Research Article

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Trophic Structure of the Riverine Macroinvertebrates in Type-specific Reference Conditions

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Abstract: The functional feeding groups of the riverine macrozoobenthos are studied in two ecoregions (East Balkan and Pontic Province) and two catchment basins (Aegean and Black Sea) in Bulgaria. Totally, 83 benthic samples from 40 sites situated at 35 rivers, which belong to ten types of water bodies are analysed for establishing site-specific referent conditions. Ecological state is assessed through the Total Number of Taxa and values of the Biotic Index and RETI/PETI Trophic Index. The specific trophic structure of benthic communities characterised as unaffected and adopted as reference conditions are described. The distribution of the functional feeding groups is in compliance with the principles of the River Continuum Concept. Assessed as Total Number of Taxa, the trophic structure is dominated by scrapers followed by predators and shredders. The analysis of the abundance shows similar distribution of shares of the functional feeding groups in the two catchment basins, with prevailing participation of scrapers. A parallel analysis of the distribution of the taxa of the functional feeding groups and those of the indicator groups defining the values of the Biotic Index is performed.

Key words: macrozoobenthos, functional feeding groups, trophic structures, reference conditions, river types

Introduction

Sixteen types of riverine (running) water bodies are recognised by the national typology of surface waters in Bulgaria (Cheshmedjiev et al. 2010). The determination of the status of water bodies of different types requires the establishment of type-specific reference conditions. Reference conditions are associated with high ecological status and are representative for the structure and functioning of biological communities under condition of no disturbance or under very minor anthropogenic disturbances (Economou 2002). The type-specific reference sites are identified in the national information cards (or passports) of river types and included in the current River Basin Management Plans.

The trophic structure of the bottom invertebrate fauna is an important characteristic of functioning of water ecosystems; it is extremely sensitive to both natural changes (fluctuations) (Ofenbock et al. 2004) and anthropogenically-induced alterations (McCormick et al. 2004, Carlisle & Clements 2005). This defines the trophic structure of bottom invertebrate fauna as a good indicator of conditions in aquatic environment (De Vaate & Pavluk 2004). To assess the bioindicative potential of functional feeding groups, trophic indices for ecological state assessment of German (Bohmer et al. 2004) and Bulgarian riverine waters (Kerakova et al. 2013) were developed.

The present article is a continuation and a summary of the one-year study on application of the trophic indices in potential referent sites. We analyse the formation of the specific trophic structure (qualitative and quantitative composition of the functional feeding groups) of the macrozoobenthic communities in running waters with known type-specific reference conditions.

Materials and Methods

During a period of three years (2011–2013), 40 river sites or stretches (22 belonging to the Aegean Catchment Basin and 18 to the Black Sea Catchment Basin) were studied (Fig. 1). A detailed description of the studied river sites are presented in the final reports of the projects devoted to the setting of the reference conditions of the river water bodies identified in the Black Sea, East Aegean and West Aegean Basin Directorates (see Acknowledgements section).

The studied sites belonged to ten river types: R1 – Alpine Rivers, R2 – Mountain Rivers in Ecoregion 12 "Pontic Province", R3 – Mountain Rivers in Ecoregion 7 "Eastern Balkans", R4 – Semi-mountain Rivers in Ecoregion 12, R5 – Semi-mountain Rivers in Ecoregion 7, R10 – Large Black Sea Rivers, R11 – Small and Medium Black Sea Rivers, R13 – Small and Medium Flat Aegean Rivers, R14 – Sub-Mediterranean Small and Medium Rivers, R15 – Karst Springs and other Spring Communities. Totally, 82 macrozoobenthic samples were taken and 66,516 individuals (43,298 from the Black Sea catchment area and 23,218 from the Aegean Sea catchment area) were collected. The sampling of the benthic materials was carried out in accordance with an adapted version of the AQEM/STAR multi-habitat sampling methodology (Cheshmedjiev et al. 2011). The method is officially adopted by the national water legislation (Regulation H-4/2012). After processing and identification, lists of taxa were compiled. Depending on the trophic affiliation, each taxon was assigned to one of the six functional feeding groups (FFG): shredders (SH), scrapers (SC), collectors (CL), predators (PR), filterers (FL) and deposit feeders (DF) (see Cheshmedjiev & Varadinova 2013).

