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Seasonal Changes in Benthic Communities of the Srebarna Lake (Northeast Bulgaria): Habitat Perspective

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Abstract: The present study was conducted to establish the seasonal changes of the macrozoobenthic communities in different habitats, within the Srebarna Lake, during the period 2009-2011. The lowest value of the total abundance was recorded during the spring of 2011 in the central open water body, where unfavorable environmental conditions were recorded.

In the peripheral zones the more diversified habitat structure and availability of refuges against fish predation were prerequisites for higher species richness and diversity of the macrozoobenthos communities, as well as for higher total abundance. In the peripheral pools the highest values of both the total abundance and species richness were found in spring.

Sörensen's similarity coefficient has shown clear differences between the taxonomic composition of macrozoobenthos in the main distinguished types of habitats – central open water body, peripheral pools within the lake area and a peripheral pool close to the lake. The maximum species similarity was found between spring and summer samples from the central part of the lake. Both indices, percentage of Oligochaeta and PETI, determined clear seasonal changes in ecological state assessment.

Key words: wetlands, seasonal and spatial changes, benthic communities

Introduction

Srebarna Lake Reserve is located in North-Eastern Bulgaria, on the right bank of the Danube River between rkm 393 and 391, close to the town of Silistra. The lake is a prominent Bulgarian nature protected site: it was declared as a Ramsar Site of International Importance, a Biosphere Reserve, a World Natural Heritage as listed by UNESCO, an Important Bird Area and a part of the EU ecological network NATURA 2000 (site BG0000241). Under the Bulgarian legislation Srebarna Lake is currently a Managed Nature Reserve. According to the surface water typology adopted in Bulgaria, Srebarna Lake is defined as a riparian lake in nearly natural condition (Cheshmedjiev *et al*. 2009).

Recently some extended studies have been carried out on the abiotic and biotic components of the Srebarna Lake ecosystem (Hiebaum *et al*. 2000, 20012, Beshkova *et al*. 2012, Pehlivanov *et al*. 2004, 2011, 2012, Pehlivanov, Pavlova 2009, Pehlivanov, Pavlova 2012, Kalchev *et al.* 2012, Kalcheva *et al.* 2009, Vulchev *et al*. 2006, Varadinova *et al*. 2009, 2011). The recovery processes of the benthic invertebrate communities and improving availability of the bottom habitats in the Srebarna Lake were recorded by Varadinova *et al*. (2009). The authors concluded that after the reconnection of the lake with the Danube River through the Dragaika canal (in 1994-1995), the stabilization of the benthic communities is still ongoing, and the species diversity has increased. Varadinova *et al*. (2011) reported that within the wetland area the local habitat parameters (modified by the flooding regime) are the leading factor that directly drives both the bottom community development patterns and spatial distribution of species.

More or less regular seasonal observations on the Srebarna aquatic ecosystem have been performed since 1998 (Vasilev 2005, Varadinova *et al*. 2009, Uzunov *et al*. 2012) and some patterns of the seasonal dynamics of the total abundance of macrozoobenthos have been reported. Nevertheless, the seasonal changes of the species distribution in different habitats have not been analyzed in details so far. The present study aims to describe and analyze the seasonal changes in the composition and distribution of macroinvertebrate communities with regard to the habitat specificity.

Studied Area

Srebarna Lake represents a complex of open water bodies surrounded by reedbeds. Samples were collected at 7 permanent sites (Fig. 1, Table 1). Six of them cover typical habitats within the lake area. The sites OG and DR are situated within the central open water area – COWA (Fig. 1). The lake bottom in this area is covered by thick fine light brown silt; the site DR was reported as the deepest point in the Srebarna (Vasilev 2005). This central open water area of the lake is characterized with scarce submerged vegetation. The sites KA, PP, CH and LI cover the peripheral zones of the lake (Fig. 1). The site KA is not always accessible because of the dynamics of the surrounded zone of floating reedbed. During the present study at the deeper points of the sites KA, PP and CH, the water depth varied from 2.5 m in OG0711 to 1.1m in KA0911; the bottom was covered by black to brown silt mixed with residues and fragments of reed and submerged vascular plants. All these peripheral areas of the lake were densely overgrown with submerged vegetation (mainly *Myriophyllum* sp.). The point Ll is situated in the temporary flooded coastal area.

