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Application of Some Zooplankton Community Characteristics as Indicators for Assessment of the Black Sea Coastal Environment

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Abstract: **The aim of the study is to test some zooplankton metrics (abundance, biomass, taxonomic composition - key groups, Shannon diversity index) as indicators for assessment of the ecological status and potential of the coastal environment along the Bulgarian Black Sea coast. The case study is performed in the system of Beloslav Lake-Varna Lake and Varna Bay, area under various anthropogenic impacts. Lakes were identified as heavily modified water bodies on the base of the WFD principles. According to the discussed zooplankton characteristics the ecosystem of Beloslav and Varna lakes could be assess as "problematic area" while Varna Bay as "potential problematic area". Applied zooplankton metrics could be used as complementary plankton indicators of the eutrophication effects, respectively for a water quality assessment.**

Keywords: **Zooplankton indicators, Black Sea, Bulgarian coast, eutrophication.**

I. INTRODUCTION

The assessment and protection of environmental health require a system of adequate measures for monitoring, diagnoses and management similarly to the field of human health protection, where indicators and regulations for assessment have been successfully exploited [1]. In 2000 EC adjusted the Framework Directive on Water Resources as a basic guideline for the introduction of clear, unified criteria, indices and indicator categories for definition of the quality status of marine environment and protection of its physical and biological integrity [2]. The development of methods for assessment of the ecological status is a key issue for a successful implementation of the Water Framework Directive.

Mesozooplankton (200 µm – 2 mm body size) fill in a key position in pelagic food webs because they link directly primary production to planktivorous fish. Moreover, plankton fauna has potentially strong top down impacts on phytoplankton and a key role in recycling mineral nutrients and in mediating sedimentation by forming fecal pellets [3]. Factors with a great impact on the dynamic of Black Sea plankton fauna are human activity, climate changes and natural variability of the ecosystem [4]. According to WFD, structural changes in the ecosystem are recognized already as indirect effects of nutrient enrichment. The analyses of zooplankton alterations could be of use for providing more detailed information on water quality. Thus the quantitative parameters of some zooplankton groups and species might be exploited as reliable indicators responding to the stresses in their environment. Moreover, among the zooplankton, key stone species could be selected as tools not only to monitor impacts, but also to manage the ecosystem and to predict effects despite the fact that zooplankton is not subject of the WFD and include in it as a complementary element.

The aim of the present study is to test some zooplankton metrics and indices as indicators for assessment of the ecological status respectively potential of the coastal environment along the Bulgarian Black Sea coast. The case study is performed in the system Beloslav Lake-Varna Lake and Varna Bay, which area is under various anthropogenic impacts [5]. Varna Bay is the second largest bay along the Bulgarian Black Sea coast connected via two channels to Varna and Beloslav Lakes. Varna Lake is characterized by significant organic load and thermal contamination leading to oxygen deficiency in the bottom waters due to the limited vertical water exchange causing eutrophication [6, 7]. Beloslav Lake is almost

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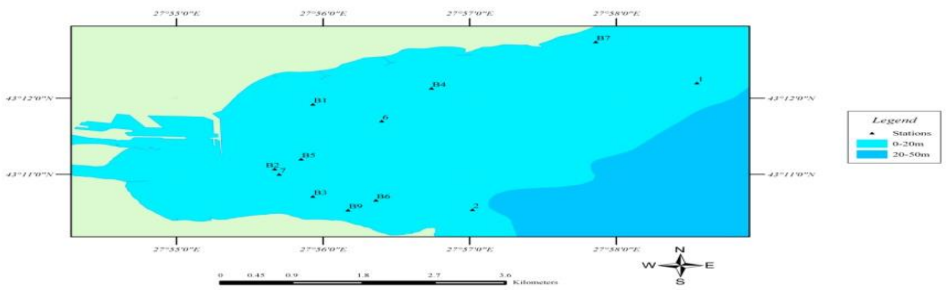
enclosed water basin where purifying capacity is very low. The investigated system is subjected to moderate levels of pollution from Varna (pop. 314 539), the adjacent lakes which receive waste water from several chemical and electric power plants, and Varna harbors that are situated in Varna Bay and Beloslav Lake. Furthermore, it is an example of a cascade, introducing nutrients and pollutants of industrial (chemical industry), agriculture and sewage origin and all the above led to increasing of anthropogenic formed sediments [8, 9]. The large amount of particulate and suspended organic matter, pesticides and other pollutants has contributed to the eutrophication processes. Lakes were identified as heavily modified water bodies on the base of the WFD principles. The ecosystem is identified as highly disturbed. According to water quality index (WQI), the two lakes fell in the category "bad", while Varna Bay was scaled as "poor" water quality, highly eutrophicated [1].