The Total Number of Taxa and the Biotic Index, as adopted for the national type-specific scale (Regulation H-4/2012), were used for the ecological state assessment of the studied sites. In addition, the RETI-PETI Trophic Index, based on functional feeding groups (Schweder 1990) and adapted for Bulgarian water bodies (Cheshmedjiev & Varadinova 2013), was also applied.

The map of the surveyed river stations was made using the software product Google Earth, Version 7.1.8.3036. Multidimensional scaling (MDS) plot analysis with statistical software Primer 6.1.6 (Clarke & Warwick 2001) was used to assess the similarity in the taxonomic composition of the macrozoobenthos between different river types.

Results

The estimation based on the Total Number of Taxa and the Biotic Index showed that all studied sites were assessed as high and good ecological state (Tables 1 and 2), which confirmed their purpose to be used as reference sites. There was only one exception, i.e. we sampled Otmanli River in 2013 instead of the dried up site of the neighbouring Velikovska-Dvoinitsa River.

The analysis of the results showed that the assessments as high ecological state based on the Biotic Index and that based on the Total Number of Taxa overlapped in 81% of the cases in the Aegean Basin and in 92% of cases in the Black Sea Basin. Previous studies of potential reference sites had

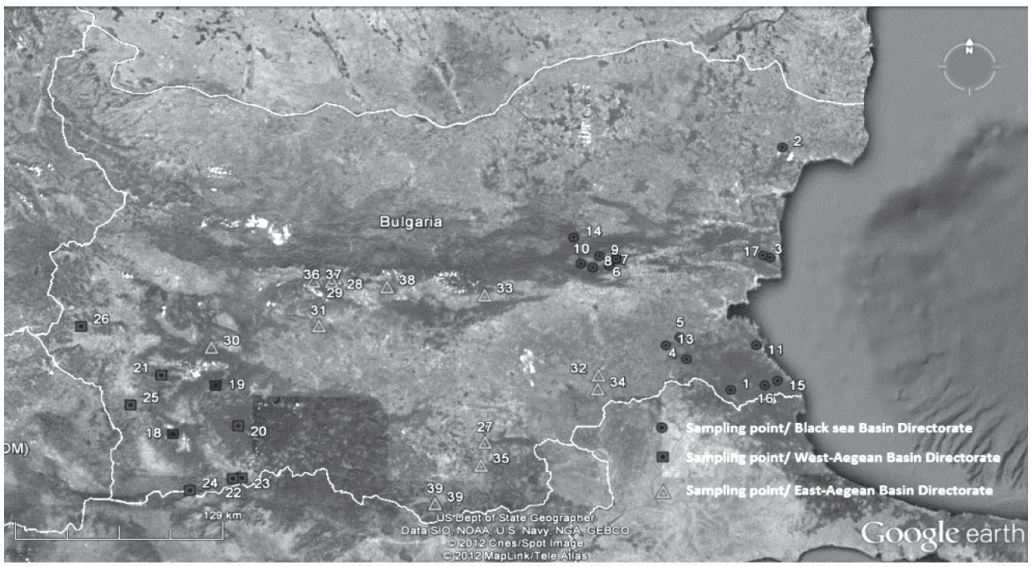

Fig. 1. Location of studied river site on the Bulgarian territory. The numbers of river sites correspond to those in Table 1.

Table 1. Ecological state assessment based on macrozoobenthos of the studied sites in the Black Sea catchment area