One sampling site (SC) is a small artificial water body situated beyond Srebarna Lake at about 100-120 m from the lake border. The site was created in 2008 through barraging a small stream that flowed into the lake. The artificial lake is partially (about 50 %) shaded by trees and about 15% of its area is overgrown with rush. The bottom is covered with accumulated silt and the maximum depth reaches 1.5 m.

The geographic coordinates and coding of the studied sites are presented in Table 1.

Material and Methods

The present study was carried out from 2009 to 2011. Twenty macrozoobenthos samples from the different habitats were collected in different seasons (spring, summer and autumn).

An adapted version of the multi-habitat sam-

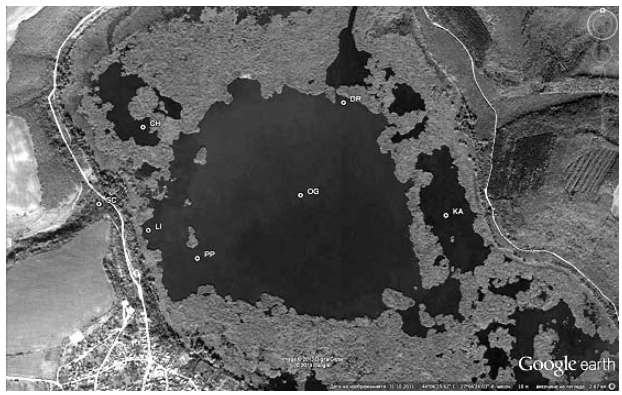

Fig. 1. Satellite image of Srebarna Lake with pointed studied sites

Table 1. Sampling dates, codes and geographic coordinates of the sampling sites in Srebarna Lake

Date	**Site**	**Code**
16.04.2011	Suhata cheshma	SC411
18.04.2011	Kamaka	KA411
18.04.2011	Chervenka	CH411
18.04.2011	Dragaika	DR411
18.04.2011	Pod pristana	PP411
18.04.2011	Ogledaloto	OG411
15.07.2011	Suhata cheshma	SC711
16.07.2011	Kamaka	KA711
16.07.2011	Chervenka	CH711
15.07.2011	Dragaika	DR711
15.07.2011	Pod Pristana	PP711
15.07.2011	Ogledaloto	OG711
20.09.2011	Suhata cheshma	SC911
20.09.2011	Kamaka	KA911
20.09.2011	Dragaika	DR911
21.09.2011	Pod pristana	PP911
20.09.2011	Ogledaloto	OG911
27.08.2009	Littoral	L809
15.09.2010	Littoral	L910
17.11.2010	Littoral	L1110
Geographic coordinates		
Site	Latitude – N	Longitude – E
Suhata cheshma (SC)	N44°6’24.32”	E27°3’35.62”
Kamaka (KA)	N44°6’23.33”	E27°4’54.04”
Chervenka (CH)	N44°6’37.69”	E27°3’44.96”
Dragaika (DR)	N44°6’41.70”	E27°4’30.38”
Pod pristana (PP)	N44°6’8.68”	E27°3’50.63”
Ogledaloto (OG)	N44°6’27.72”	E27°4’18.72”
Littoral (LI)	N44°6’21.54”	E27°3’46.05”

pling method (Cheshmedjiev *et al*. 2011) was applied using two techniques in accordance to the Standards EN 27828: 1994 (ISO 7828: 1985) and EN 9391: 1995 (ISO 9391: 1993). The samples were collected with a hand net (0.5 mm mesh-size) in the shallow wadable areas (≤ 0.5 m depth) and with Eckmann's dredge (181 cm^2 surface range) in deeper non-wadable sites.

All benthic samples were fixed in 4% formalin. During the processing at the laboratory, both sorting by systematic groups and species determination of the organisms were made. Most of the invertebrate groups were identified to the species or to the nearest possible taxa. The total number of species and the number of specimens of each species in the samples were determined and the total abundance (ind. x m^{-2}) was calculated.

