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Comparative Analysis of the Structure of Benthic Macroinvertebrate Communities in Maritsa River (Bulgaria) and Han River (South Korea)

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Abstract: The aim of this paper is to compare the taxonomic composition and species diversity of the macrozoobenthos in Maritsa River (Bulgaria) and Han River (South Korea). Samples were collected at 15 selected sites in each river, including some of their main tributaries in 2020 and 2021. The number of the taxa recorded in Maritsa River was more than twice as great as in Han River: 192 taxa belonging to 19 systematic groups compared to 88 taxa belonging to 18 groups respectively. The order Ephemeroptera had the highest species richness: 31 taxa in the Bulgarian rivers and 26 taxa in the South Korean ones. The macrozoobenthic communities responded and adapted to the various conditions and impacts in the water environment with changes in the species composition and structure. The analysis of the similarity in the taxonomic composition showed low resemblance between all study sites but displayed distinct separations between the rivers and the two years. In general, the species structure of the macrozoobenthic communities in Maritsa River and its studied tributaries was better than in Han River. In both years, high species diversity was recorded at the reference sites in the rivers, characterized by conditions closely resembling natural environments. The species richness and the evenness of macrozoobenthos were very low at sites downstream subjected to considerable anthropogenic pressure. Some of the communities in Han River were almost destroyed completely.

Keywords: lotic ecosystems; community ecology; biodiversity indices

1. Introduction

Most lotic ecosystems in the world are subjected to various anthropogenic impacts, which together with the global warming processes disrupt the integrity of lotic ecosystems and adversely affect macrozoobenthic communities and their habitats [8, 25]. As key communities in rivers, through which the main flow of matter and energy passes, they have proven their resilience and ability to quickly recover in harsh environments [8, 11, 31]. The presence and abundance of macroinvertebrates are determined by their location and their ability to tolerate the specific environmental conditions in which they live [32]. The species structure of the benthic communities is used as an indicator for their status and for the aquatic ecosystem health [7, 11, 31].

Several studies on benthic macrofauna in Maritsa River and some of its tributaries have been published to date [5, 24, 33-35, 37]. The taxonomic compositions and dominant structures of the macrozoobenthos in Maritsa River and estuarine zones of its main tributaries (Chepelarska, Sazliyka, Stryama, and Topolnitsa) recorded in 2020 were published by Park et al. [20]. Varadinova et al. [36] analysed the macroinvertebrate communities at the study sites in relation to various environmental factors and determined the ecological status of the studied aquatic ecosystems through the macrozoobenthos in 2021 and 2022.

Research on benthic macroinvertebrates in five major River Watershed Regions (RWRs: Han, Geum, Nakdong, Yeongsan, and Seomgin) has been published [2, 6, 8, 13, 17]. The taxonomic composition and species diversity of benthic macroinvertebrate communities within the RWRs from 2010 to 2020 were identified, and their similarities as well as correlations with physicochemical variables were analysed [14, 15]. Kwak et al. [8] identified distributional characteristics based on the frequency of benthic macroinvertebrate taxa in the Han RWR (the South, North, and mainstream of Han River, and Anseong stream) during the period from 2009 to 2016, and analysed their relationship with altitude, current velocity, and substrate composition.

The aim of this study is to compare the composition and diversity of the macrozoobenthos in two selected rivers with similar latitude and hydromorphological features but located on different continents with distinct geographical characteristics: Maritsa River in Bulgaria and Han River in South Korea, considering different ecological situations and various anthropogenic impacts.

2. Material and Methods

Maritsa River, located in the East Aegean Sea River Basin District in Bulgaria and Han River, situated in the Han RWR in South Korea, were selected for this study. A total of 15 study sites from different sections of the main rivers and their tributary systems were sampled to ensure the representativeness [20]. These were both unaffected reference sites and sites affected by diverse human activities. Some characteristics of the sampling sites were published by Park et al. [19, 20]. Two sampling sites were located downstream in 2021 compared to their locations in 2020: site 13 in Maritsa River (4.9 km) and site 3 in Han River (17.4 km).

Benthic invertebrates from the different sites in Maritsa River were collected according to EU standards and national water legislation (standards BDS EN ISO 10870:2012 and EN 16150:2012) from 11 August to 17 September 2020 and on 23 and 24 July 2021. The macrozoobenthos surveys of Han River were conducted twice a year (spring and autumn) as part of the Water Environment Monitoring Network system, following the Guideline for Aquatic Ecosystem Status survey and health assessment method (2019-52) [9]. The data is publicly available on the Water Environment Information System. Data from September and October (autumn data) in both 2020 and 2021 were used in this study.

The similarity in the taxonomic composition of the macrozoobenthos in the two rivers, was presented by the *Sørensen* similarity index [29]. Cluster analysis using the Complete linkage method and Bray-Curtis similarity in the Statistical Software Package Primer 6 was also conducted. Margalef's index of species richness (d) [12], Simpson's index of dominance (c) [28], Pielou's index of evenness (e) [21] and Shannon-Weaver diversity index (H) [27] were used for the species diversity analysis.