Name of river stations/Type/ (Number in the map)/Date of sampling	Biotic Index	RETI-PETI	Total Number of Taxa	Name of river stations / Type / (Number in the map) / Date of sampling	Biotic Index	RETI-PETI	Total Number of Taxa
Black Sea Basin Directorate							
Veleka - Aydere R10 (1) X.11	high	high	good	Medvenska - Medven R4 (9) VIII.12	high	moder-ate	high
Veleka - Aydere R10 (1) VIII.12	high	high	high	Medvenska - Medven R4 (9) VII.13	high	good	high
Veleka - Aydere R10 (1) VII.13	high	high	high	Neykovska - Neykovo R2 (10) IX.11	high	high	high
Batova - Batovo R11 (2) VII.11	high	high	high	Neykovska - Neykovo R2 (10) VIII.12	high	high	high
Batova - Batovo R11 (2) VIII.12	high	high	high	Neykovska - Neykovo R2 (10) VII.13	high	moder-ate	high
Batova - Batovo R11 (2) IX.13	high	good	high	Ropotamo - Velyov vir R11 (11) IX.11	high	good	high
Dvoinitsa - Popovich R11 (3) VIII.11	high	mod-erate	high	Ropotamo - Velyov vir R11 (11) X.12	good	very bad	high
Dvoinitsa - Popovich R11 (3) VIII.12	high	good	high	Ropotamo - Velyov vir R11 (11) VII.13	high	good	high
Dvoinitsa - Popovich R11 (3) IX.13	high	good	high	Sadovska - River estuary R4 (12) VIII.11	high	high	high
Fakiyska - Varovnik R11 (4) VIII.11	high	good	high	Sadovska - River estuary R4 (12) VIII.12	high	high	high
Fakiyska - Varovnik R11 (4) VIII.12	high	good	high	Sadovska - River estuary R4 (12) VII.13	high	high	high
Fakiyska - Varovnik R11 (4) IX.13	high	good	high	Sredetska - Valchanovo R11 (13) VIII.11	high	good	high
Golyamata River - Svetlina R11 (5) VIII.11	high	high	high	Sredetska - Valchanovo R11 (13) X.12	high	moder-ate	high
Golyamata River - Svetlina R11 (5) X.12	high	good	high	Sredetshka - Valchanovo R11 (13) IX.13	high	moder-ate	high
Golyamata River - Svetlina R11 (5) IX.13	high	mod-erate	high	Kamchiya (Ticha) - Bratan R2 (14) VIII.11	high	high	high
Kamchiya - Beronovo R2 (6) VIII.11	high	high	high	Kamchiya (Ticha) - Bratan R2 (14) VIII.12	high	high	high
Kamchiya - Beronovo R2 (6) VIII.12	high	high	high	Kamchiya (Ticha) - Bratan R2 (14) VII.13	high	high	high
Kamchiya - Beronovo R2 (6) VII.13	high	high	high	Veleka - Brodilovo R10 (15) X.11	high	good	high
Kamchiya - Dabovitsa R2 (7) X.11	high	high	high	Veleka - Brodilovo R10 (15) X.12	high	moder-ate	high
Kamchiya - Dabovitsa R2 (7) IX.12	high	good	high	Veleka - Brodilovo R10 (15) VII.13	high	good	high
Kamchiya - Dabovitsa R2 (7) VII.13	high	high	high	Veleka - Kosti R11 (16) VIII.11	high	good	high
Kamchiya - Ichera R2 (8) VIII.11	high	high	high	Veleka - Kosti R11 (16) X.12	high	moder-ate	high
Kamchiya - Ichera R2 (8) VIII.12	high	good	high	Veleka - Kosti R11 (16) VII.13	high	good	high
Kamchiya - Ichera R2 (8) VII.13	high	mod-erate	high	Velikovska - Dvoinitsa R11 (17) VIII.11	high	good	high
Medvenska - Medven R4 (9) IX.11	high	high	high	Velikovska - Dvoinitsa R11 (17) X.12	high	moder-ate	high
				Otmanli - before the drinking-water supply area R11) X.13	mod-erate	very bad	bad

Table 2. Ecological state assessment based on macrozoobenthos of the studied sites in the Aegean catchment area.