The software package PAST (Hammer *et al*. 2001) was used to calculate the Shannon-Weaver diversity index (HIND), which characterizes species structure of the communities.

The percentage of similarity between different seasons and habitats was determined through Sörensen's coefficient. The similarity in species composition at the different studied sites was assessed and the cluster analysis was made using a PRIMER 6.1.6 (Clarke, Gorley 2006) software package.

The ecological status (Ecological Quality Ratio) of studied habitats in Srebarna Lake was defined through two indices recommended for ecological classification of the lakes in Bulgaria: 1) the percentage of Oligochaeta (Cheshmedjiev *et al*. 2009, Varadinova *et al.* 2011) and 2) the Trophic index PETI (Schweder 1990). Both indices were proposed and tested for the purposes of developing of the classification system for ecological status/potential assessment of the standing freshwater bodies in Bulgaria.

The index "% Oligochaeta" was not estimated for the samples KA711, KA911 and SC711 due to the lack of the representatives of this class. The PETI index could not be calculated for the samples KA411, DR911, OG411, OG711 and PP911, because the macrozoobenthos was represented with only one species.

Results and Discussion

Macroinvertebrate community parameters

Wide seasonal variations in the species number occurred at the different studied areas. The most pronounced changes were recorded at the site DR. The highest species richness of the benthic community for the studied period was registered at the mouth of Dragaika canal in July 2011 (sample DR711), and the lowest one – in the spring of 2011 in the central open water body (OG411) (Fig. 2).

The maximum values of taxonomic richness recorded in different seasons varied among the sampling sites. Thus, in spring the highest richness occurred at the site Pod Pristana (PP411), in summer it was recorded at the sites Dragaika (DR711) and Suchata Cheshma (SC711). Pronounced seasonal variations in the species composition (Fig. 3), together with the changes in the total number of taxa, occurred as well. Only a few perennial species were found at some of the studied sites, e.g.: *A. aquaticus* and *Baetis* sp. (at site SC), *Ch. cristalinus* (at sites PP and OG), *Ch. plumosus* and *G. gripenkoveni* (at site DR). Therefore, the low similarity registered between the species composition during the different seasons within the same habitats (Fig. 3) is an expected result.

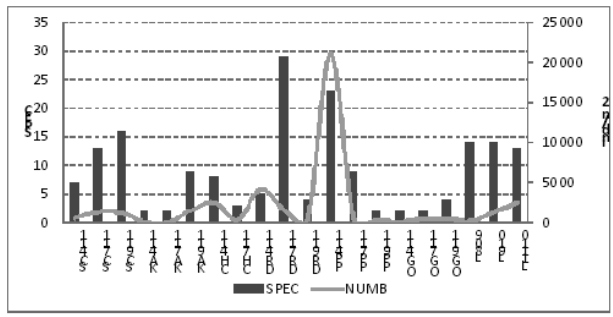

Fig. 2. Total number of individuals per m^2 (NUMB) and total number of taxa (SPEC) of the macrozoobenthos in Srebarna Lake for the period 2009-2011

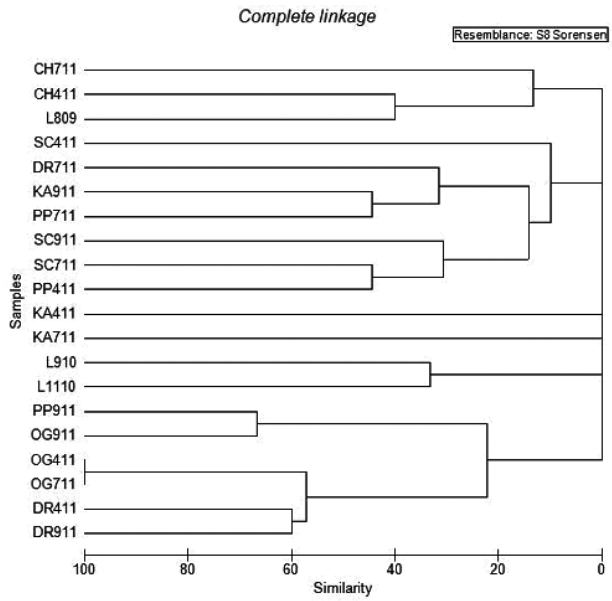

Fig. 3. Cluster analyses of the species similarity of the macrozoobenthos from different samples of Srebarna Lake (based on Sörensen's coefficient)

