caenis macrura* Stephenes, 1835),
- 1 taxon Odonata (*Gomphus vulgatissimus* (Linnaeus, 1758)),
- 2 taxa Trichoptera (*Ecnomus tenellus* (Rambur, 1842), *Holocentropus stagnalis* (Albarda, 1874)) and
- 9 Diptera taxa (*Chironomus* gr. *riparius* Meigen, 1804, *Chironomus* sp., *Cricotopus* sp., *Cryptochironomus* gr. *defectus* Kieffer, 1913, *Dicrotendipes* sp., *Eukiefferiella* sp., *Tanytarsus* gr. *gregarius* Kieffer, 1909, *Tvetenia* sp., Chironomidae, gen. sp.) (Vidinova et al., 2016).

None of these taxa were recorded in the present study for the Nenkovo biotope of the Borovitsa River.

The abundance of macroinvertebrate fauna is represented by the metrics: % (Oligochaeta & Diptera), % Filtering feeders and % EPT taxa. In the present study, no representatives of Oligochaeta were found. Two Diptera taxa were found (with 33 specimens). Only one taxon (9 specimens) belongs to the filtering feeders

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

group. EPT taxa contributed the highest proportion of macrozoobenthos (Table 2).

The Margalef species richness index (Dmg) is low. The Shannon-Weaver species diversity index (H') is also low, indicating α-mesosaprobic conditions. However, the Pielou's evenness index (E) is high, the Simpson's dominance index (C) is low, which indicates favourable environmental conditions (Table 3).

Table 1. Taxonomic composition and abundance of bioindicator macroinvertebrate organisms from the Borovitsa River, Nenkovo biotope

No.	Taxa	Number of specimens	Genus	Family	Order
1	*Limnephilus rhombicus* (Linnaeus, 1758), larva	36	*Limnephilus* Leach, 1815	Limnephilidae	Trichoptera
2	*Hydropsyche* sp., larva	2	*Hydropsyche* Pictet, 1834	Hydropsychidae	Trichoptera
3	*Hydropsyche ornatula* McLachlan 1878, larva	40	*Hydropsyche* Pictet, 1834	Hydropsychidae	Trichoptera
4	*Psychomyia pusilla* (Fabricius, 1781), larva	1	*Psychomyia* Latreille, 1829	Psychomyiidae	Trichoptera
5	*Chironomus plumosus* (Linnaeus, 1758), larva	24	*Chironomus* Meigen, 1803	Chironomidae	Diptera
6	*Hydroptila* sp., larva	5	*Hydroptila* Dalman, 1819	Hydroptilidae	Trichoptera
7	*Simulium* sp., larva	9	*Simulium* Latreille, 1802	Simuliidae	Diptera
8	*Baetis* sp., nymph	3	*Baetis* Leach, 1815	Baetidae	Ephemeroptera
9	*Schmidtea polychroa* (Schmidt, 1861)	79	*Schmidtea* Ball, 1974	Dugesiidae	Tricladida
10	*Gomphus* sp., nymph	10	*Gomphus* Leach, 1815	Gomphidae	Odonata
11	*Enallagma cyathigerum* (Charpentier, 1840), larva	2	*Enallagma* Charpentier, 1840	Coenagrionidae	Odonata
12	*Platambus maculatus* (Linnaeus, 1758)	1	*Platambus* Thomson, 1859	Dytiscidae	Coleoptera
13	*Oligotricha striata* (Linnaeus, 1758) (syn. *Phryganea striata* L.), larva	3	*Oligotricha* Rambur, 1842	Phryganeidae	Trichoptera
14	*Ecdyonurus* sp., nymph	4	*Ecdyonurus* Eaton, 1868	Heptageniidae	Ephemeroptera

Table 2. Abundance of macroinvertebrate organisms from the Borovitsa River, Nenkovo biotope

Metrix	% (Oligochaeta & Diptera)	% Filtering feeders	% EPT taxa
14 taxa (219 specimens)	15.07%	4.11%	42.92%

A total of five macrozoobenthos taxa were associated with 0-β-mesosaprobic conditions; three taxa corresponded to β-α-mesosaprobic conditions, three to β-mesosaprobic conditions and one taxon each - χ-0 saprobic; χ-β-mesosaprobic and p saprobic conditions. The study reports a saprobic index SPUB of 2.38, indicating a moderate ecological state of the Borovitsa River.

Table 3. Biotic indices of the bioindicator macrozoobenthos from the Borovitsa River, Nenkovo biotope

Indices	Margalef species richness index (Dmg)	Shannon-Weaver species diversity index (H')	Pielou's evenness index (E)	Simpson's dominance index (C)
14 taxa (219 specimens)	2.41	1.9	0.721	0.208

The macroinvertebrate organisms discovered in this study belong to four sensitivity groups. The largest number of taxa and specimens (9 taxa with 99 specimens) were classified as relatively tolerant forms (group C), followed by the group of less sensitive ones (group B) - 3 taxa with 92 specimens. With one taxon each (4 and 24 specimens), the groups of sensitive (group A) and the most tolerant forms (group E) are represented, respectively. Notably, no taxa belonged to the tolerant group (Group D). The determined biotic index (BI (nEQR) = 3 (0.6)) indicates a moderate ecological state.
According to a report from the East Aegean River Basin Directorate (EARBD) covering the period 2020-2023, the ecological state of the Borovitsa River varies along different sections. The section from the river's source to the Borovitsa Reservoir is classified as good, while the section from the Borovitsa River and tributaries from the Borovitsa Reservoir to the confluence with the Kardzhali Reservoir is categorized as having a moderate ecological state (Table 4). In the spring (March-June) of 2024, there were no exceedances of key physicochemical parameters, specific pollutants, or priority substances in the Borovitsa River's freshwater ecosystem (East Aegean River Basin Directorate, 2018).

Table 4. Comprehensive ecological assessment for the period 2020-2023 (EARBD) (ES - ecological state; EP - ecological potential; BQEs - biological quality elements; PQEs - physicochemical quality elements)

	Overall assessment of the ES/EP on the BQEs	Overall assessment of the ES on the PQEs	Overall assessment of the ES/EP	Chemical state
Source of the Borovitsa River to the Borovitsa Reservoir - R14				
2023	good	good ES	good	good
2022			good	good
2021	good		good	unknown
2020	good		good	unknown
Borovitsa River and tributaries from Borovitsa Reservoir to the confluence with Kardzhali Reservoir - R14				
2023	moderate	good ES	moderate	Good
2022			moderate	Good
2021	good		good	Unknown
2020	good		good	Unknown

The findings of this study confirms preserving the ecological state from 2022-2023 - moderate ecological state.

CONCLUSIONS

This study assessed the ecological state of the Borovitsa River, focusing on macrozoobenthos as a biological quality element.
The identification of 14 macroinvertebrate taxa comprising 219 specimens confirmed that the Borovitsa River exhibits a moderate ecological state.
The relatively high proportion of EPT taxa (Ephemeroptera, Plecoptera, Trichoptera) indicates good ecological integrity, although the absence of certain previously recorded species suggests potential environmental pressures. It is hypothesized that this moderate classification is primarily influenced by reduced water levels, potentially leading to habitat degradation and adverse effects on macroinvertebrate communities.
Although no physicochemical exceedances were detected during the study period, long-term monitoring is required to evaluate potential

impacts from seasonal variations, climate change, and anthropogenic activities on water quality.

ACKNOWLEDGEMENTS

The results of this study have been published with the financial support of the Agricultural University-Plovdiv.

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