Name of river stations/Type/(Number in the map)/Date of sampling	Biotic Index	RETI-PETI	Total Number of Taxa	Name of river stations/Type/ (Number in the map)/Date of sampling	Biotic Index	RETI-PETI	Total Number of Taxa
West Aegean Basin Directorate				**East Aegean Basin Directorate**			
Banderitsa -Vihren R1 (18) X.11	high	high	high	Biserska - Dolno Botevo R14 (27) IX.11	high	high	high
Banderitsa -Vihren R1 (18) IX.12	high	high	high	Biserska - Leshnikovo-Nadezhden R14 (28) IX.11	high	good	high
Cherna Mesta - Cherna Mesta R3 (19) VIII.11	high	high	high	Damladere - Rozino R3 (29) IX.11	high	high	high
Cherna Mesta - Cherna Mesta R3 (19) IX.12	high	high	high	Ibar - Raduil R3 (30) IX.11	high	good	high
Dospatska - Selishte R3 (20) IX.11	high	good	high	Kalavashtica - Malo Krushevo R5 (31) IX.11	good	moderate	high
Dospatska - Selishte R3 (20) IX.12	high	moderate	high	Krumovitsha - Melnitsha R14 (32) IX.11	good	good	high
Mesta - Ablanitsa R5 (23) IX.11	high	good	high	Manastirska - Mina Mramor R3 (33) IX.11	high	high	high
Mesta - Ablanitsa R5 (23) IX.12	good	very bad	high	Melnishka - Melnitsha R14 (34) IX.11	high	high	high
Iliyna - Rilska R3 (21) IX.11	high	good	high	Popovska - River estuary R3 (35) IX.11	high	good	high
Iliyna - Rilska R3 (21) VIII.12	high	high	high	Stryama - Klisura R3 (36) IX.11	high	high	high
Matnitsa - Petrelik R13 (22) V.11	high	good	high	Stryama - Slatina R3 (37) IX.11	high	good	high
Matnitsa - Petrelik R13 (22) IX.12	high	bad	high	Varbitsa - Krilatitsa R3 (39) IX.11	moderate	good	high
Petrovska - karst spring R15 (24) X.11	good	high	bad	Tundzha - Panitsite R3 (38) IX.11	high	very bad	high
Petrovska - karst spring R15 (24) VIII.12	good	***	moderate				
Stara River - Jeleznitsa R14 (25) IX.11	high	good	high				
Stara River - Jeleznitsa R14 (25) VIII.12	high	good	high				
Struma-Razhdavitsa R5 (26) X.11	high	moderate	high				
Struma-Razhdavitsa R5 (26) VIII.12	high	good	high				

demonstrated the relevance of RETI/PETI trophic Index assessment of the ecological status of the running waters (Kerakova et al. 2013). Applicability of the RETI/PETI Trophic Index in this study registered lower values compared to those obtained with the other two descriptors. The higher sensitivity of the Trophic Index (Dahl et al. 2004, Ofenbock et al. 2004) towards different kind of impacts and lack of a type-specific evaluation scale based on RETI/PETI were likely reasons for assessing conditions as more unfavourable.

Functional feeding groups' distribution expressed through the total number of benthic taxa showed similar proportions in the studied river reference sites situated at Aegean and Black Sea catchments (Fig. 2).

The scrapers were dominants and characterised with the greatest taxonomic richness, followed by the groups of predators and shredders. In the taxonomic composition of the scrapers prevailed sensitive taxa such as *Ecdyonurus* sp. and *Rhithrogena* sp. (Ephemeroptera). The group of predators predominantly consisted of larvae of dragonflies (Odonata) and that of shredders included mostly *Ephemerella* sp. (Ephemeroptera), *Nemoura* sp. (Plecoptera) and larvae of the subfamily Drusinae (Trichoptera). Earlier studies also demonstrated that under reference conditions, the benthic community was formed mainly by indicator species, which were representative for unaffected (unpolluted) rivers (De Vaate & Pavluk 2004, Varadinova 2006) and lotic stretches were characterized by high and good ecological state (Kerakova 2015). The other three functional feeding groups (deposit feeders, collectors and filterers) were represented with smaller number of taxa. A similar trend was also demonstrated by the percentage share