3. Results

3.1. Taxonomic Composition and Number of Macrozoobenthic Taxa

The total number of taxa recorded in Maritsa River in 2020 and 2021 was more than twice as high as in Han River: 192 taxa belonging to 19 systematic groups with different taxonomic level compared to 88 taxa belonging to 18 groups respectively (Figure 1). Taxa of class Arachnida and order Plecoptera were found only in Maritsa River while a representative of class Polychaeta was recorded only in Han River. Only 13 cosmopolitan taxa which belong to the groups of classes Oligochaeta, Hirudinea, Bivalvia and Gastropoda, and orders Amphipoda, Coleoptera, Hemiptera, Diptera and Ephemeroptera were common for both rivers. There was a decrease (1.5 times) in the total number of taxa found in Maritsa River in 2021 compared to the previous year: from 165 [20] to 110, while the number of taxa in Han River was almost the same: 62 in 2020 and 60 in 2021. The 110 taxa of benthic macroinvertebrates recorded in Maritsa River in 2021 belonged to 68 genera and 49 families and were representatives of 17 systematic benthic groups. The similarity in the taxonomic composition of macrozoobenthos in the two years was about 60%. The species found at all sampling sites in Han River in 2020 belonged to 47 genera, 37 families and 16 benthic groups. The situation was similar in 2021, all taxa recorded were representatives of 46 genera, 35 families, and 16 groups. However, there was a great change in the composition compared to the previous year. The value of the *Sørensen* similarity index was 55%.

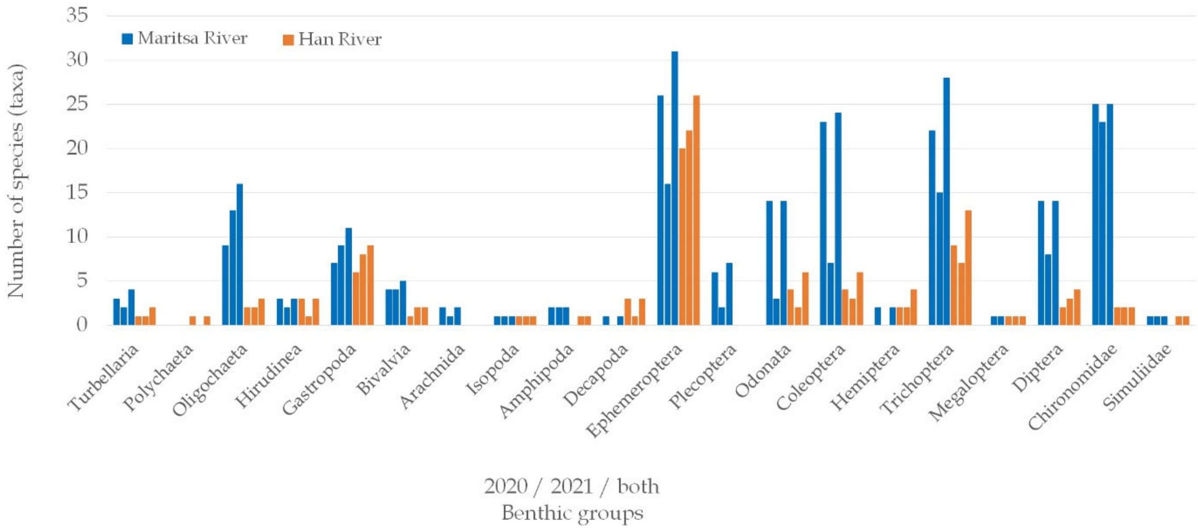

Figure 1. Number of taxa belonging to different benthic groups found at all sampling sites in Maritsa and Han rivers in 2020 and 2021, and the total number of taxa for both years.

In total for both years, the order Ephemeroptera had the highest species richness in the two rivers: 31 taxa (16.15% of all taxa) in Maritsa River and 26 taxa (29.55%) in Han River (Figure 1). The order Trichoptera followed in both rivers with 28 taxa (14.58%) found in the Bulgarian rivers and 13 taxa (14.77%) in the South Korean ones. Other groups that were present with more species in Maritsa River were family Chironomidae (13.02%), order Coleoptera (12.50%) and class Oligochaeta (8.33%), and in Han River: class Gastropoda (10.23%). The three benthic groups with the highest richness in Maritsa River remained the same in 2021 compared to 2020 [20], but family Chironomidae (23 taxa, 20.91%) was at first place followed by the orders Ephemeroptera (16 taxa, 14.55%) and Trichoptera (15 taxa, 13.64%) (Figure 1). The groups presented with the largest number of taxa in Han River were the same in 2020 and 2021: the orders Ephemeroptera (20 taxa, 32.26% in 2020 and 22 taxa, 36.67% in 2021) and Trichoptera (9 taxa, 14.52% in 2020 and 7 taxa, 14.77% in 2021) and class Gastropoda (6 taxa, 9.68% in 2020 and 8 taxa, 13.33% in 2021). Some benthic groups were represented by only one taxon in the two rivers: orders Isopoda and Megaloptera and family Simuliidae.

Based on the total number of species found at each sampling site in Maritsa River in both years, the highest species richness was observed at site 3 (41 taxa), while the lowest one was at site 14 (21 taxa) (Figure 2). The total number of taxa was more than 35 at six sites, between 25 and 35 at five sites, and between 25 and 21 at only four sites. A decrease in the number of taxa was registered at each site in Maritsa River in 2021 compared to 2020. Large numbers of taxa were found at sites 11, 3, 13, 12 in 2020 (35, 34, 31, and 30, respectively). However, the number of taxa at most of these sites (except at site 3, but also at sites 6, 4, 10, 5, and 9) decreased by more than a half in 2021, particularly at site 13, which was the least diverse site then (6 taxa) overall, which belonged to three groups: classes Oligochaeta (4 taxa) and Bivalvia, and order Amphipoda (1 species each). The least change was observed at site 15 (from 17 in 2020 to 15 in 2021).