Pronounced similarities between different habitats were also not found, which can be explained with the low intensity of the exchange of species among the studied habitats in a short-term scale regardless of the seasonal changes in the water bodies. The hypothesis of the leading role of the local habitat parameters for the spatial distribution of macrozoobenthos within Srebarna Lake was suggested by earlier studies (Varadinova *et al.* 2009). According to the same authors the redistribution of the bottom invertebrate species among the habitats was strongly influenced by the considerable changes in the water level due to the flooding by the Danube River.

Some separation and self-clustering was found among the samples collected at the sites OG, DR and PP (Fig. 3). Sörensen's similarity coefficient showed a clear difference (K>50%) among the taxonomic composition of macrozoobenthos in the main distinguished types of habitats – the central open water body, peripheral pools within the lake area and the peripheral pool close to the lake. Relatively high similarity (K=67%) was found through the seasons, between the species composition of benthic communities in PP911 and OG911 and also between OG411 and DR411 (K=57%). The result suggests similar environmental drivers of their seasonal succession and corresponds to the assumption that these three areas currently form an integral water body.

Seasonally, the maximum species similarity (K=100%) was found between the spring and summer samples in the central lake part (OG). The high similarity (K=60%) between the spring and autumn samples in the north area of the central open water body (DR) may be explained by the low seasonal variability of the environmental parameters.

During the studied period the total abundance of the macrozoobenthos varied from 88 ind./m^2 in KA711 to 21024 ind./m^2 in PP0411. The lowest value of the total abundance (corresponding to the lowest number of the found species) was recorded during the spring of 2011 in the central open water body (OG411), in which unfavorable environmental conditions were recorded. The thick unstable silt substrate that covered the lake bottom was discussed by Varadinova *et al*. (2009) as being probably the main reason for the low species diversity and abundance registered in the central lake area.

The highest values of both the total abundance and species richness were found in the southwest peripheral area of the lake in spring (PP411). This was probably determined by the variable physical and chemical parameters. In addition, the presence of submerged macrophytes created various spatial niches for the benthic invertebrates and refuges against fish predation.

The seasonal changes in the total abundance considerably differed from the patterns reported in the previous studies (Vasilev 2005), where the water level variations were not taken into account. Moreover, different patterns in the seasonal changes of the total abundance occurred in the different habitats. The spring maximum, which corresponded to the higher depth (Fig. 4) recorded at the sites CH and PP, suggests a decrease in the predatory press by fish. That decrease has a positive effect on the seasonal succession of the macrozoobenthos. In contrast, the summer and autumn maximums in the sites SC, KA, DR and OG may be related mainly to the life cycles of the predominant organisms and/or to the seasonal changes in the abiotic environmental parameters.

Clear seasonal changes in the dominance of the main presented taxonomic groups were not recorded in the studied peripheral areas. Although the same taxonomic groups prevailed through all seasons within the same sites, those groups being as follow: Chironomidae at site CH, Malacostraca at SC and Diptera at PP (Fig. 5). An exception was found at the site KA where the gastropods were displaced by predominant chironomid larvae in summer. In contrast, pronounced seasonal changes occurred within the central open water area. During spring and autumn gastropods totally replaced chironomid larvae at the site OG. During the same seasons the chironomid larvae prevailed at the site DR and were replaced by Malacostraca in summer.