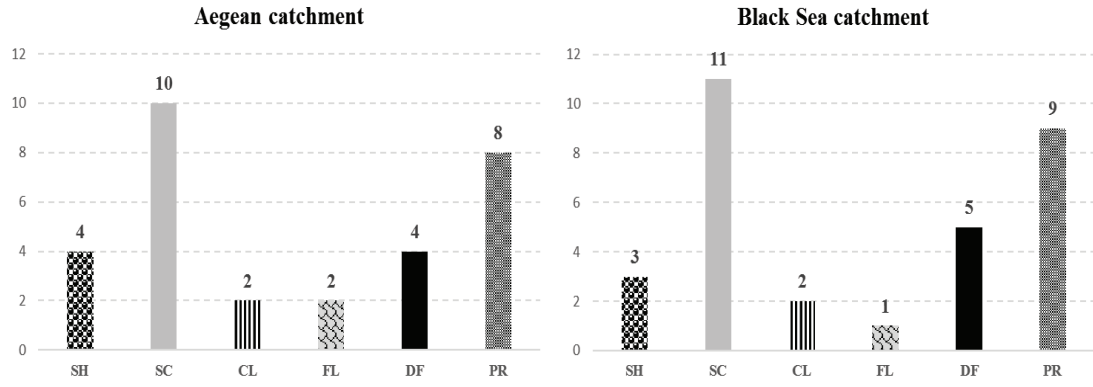

Fig. 2. Functional feeding groups distribution based on average number of taxa in the two catchments for the whole studied period.

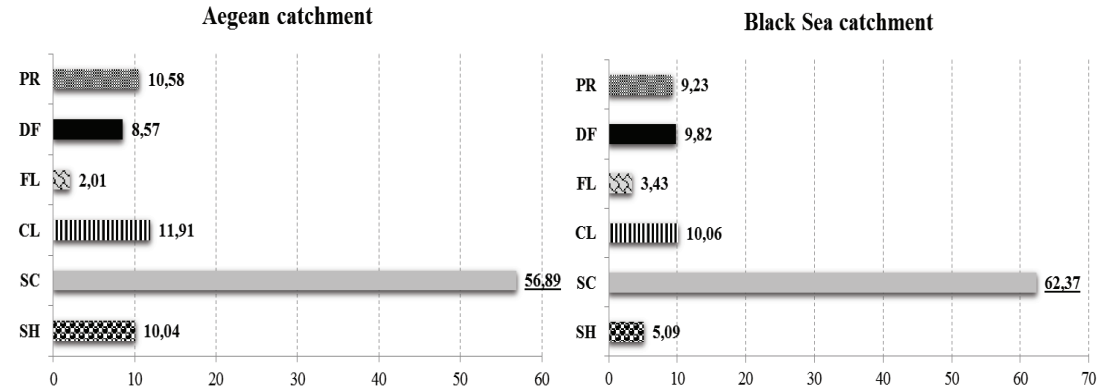

Fig. 3. Percentage share functional feeding groups distribution, based on total number of individuals in the two catchment area for the whole studied period.

of abundance of the functional feeding groups, i.e. the primary consumers (scrapers) dominated in the trophic structure (about 60%) (Fig. 3).

The predominance of the scrapers was mainly due to the significant numbers of *Gammarus* spp., which achieved high abundance in some reference sites at the studied rivers (Ticha River, Sadovska River, Petrovska River, Medvenska River, etc.). E.g., at the site Kamchia-Dabovitsa (2013), gammarids formed 76% of the benthic structure; at the Veleka-Aydere (2013) site, this value reached 92% (Kerakova 2015). *Gammarus* spp. were highly successful from ecological point of view due to their foraging plasticity, high reproductive capacity, migration ability and tendency to drift, which allowed them to invade and colonize ecosystems. Because their wide distribution, significance in food webs and sensitivity to a wide range of pollutants, they were important bioindicators for water quality assessment (Gerhardt et al. 2011).

The abundance of the representatives of *Baetis* spp. (Ephemeroptera), the species of the family Elmidae (Coleoptera) and the freshwater gastropods also contributed for the significant dominance of the group of scrapers. Characteristic feature of this functional feeding group was its permanent presence along the river continuum but with specific intra-grouping transformation of the species composition – gradual replacement of more sensitive by more tolerant species from springs to the river mouth. Similar transformation was also observed in the organic load gradient in the river ecosystem (Varadinova 2006, Kerakova 2015).

The remaining trophic groups (except filterers, which were the group with the lowest density) were characterised by a relatively uniform percentage distribution.