According to the total number of species found at each sampling site in Han River in both years, the highest species richness was registered at site 5 (28 taxa) and the lowest one at site 11 (3 taxa only) (Figure 2). More than 25 taxa were recorded at five sites: 5, 2, 1, 3, and 7 with 28, 27, 26, 24, and 22 taxa respectively. The total number of taxa was between 15 and 25 at six sites (4, 6, 10, 12, 9 and 8), and less than 15 at four sites (13, 15, 14, and 11). The number of taxa at the study sites varied from 21 taxa at site 5 to one species belonging to order Decapoda at sites 11 (*Macrobrachium nipponense*) and 14 (*Palaemon paucidens*) in 2020, and from 21 taxa at site 2 to 2 species at site 11 in 2021. The species richness changed differently in Han River in 2021 in comparison with 2020. An increase was recorded at seven sites: 2, 1, 12, 14, 3, 8 and 11, particularly at site 2 where the number of species was with 9 more in 2021. A decrease in species richness was registered at other seven sites in 2021: 4, 5, 7, 6, 10,

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9 and 15. In both years, the number of taxa was the same (6) only at site 13, but some of the species belonged to different groups (class Oligochaeta, order Isopoda and family Chironomidae in both years, order Ephemeroptera only in 2020, and orders Trichoptera and Diptera only in 2021).

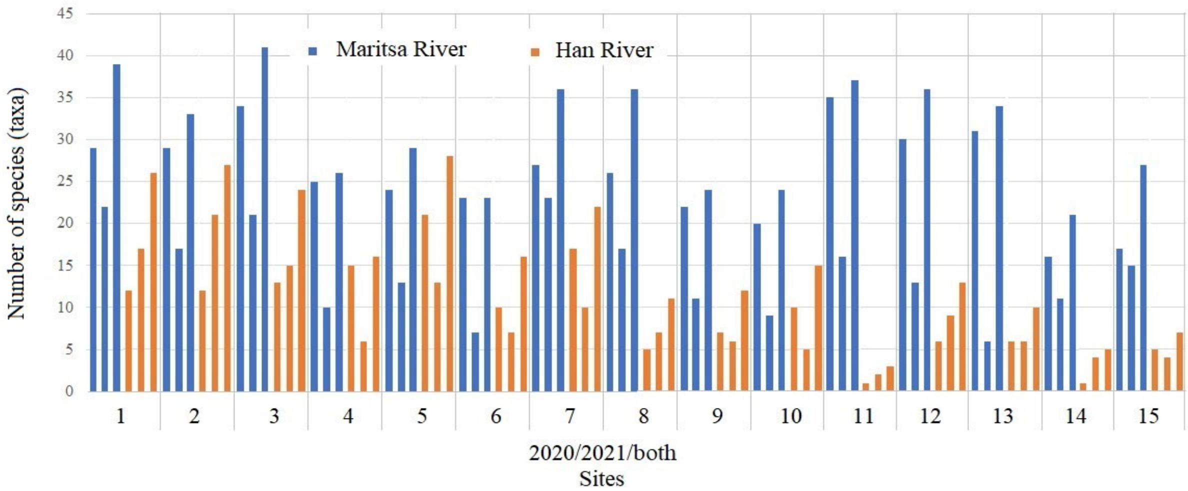

Figure 2. The number of species (taxa) recorded at each sampling site in Maritsa and Han rivers in 2020 and 2021, and the total number of taxa for both years.

3.2. Similarity Analysis

The similarity analysis of the taxonomic composition showed a distinct separation between the study sites in Maritsa River and Han River (Figure 3). Especially, a more pronounced division between 2020 and 2021 was observed at most of the sites in Maritsa River. Sites 9 and 10 in 2020 in Maritsa River were determined to be the most similar (over 60%). Site 15 between the two years, and sites 13 in 2020 and 14 in 2021 in Han River, showed the second highest similarity at approximately 60%. On the other hand, sites 11 and 14 in 2020 in Han River displayed the least similarity with any other site (0%).

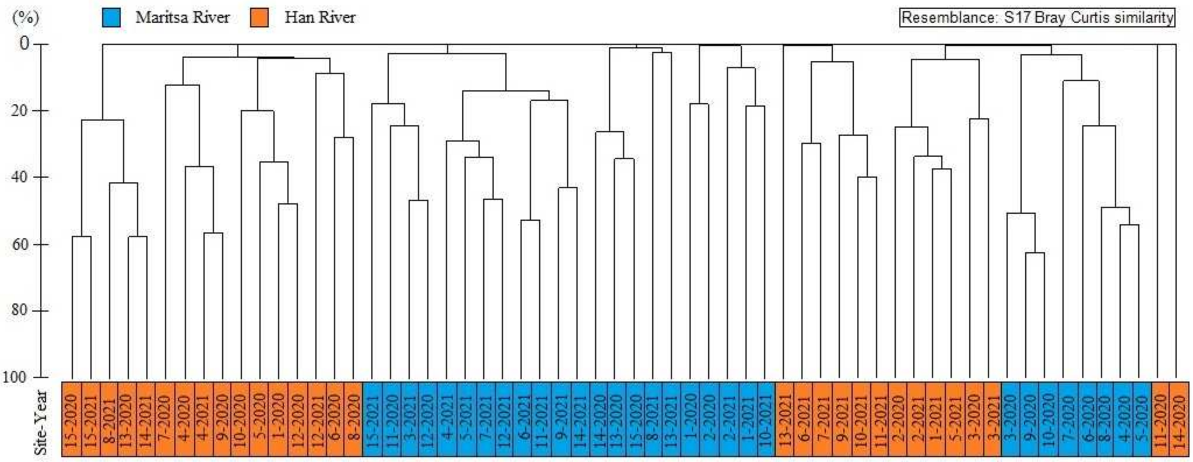

Figure 3. Similarity in the taxonomic composition of the macrozoobenthos in Maritsa and Han rivers in 2020 and 2021.