II. MATERIAL AND METHODS

The study area was the hydrological complex Beloslav Lake – Varna Lake – Varna Bay located at the North Bulgarian coast (Western Black Sea). Investigations were carried out during the seasonal scientific cruises of the IO-BAS with N/V "Adm. Br. Ormanov" and R/V "Akademik" in Varna Bay, and on a boat in Varna –Beloslav Lakes in the period 1996-2005. Data were collected at 7 stations in Beloslav Lake, 13 in Varna Lake, 12 in Varna Bay and 4 stations located in the canals (lake-lake, lake-sea) (Fig. 1).

Zooplankton samples were collected by vertical plankton Juday net (14.5 cm and 36 cm diameter, 150 µm mesh size). Samples were fixed to 4% formalin solution after sorting out, counting and measuring the size of gelatinous species (*Mnemiopsis leidyi*, *Aurelia aurita* and *Beroe ovata*). Taxonomic identification to the species or possible lower taxonomic level was done under a stereo microscope "Olympus". Species abundance per cubic meter was performed according to Dimov's method [10]. Biomass was estimated by using individual standard weights [11]. The number of species, total and average zooplankton abundance (ind.m^{-3}) and biomass (mg.m^{-3}) were defined. To assess zooplankton diversity and stability of the community, Shannon-Weaver diversity index [12] and Pielou's evenness were calculated. For statistical analysis the programme STAT 6 (2001) was applied. Available data [13] for the period 1990-1991 were used for comparison.



a)

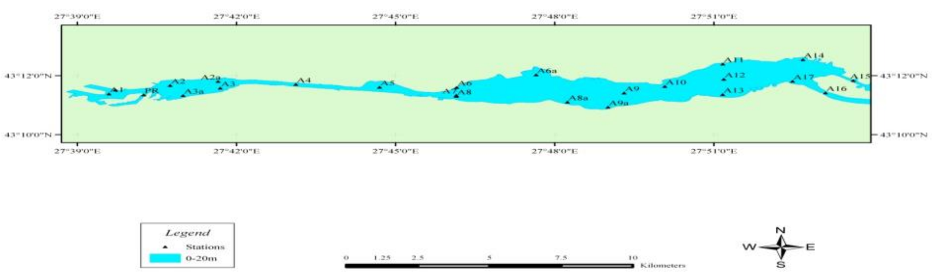


Fig.1. Map of sampling stations of Varna Bay (a) and Varna-Beloslav Lakes (b)

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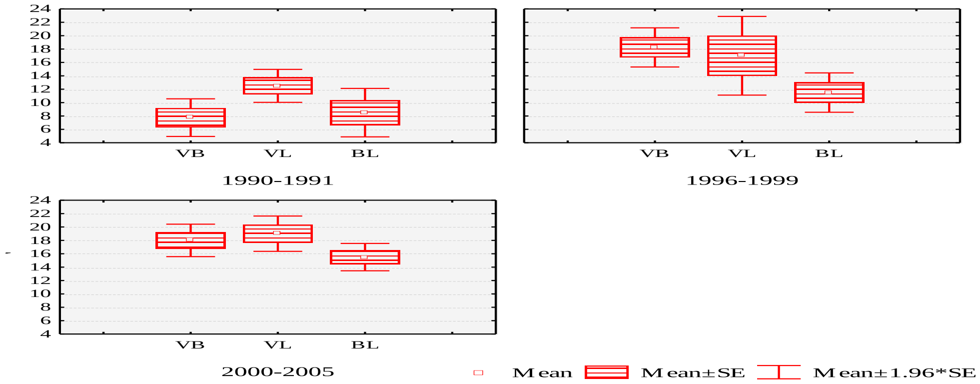
III. RESULTS AND DISCUSSIONS

a) Zooplankton taxonomic structure and key groups as environmental indicators:

Biodiversity of the ecosystem and species richness in terms of number of species regularly remain steady over the time. Generally, the observed changes in the zooplankton assemblages, such as adaptation of new comers (aliens) or loss of local species appeared to be related to the high anthropogenic pressure. Thus the alterations of zooplankton taxonomic structure could be perceived as a signal for changes in water quality due to toxic substances, organic pollution and eutrophication [14].