The group of the collectors formed the second largest trophic group in the composition of the trophic structure of the macrozoobenthos in the two river basins. The registration of the high percentage of the group of collectors is due to the dominance of *Hydropsyche* sp. (Trichoptera). The functional groups of deposit feeders and predators were

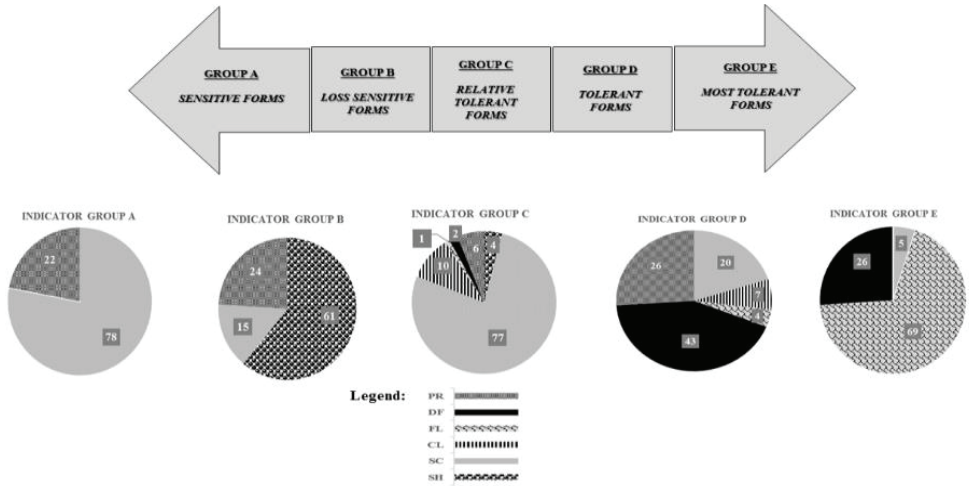

Fig. 4. Percentage distribution of functional feeding groups within the indicator groups determining values of the Biotic Index.

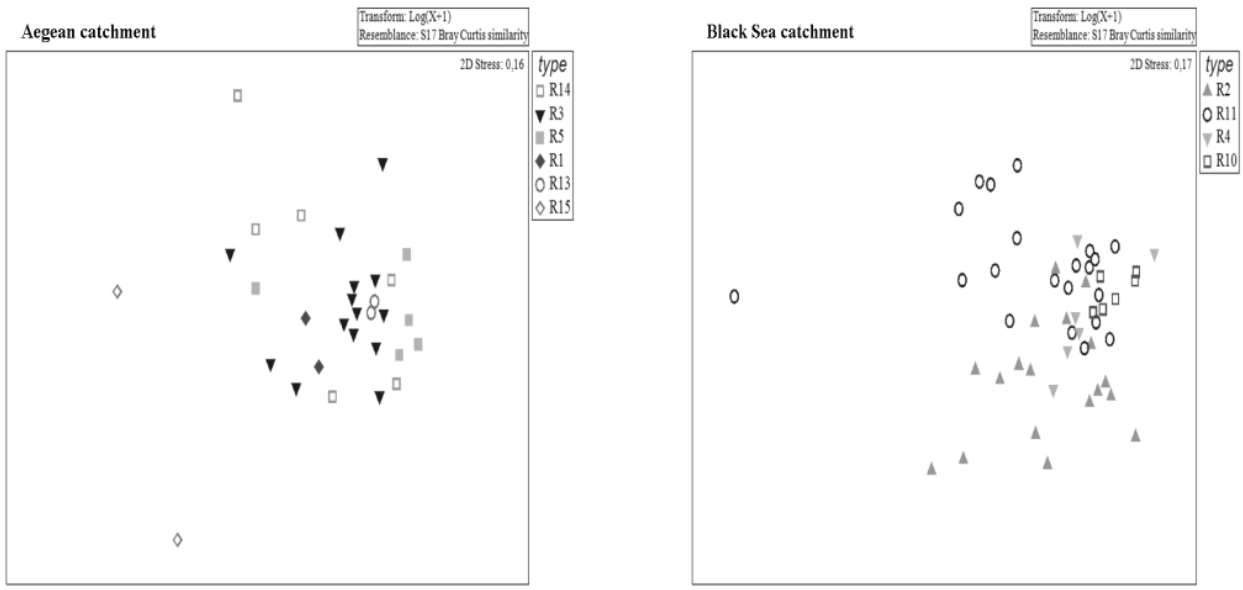

Fig. 5. MDS-plot of similarity between macrozoobenthos found in different river types in the two catchment areas for the whole studied period.

comparatively equally distributed in the reference sites. A slight predominance of predators in the rivers of the Aegean Basin was found. The group of the deposit feeders consisted mostly of chironomid larvae as well as less-represented oligochaetes. With the greatest density among the predators, larvae of dragonflies and stoneflies were present, being indicators for unpolluted river stretches.