3.3. Abundance of the Macrozoobenthos

The total relative abundance of the macrozoobenthos in Maritsa River in 2021 compared to the previous year decreased more than 3,2 times (from 7,627 to 2,356 individuals), while in Han River, it increased more than twice (from 2,204 to 4,723 individuals). In Maritsa River, in 2020, the order

Ephemeroptera dominated in abundance with 3,174 individuals (41.62%), followed by the order Trichoptera (1,420 individuals, 18.62%) and family Chironomidae (667 individuals, 8.75%) (Figure 4). However, in 2021, the family Chironomidae (801 individuals, 34%) had the highest abundance, followed by the classes Oligochaeta (596 individuals, 25.30%) and Gastropoda (526 individuals, 22.33%). In Han River, the order Ephemeroptera dominated in abundance in both years with 987 and 1,514 individuals (44.78% and 32.06%) respectively. The family Chironomidae (491 individuals, 22.28%) followed in 2020, and the order Isopoda (1,466 individuals, 31.04%) and family Chironomidae (668 individuals, 14.14%) in 2021. The abundance of all other groups was less than 10% in the two rivers both in 2020 and 2021. The least abundant groups in Maritsa River were the orders Decapoda (only 7 individuals of *Potamon ibericum*, 0.09%) in 2020 and Megaloptera (a single individual of *Sialis lutaria*, 0.04%) in 2021. In Han River, the orders Isopoda (5 individuals of *Asellus* sp., 0.23%) in 2020 and Odonata (*Sieboldius albardae* and *Macromia manchurica* with 2 and 4 individuals respectively) in 2021 were the least abundant benthic groups.

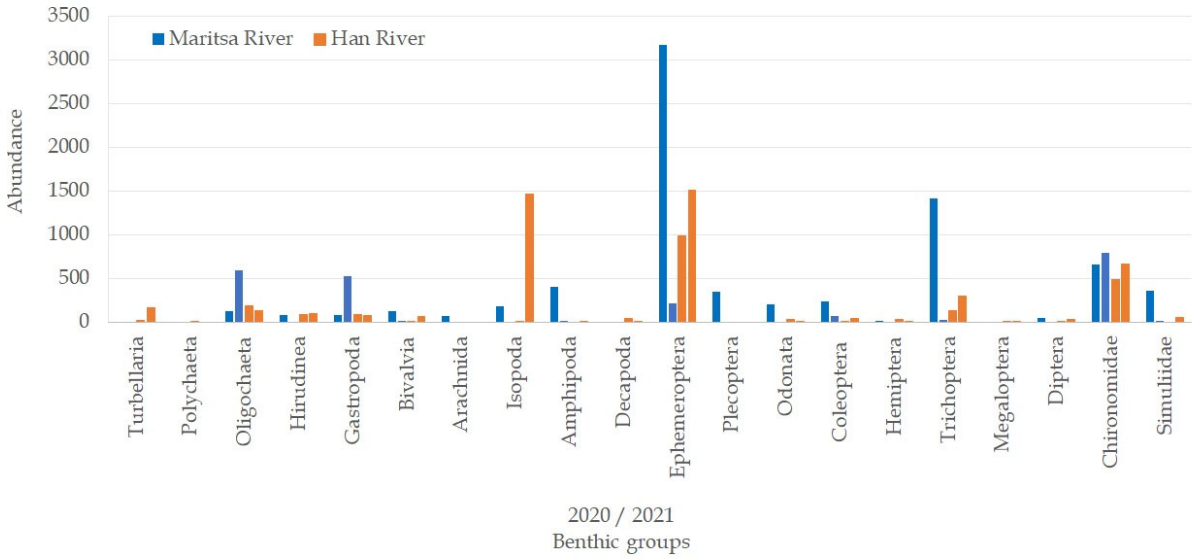

Figure 4. Total number of individuals belonging to different benthic groups found at all sampling sites in Maritsa and Han rivers in 2020 and 2021.

The highest relative abundance of macrozoobenthos in Maritsa River was recorded at sites 3 and 6 (1,131 and 1,088 individuals respectively) in 2020, and the lowest number of individuals was registered at sites 9 and 10 (34 individuals at each) in 2021 (Figure 5). The total relative abundance decreased at thirteen sites, at most of them considerably in 2021. An increase was recorded only at sites 8 (from 479 to 564 individuals) and 13 (from 266 to 516 individuals). A very low abundance was recorded at site 14 in both years: 100 individuals in 2020 (the lowest one in this year) and 45 individuals in 2021. In Han River, site 13 in 2021 had the highest abundance with 1,621 individuals, considerably higher than the others. In 2020, the highest number of individuals was recorded at site 5 (409). The lowest abundance was registered at sites 11 and 14 (4 Individuals at each) in 2020, and at site 7 (24 individuals) in 2021.