Species diversity

The aggregated values of HIND for the entire period of study indicated the lowest species diversity of macrozoobenthos in the open water area (OG) (Fig. 6). On the contrary, almost equally high values were calculated for the three peripheral sites within the lake area (DR, PP and Ll) as well as for the

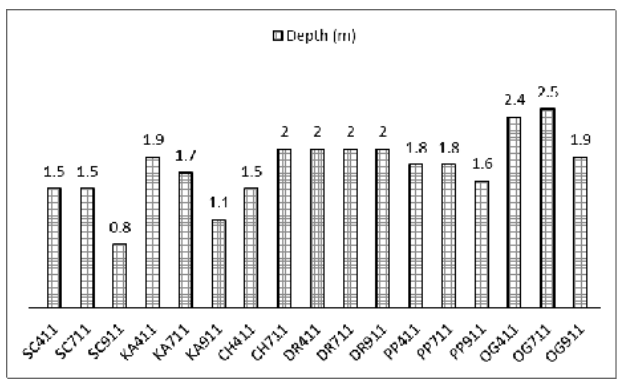

Fig. 4. Water depth fluctuations in Srebarna Lake during 2011

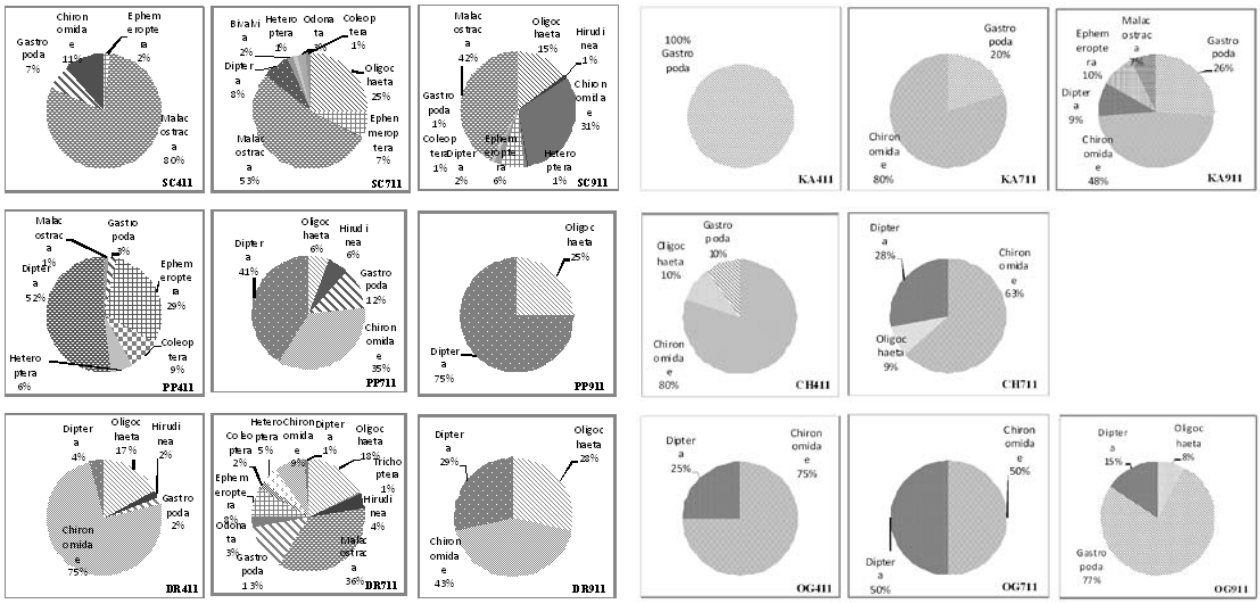

Fig. 5. Seasonal changes in the percentage of the main taxonomic groups of macrozoobenhos at the studied habitats in Srebarna Lake

outside water body (SC). During the investigation period, the spatial and seasonal distribution of the HIND among the studied sites was rather irregular. The data obtained suggests that the seasonal variations of the HIND values reflected the changes in the variation patterns of the species richness (Figs. 2 and 6).

Ecological assessment

Two indices: Percentage of Oligochaeta and PETI have been used to determine the effect of the seasonality and habitat diversity on the ecological status based on benthic macroinvertebrates.

During the period of study, the dynamics of the Percentage of Oligochaeta index varied from 0.48% in PP411 to 28.57% in DR911. Based on this index, the ecological status of the water bodies of Srebarna Lake was assessed as "Good" and "High" (Fig. 7). The values of the Percentage of Oligochaeta index and respectively the EQR values did not show clear differences among the ecological status of the studied habitats: the peripheral pools, COWA and the site close to the lake. Some seasonal changes were observed at the sites DR and PP, at which the ecological status changed from "High" (in spring and summer) to "Good" (in autumn). It has to be pointed that in contrast to the site DR, where the water depth remained almost constant over the entire period, at PP the changes in the EQR values corresponded to the decrease in the water level in autumn.