The numbers of shredders were twice higher in the studied sites of the Aegean Basin compared to those in the Black Sea Basin. According to the principles of the River Continuum Concept (Vannote et al. 1980), this group was dominant in the upper river stretches as well as in unpolluted waters; a reduction in their abundance could be found as a result of anthropogenic influence (Liang & Ding 2004, Jiang et al. 2011). In our study, a significantly smaller presence of shredders in the trophic structure of macrozoobenthos in the reference sites was compensated by the group of scrapers represented mostly by taxa indicative for clean waters (Kerakova 2015).

The most weakly represented functional feeding group in the sites with reference conditions was that of filterers. This group consisted mostly of mussels (Bivalvia), blackfly larvae (family Simuliidae) and other water dipterans.

We performed comparison between the distribution of the functional feeding groups and the indicator groups used to define the Biotic Index.

Previous studies demonstrated that species belonging to shredders instead SH are defined as less sensitive (indicator group B) (Kerakova et al. 2013). In the present study, it was found that not only sensitive benthic representatives of shredders but also those of scrapers and predators predominated in the indicator groups A and B, which characterised favourable environmental conditions (Fig. 4). The taxa tolerant towards pollution and affiliated to feeding groups of scrapers, filterers and deposit feeders were found in the indicator group C.

Benthic taxa found at the studied reference sites, which belonged to different river types, were subjected to MDS–analysis (Fig. 5).

A close similarity between reference sites in the Aegean and Black Sea catchment areas was registered. The highest distinction for river type R15 was represented by two samples from the reference site at the Petrovska River. Given the specific characteristics of this river type, the macrozoobenthic communities had a different, incomplete trophic structure characterised by the absence of shredders, collectors and filterers. In addition, in 2011, besides the mentioned groups, the group of predators was also lacking in the benthos. The other river types in Aegean catchment area exhibited more compact composition and similarity (Fig. 5). However, type-specific distinctions were observed, especially for types R13 and R1 (represented by the Banderitsa River situated in the catchment area of Mesta River, which is located in the alpine zone above 1800 m altitude). The reference sites belonging to the mountain type (R3) also demonstrated greater similarity due to the typical bottom invertebrate fauna, which was formed in the conditions of the rocky substrate, river slopes and high-speed flow. The substrate type was one of the main environmental factors affecting the distribution and abundance o the zoobenthos (Oloviera & Nessimian 2010). This was also in agreement with the opinion of Chung et al. (2011) that the characters of the habitat had a primary role in the formation of the trophic structure of the macrozoobenthic communities.

Macrozoobenthos in the Aegean river type R14 exhibited the most heterogeneous distribution and highly specific composition. The most possible reason for the differences in their taxonomic composition was the partial or complete desiccation of the river bed followed by re-colonization and subsequent adaptation processes of the bottom communities. The establishment of more extreme conditions during the dry period and the local specific hydromorphological characteristics of the studied river sections affected the formation of species composition and trophic structure of the macrozoobenthos in them.

The closest resemblance between the benthic invertebrates among the studied river types in the Black Sea catchment area was found for the R10, which was presented by two points of the Veleka River (Brodilovo and Kosti) (Fig. 5). Our results showed that the greatest similarity in the composition and the percentage shares of the functional feeding groups could be observed between these two sites. No significant differences between reference sites belonging to two hydro-morphologically similar river types (R2 and R4) and type R11 were detected.

Discussion

Under reference conditions, the macrozoobenthic communities form a specific trophic structure with a defined ratio between the functional feeding groups. Regardless of the river type, the group of scrapers is dominant, both as species diversity and abundance. In addition, some of the studied sites are located in the upper river sections, which are characterized by similar hydro-morphological and physico-chemical environmental parameters.

The comparison analyses of the functional feeding groups and the indicator groups of the Biotic Index confirm the good bioindicative capability of the trophic structure of the river macrozoobenthos.

It can be summed up that the species composition and the trophic structure of macrozoobenthic communities show greater similarity between studied reference water bodies of the Aegean catchment area compared to those in the Black Sea catchment area. Within a certain river type, close resemblance in bottom invertebrates from the same site during different years and between reference sites located in the same river system was observed.

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