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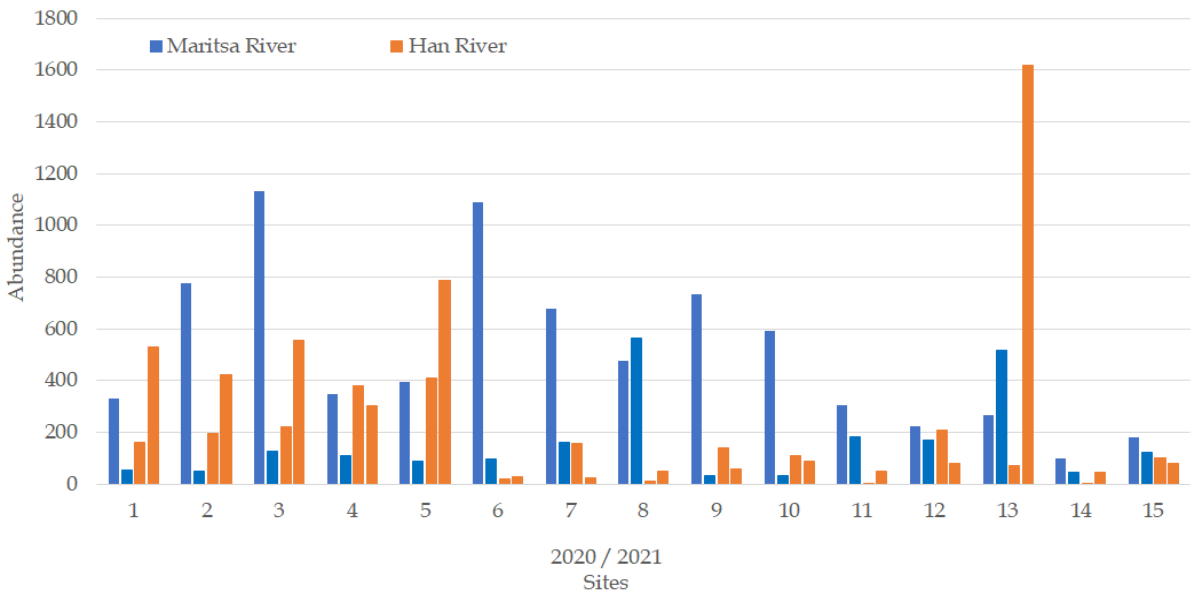

Figure 5. Total number of individuals of all species recorded at each sampling site in Maritsa and Han rivers in 2020 and 2021.

3.4. Species Diversity

The values of the Margalef's index of species richness for the macrozoobenthic communities in Maritsa River were higher at almost all sampling sites in 2020 than in 2021 (Figure 6). They varied from d = 5.94 (site 11) to d = 2.98 (site 10) in 2020, and from d = 5.29 (site 1) to d = 0.80 (site 13) in 2021. High species richness was recorded also at site 13 (d = 5.37), site 12 (d = 5.36) and sites 1 and 3 in 2020. According to the Margalef's index, the species richness of macrozoobenthos in Han River was lower. In 2020, the values ranged between d = 3.33 at site 5 and d = 0 at sites 11 and 14 where only one species was found. In 2021, the index varied from d = 3.31 (site 2) to d = 0.26 (site 11). The higher values of Margalef's index of species richness correspond to the larger number of species at different sites. Vice versa, low values were determined for sites with low number of species.

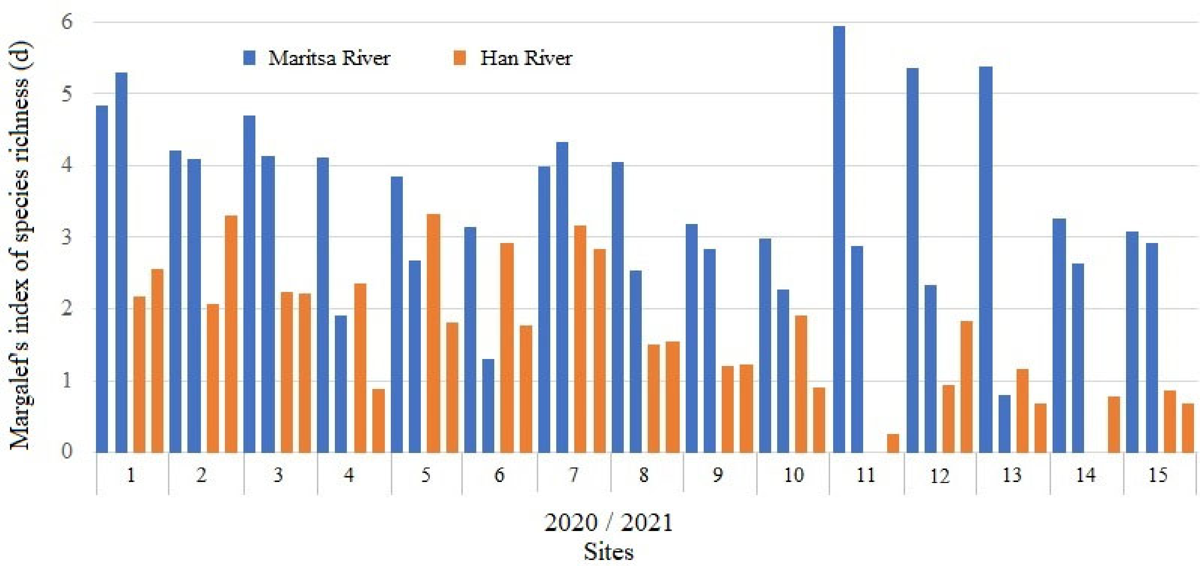

Figure 6. Values of the Margalef's index of species richness (d) at each sampling site in Maritsa and Han rivers in 2020 and 2021.