The values of the PETI varied in a wide range between "Bad" and "High" status. The lowest value of PETI 9.1% (Fig. 8) was calculated for the central part of the lake in the autumn of 2011 in OG911 where only *Chironomus plumosus* and *Chaoborus crystalinus* were represented in the macrozoobenthos. Based on the trophic index, the ecological status at site OG911 was assessed as "Bad" which is an indication of imbalance of the aquatic ecosystem. The maximum values of the PETI were registered in

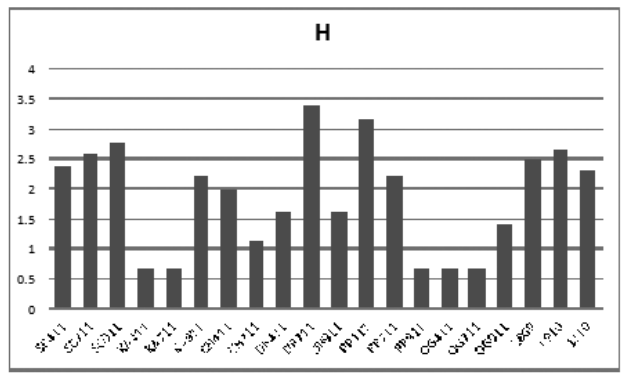

Fig. 6. Changes of the Shannon-Weaver's diversity index (HIND) by sampling sites in 2011

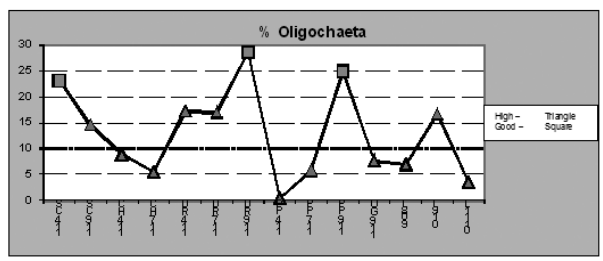

Fig. 7. Dynamics of the percentage of Oligochaeta index for the studied period

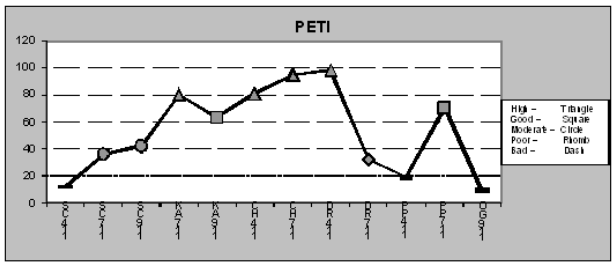

Fig. 8. Values of the trophic index PETI for the sites sampled in Srebarna Lake in 2011

CH711 (94.45%) and DR411 (97.85%), in both of which the ecological status was defined as "High" according to the adopted classification.

The values of PETI ≥ 70%, which demonstrate a stable, non-influenced or slightly affected ecosystem, were calculated for the spring and summer samples from the peripheral pools: KA711, PP711, CH711, DR411 and CH411.

Conclusions

The results obtained suggest that the macrozoobenthos within the Srebarna Lake Reserve can be seen as a metacommunity composed by a set of local bottom invertebrate communities, which are linked through the dispersal of multiple interacting species. Notwithstanding the potential interactions within the integral lake ecosystem, the macrozoobenthic local communities can be distinguished by their specific composition, structure, diversity parameters and seasonal patterns.

In the most peripheral zones the more diversified habitat structure and the availability of refuges against fish predation favour the development of bottom invertebrate communities with greater species richness and diversity, as well as higher total abundance. The thick unstable silt substrate covering the lake bottom in the central open water area and the very low density of submerged macrophytes there determine the poor taxa composition of macrozoobenthos. Unlike the index Percentage of Oligochaeta, the PETI, which is characterized with higher sensitivity, demonstrated clear seasonal changes. Furthermore, the variations in that trophic index at different sites reflected the differences between the studied habitats.

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