The values of the Simpson's index of dominance (c) were low and showed relatively little variation between the two years at the most sampling sites in both rivers (Figure 7). In 2020, the highest dominance in Maritsa River was recorded at site 2 (c = 0.25) and two cases of complete dominance (c = 1) were observed in Han River (sites 11 and 14) in 2020. In 2021, the index had very high values at sites 8 (c = 0.82) and 6 (c = 0.80) in Maritsa River and at sites 13 (c = 0.81) and 11 (c = 0.73) in Han River. The lowest dominance was recorded at site 11 (c = 0.08) in 2020 and site 1 (c = 0.07) in 2021 in Maritsa River and at sites 5 and 10 (c = 0.12) in 2020 and site 2 (c = 0.08) in 2021 in Han River. In general, the index of dominance had lower values for the benthic communities in Maritsa River than in Han River.

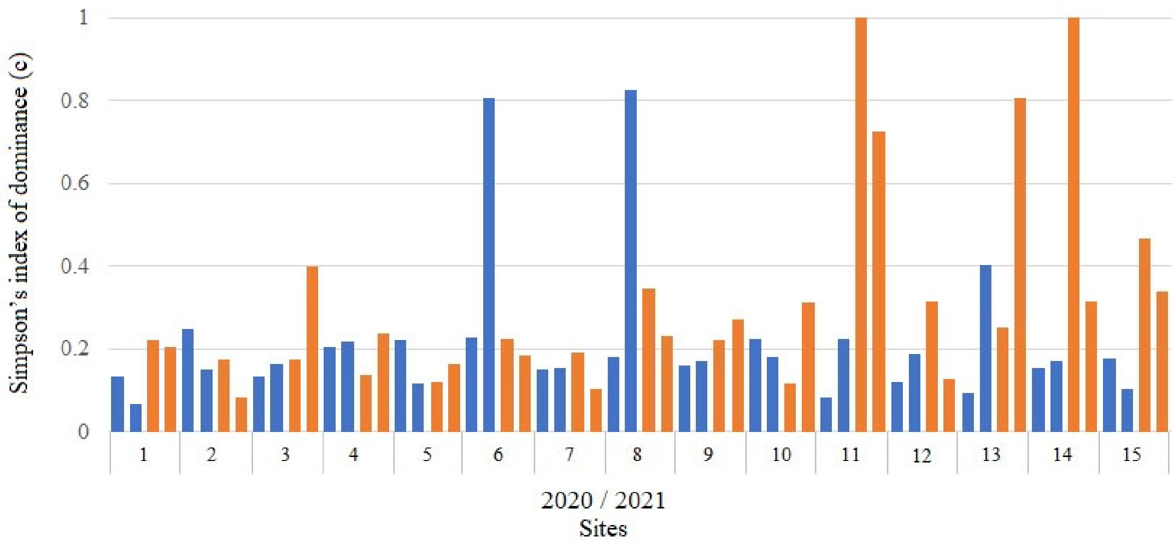

Figure 7. Values of the Simpson's index of dominance (c) at each sampling site in Maritsa and Han rivers in 2020 and 2021.

The values of the Pielou's index of evenness (e) were relatively high for the majority of sites in both rivers (Figure 8). In Maritsa River, the index ranged from e = 0.52 (site 2) to e = 0.80 (sites 11 and 14) in 2020 and the values were even higher at most of the sites in 2021 with the highest value registered at site 1 (e = 0.93). Very low levels of evenness were recorded only at site 8 (e = 0.19) and site 6 (e = 0.26) where high levels of dominance were observed in 2021. In Han River, the evenness was low at three sites: 11 and 14 (e = 0) in 2020, and site 13 (e = 0.25) in 2021.

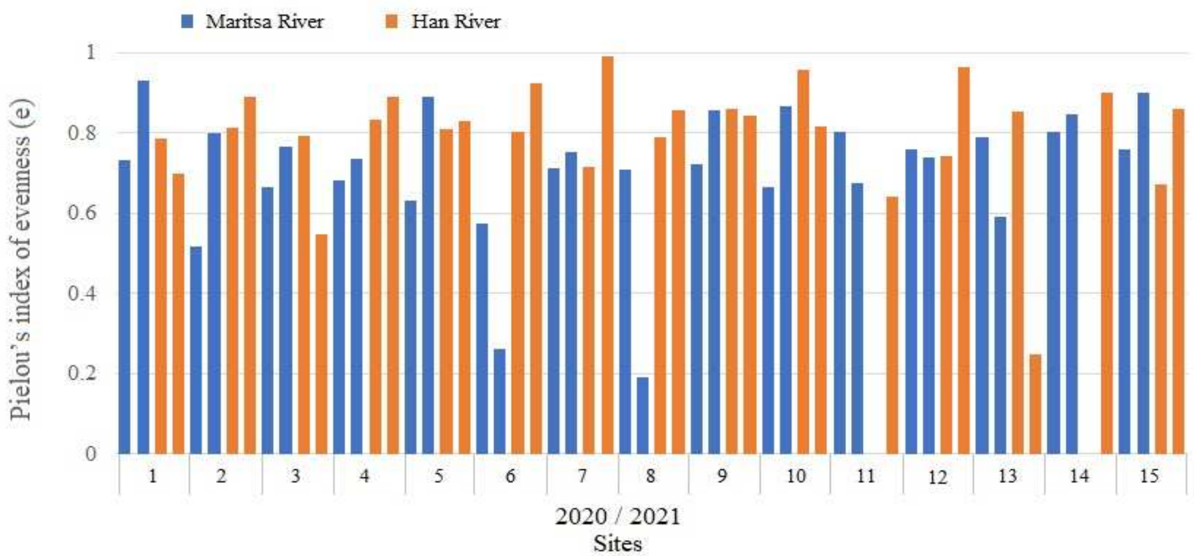

Figure 8. Values of the Pielou's index of evenness (e) at each sampling site in Maritsa and Han rivers in 2020 and 2021.

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According to the Shannon-Weaver index (H), the highest diversity in Maritsa River was recorded at sites 1 (H = 2.87) and 15 in 2021 and at sites 11 (H = 2.85), 13 (H = 2.71), 12 (H = 2.59) and 1 in 2020 (Figure 9). Species diversity was low at sites 6 (H = 0.51) and 8 in 2021 and 2 (H = 1.74) in 2020. In Han River, H values ranged from 0 (sites 11 and 14) to 2.46 (site 5) in 2020, and from 0.44 (site 13) to 2.71 (site 2).

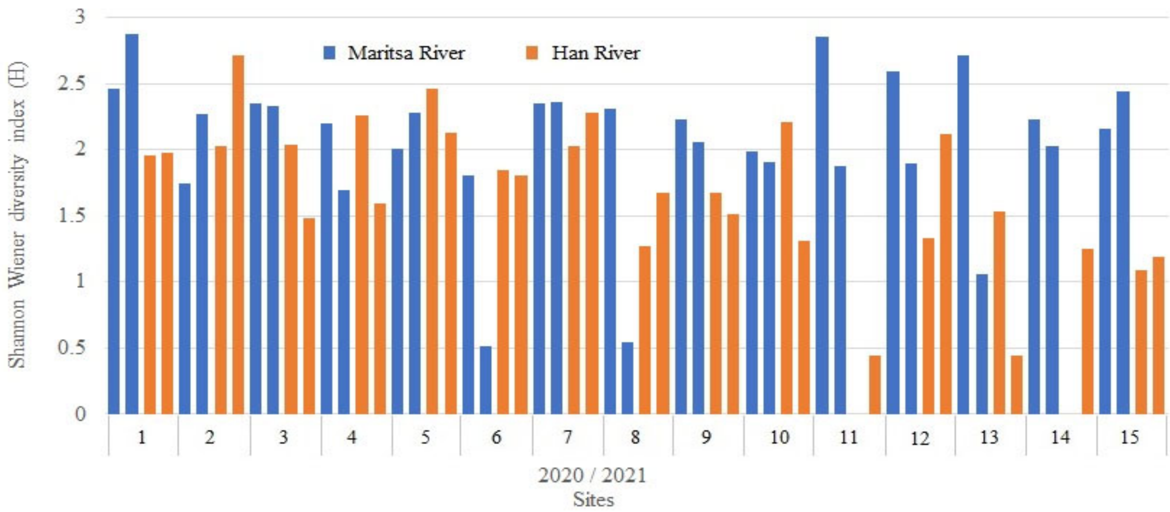

Figure 9. Values of the Shannon-Weaver diversity index (H) at each sampling site in Maritsa and Han rivers in 2020 and 2021.

In general, the species diversity indices showed greater values of d, e and H, and lower values of c at the study sites in Maritsa River than in Han River. Strong dominance (high values of d) and correspondingly less evenness (low values of e) in the macrozoobenthic communities in the two rivers were observed only at some sites. Overall, high species diversity in both years was recorded at site 1 in Maritsa River and site 2 in Han River. The sites with the lowest benthic fauna diversity recorded were 6 and 8 in Maritsa River as well as 11 and 14 in Han River.

4. Discussion

The numbers of identified taxa have decreased over the last several decades in both rivers. Even in the relatively short period of this study, a considerable reduction in species richness was observed in Maritsa River and a very slight decrease in Han River. A tendency of reducing the number of species recorded in Maritsa River have been observed for the last 65 years: from 305 species in 1955 [21, 22] to 284 in 1966 [23] and 229 in 1976-1977 [35]. In 2021, the species richness (110 taxa) reduced by almost a third when compared to 1955. Even if we compare the total number of taxa recorded in Maritsa River in both 2020 and 2021 (192) the reduction is more than 1,5 times. This trend has been related to the deteriorating conditions of the aquatic environment, particularly to the increased pollution of the river over the years [22, 23, 33-35], but some hydromorphological changes as well as the global warming can also contribute to that. In a study of Han River, conducted at similar locations, 120 species were recorded in 1994 [1], but the number has been reduced twice for the last 30 years. Between 1986 and 2002, the number of taxa in the lower stretches of the Han RWR increased from 68 to 114 species, attributed to the Ecological Stream Restoration Project initiated in 1987 [2, 19]. However, despite such efforts, the overall reduction in species richness couldn't be avoided, due to the rapidly expanding urbanization and increasing population.

In this study, the most diverse and dominant groups are Ephemeroptera and Trichoptera, in the composition of which there are both indicative of unaffected conditions species and species, which are tolerant to adverse influence (Figure 1). In Bulgarian rivers, Diptera, Ephemeroptera, Oligochaeta, Plecoptera and Trichoptera have been commonly found [3, 11, 18, 26]. However, in Maritsa River, the richness of the order Ephemeroptera, historically the most dominant group, was reduced considerably, from 51 species in 1955-1966 [22, 23] to 16 species in 2021. In the main RWRs of South Korea, the phylum Arthropoda accounted for over 80% of benthic macroinvertebrates between 2009 and 2016: family Chironomidae had the largest number of taxa (20.8%), followed by the families Hydropsychidae (17.1%), Baetidae (12.6%) and Tubificidae (10.3%) [8, 17]. The Han RWR exhibited the highest number of species and abundance among the main RWRs, with Chironomidae accounting for 18.6% (26 taxa), Hydropsychidae for 18.2% (25 taxa), and Baetidae for 14.8% (20 taxa). From 1986 to 2002, the most dominant groups in the Han RWR were Ephemeroptera and Trichoptera upstream, and Mollusca and Annelida downstream [2]. In the recent five years, Chironomidae (31.95%), Ephemeroptera (30.12%), and Trichoptera (11.66%) were the most abundant and dominant groups in the Han RWR [17]. In line with previous studies, the absence of Plecoptera species, known for their high sensitivity to pollution, is likely attributed to the anthropogenic impacts on the lotic ecosystems of Han River [1, 2].

The low levels of similarity in the taxonomic composition of macrozoobenthos between the years and rivers (Figure 3) might be due to variations in the hydrological characteristics recorded in the two years, leading to different water environmental conditions. It is notable that the reference sites 1 and 2 in both Maritsa and Han rivers formed independent but distinct clusters for the two lotic ecosystems. The reference sites, characterized by conditions closely resembling natural environments, exhibited among the highest species diversity in the rivers is the cause of the distinct separation.

Different benthic groups had the greatest species richness and abundance in Maritsa River in both years (Figure 1 & 4). That fact together with the substantial decrease in the total number of taxa and the total abundance of macrozoobenthos in 2021 testified to a considerable change in the water environmental conditions in Maritsa River compared to 2020. The species richness and abundance of macrozoobenthic communities decreased at all sampling sites except for sites 8 and 13 where the reduced number of taxa, especially at site 13 (only 6 tolerant species remained) increased considerably their abundance. That resulted in strong dominance of one freshwater snail (class Gastropoda.) at site 8 and of two taxa of aquatic worms (class Oligochaeta) at site 13, and very low species diversity compared to the other sites. Sites 8 and 13 were located at the mouths of Vacha and Sazliyka rivers tributaries of Maritsa River [19, 20, 36]. Their upstream stretches were characterized with good ecological status, however, downstream, they accumulated various anthropogenic pollutants, including toxins and domestic [38-39]. Despite self-purification processes, the lower stretches of the rivers remained polluted, especially when the river flows were reduced. Very strong dominance (Figure 7) and very low species diversity were well exhibited also at site 6 in 2021 (Figure 9).

The causes of the changes in the macrozoobenthic communities are difficult to precisely define due to the multiple factors and their correlations [7]. Two main reasons could explain the differences between the two years. Firstly, the values of the most physicochemical parameters of the water environment were changed in 2021 [36] and the macrozoobenthic communities responded to them with changes in the taxonomic composition and abundance. The indicative response of pollution-sensitive macrozoobenthic taxa has also been proven in other studies of Bulgarian rivers [4, 30, 31]. Secondly, there was a difference in the sampling periods with a shorter sampling duration of two days in 2021 compared to a month-prolonged sampling in 2020. Macrozoobenthic communities change in dominance through the year by their specific life cycles and environmental conditions [18]. The sampling period in 2021 might be before the blooming of certain macrozoobenthic species.

Although the number of taxa in Han River in 2020 and 2021 was almost the same, and the order Ephemeroptera dominated in terms of species richness and abundance in both years, the conditions in the water environment were not stable. This was confirmed by the greatly changed taxonomic composition of the macrozoobenthos in 2021. The total abundance increased in that year, but mainly upstream (2-3 times) and at sites 13, 11 and 14 (22.5, 12.3 and 11.5 times, respectively). The physicochemical and biological parameters remained unchanged upstream (at sites 1 to 3). Downstream (at sites 12 to 15), the status based on physicochemical parameters got worse by one class, but the one assessed on macrozoobenthos got better at sites 11 to 13 and 15, and only had worsened at site 14 [17]. The number of taxa as well as the abundance of the macrozoobenthic communities were very low at all sites from 6 to 15 in both years (except for the abundance at site 13 in 2021). Firstly, these stretches are characterized by relatively uniform hydro-morphological features, artificial structural elements such as concrete blocks and impermeable pavement along the riverbanks and riverbed. These elements isolate the river ecosystem from its surroundings, thereby creating an environment unsuitable to many benthic organisms [10, 17]. Secondly, the downstream region is stagnant due to a slow and deep flow rate, which consequently limits the available habitat for macrozoobenthos [16]. Thirdly, the inflow of pollutants from the central metropolitan area, particularly affecting sites 11 to 15, contributes to the dominance of contamination indicator taxa such as Chironomidae sp. and *Limnodrilus gotoi* [10, 16]. Historically, the ecological status downstream has consistently been 'poor' or 'very poor' [17]. The small number of taxa, represented in limited quantities, had led to low species diversity and relatively close values of dominance and evenness as observed at sites 11 and 3 in 2021. In fact, some of the communities were almost destroyed completely.

5. Conclusions

The macroinvertebrate communities in the two rivers responded and adapted to the aquatic environment and human impacts with changes in the species composition and structure. The structure of the macrozoobenthos in Maritsa River and its studied tributaries was better than in Han River, indicating more favourable conditions in the water environment. The species diversity was higher (a greater number of taxa, greater values of d, e and H, and lower values of c) at the sampling sites in Maritsa River than in Han River in both years. In both years, high species diversity was recorded at the reference sites in the rivers, characterized by conditions closely resembling natural environments. The species richness and the evenness of macrozoobenthos were very low at sites downstream subjected to considerable anthropogenic pressure.

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