During the period of intensive anthropogenic eutrophication in the Black Sea (late 70-ties -early 90-ties), typical ecosystem characteristic was the substitution of large-size crustacean by small size species [15]. Results revealed higher zooplankton diversity in 1999-2005 in comparison to the period 1990-1991, when the dominant taxonomic groups Copepods and Cladocera diminished substantially in response to eutrophication, Jellyfish blooms and pressure by *M. leidyi* [16]. Lake-bay ecosystem was presented by low number of species/taxa (10±2) in the period 1990-1991 while in 2000-2005 it increased to 18±2 mainly due to Cladocera, copepods and benthic larvae diversity (Fig. 2 a, b). During the discussed period, the number of species per sample (a measure of richness) varied from 8 to 23 species (in average 16). The main taxonomic groups were Copepoda (9 species), Meroplankton (8 species), Rotifera (6 species), and Cladocera (4 species). Group Varia (*Parasagitta setosa*, *Oicopleura dioica*) was the minor component. Zooplankton diversity has diminished from Varna Bay toward Varna and Beloslav Lakes, together with the outer area of Varna Bay (Fig. 3). The richness of plankton fauna was higher in the eastern part of Varna Lake and in the central zone of Varna Bay. Hydrological regime of the bay contributes to the increasing of species enrichment via marine currents and flows [13]. Therefore the zooplankton richness was higher in the transitional zone (lake-bay). A distinguishing feature of the zooplankton structure was the occurrence of species rare in the past, such as *Paracalanus parvus*, *Oithona similis* and *Centropages ponticus*, parallel with species tolerant to the eutrophic conditions (*Brachionus rubens*, *Brachionus pilicatilis*, *Synchaeta vorax*, *Acartia clausi*).



a)

b)

Fig.2. Number of species (a) in separate areas Varna Bay (VB), Varna Lake (VL), Beloslav Lake (BL) and (b) periods 1990-1991 and 1996-1999, 2000-2005

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The main group with a high ecological significance for both lakes was the rotifers. Microzooplankton (rotifers) acts as a trophic link between phytoplankton - mesozooplankton, contributing to the microbial loop and to higher trophic levels. The abundance of rotifers correlates with trophic state indicators (chlorophyll a and total phosphorous). Because of their high feeding and assimilation efficiencies, their role is important in energy flow and nutrient cycling, accounting for more than 50% of the zooplankton production due to the great reproduction rate [17]. In addition, species assemblages of rotifers are useful in characterizing lakes in relation to their trophic status. Thus species *Brachionus calyciflorus*, *B. rubens*, *Synchaeta vorax*, which dominate in Beloslav lake could be used as indicators for eutrophicated waters [18, 19].

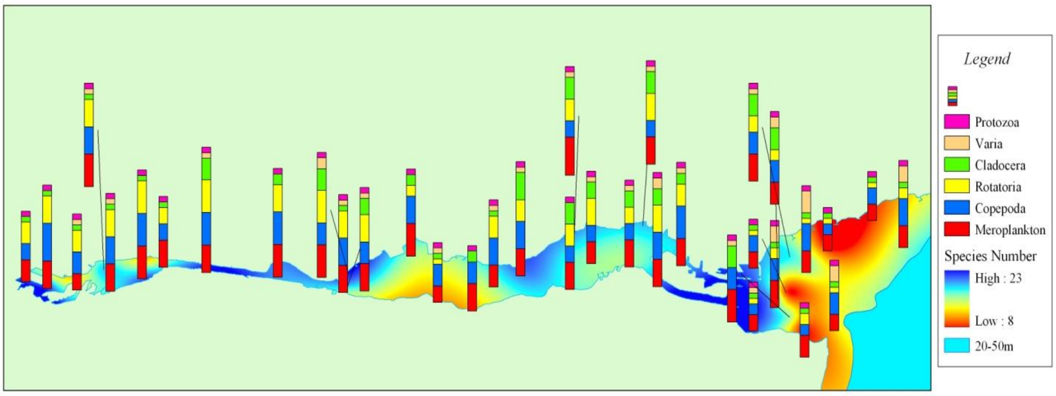

Fig.3. Distribution of zooplankton species number in the system Beloslav-Varna Lakes-Varna Bay during 1999-2002

b) Zooplankton abundance and biomass as environmental status indicators:

The alterations in the long-term dynamic of the main zooplankton taxonomic groups (key groups) were already recognized as an adequate response to the modified Black Sea environment [4]. Further, the quantitative parameters (abundance and biomass) could be seen as an indicator for the eutrophication impact in accordance with DPSIR concept.

The results revealed a range of zooplankton abundance from 11341 ind.m^{-3} to 436967 ind.m^{-3} (Fig. 4). Maximum values were recorded in Beloslav Lake, in front of Provadiiska River mouth and close to ferry terminal. The largest part in the zooplankton structure was shared by the rotifers. The density of rotifers and diversity as well highly correlated with the acidity status [20, 21, 22] and trophic state indicators chlorophyl a, total phosphorous [23]. Therefore, neutral to low alkaline pH, especially closed to river discharge in Beloslav lake [24], could be one of the reason for the high concentration of rotifers. The ecological significance of the group decreased towards the bay, where the zooplankton structure was dominated by benthic larvae and co-dominated by copepods. The naupilus stages of Cirripedia were presented with 100% frequency of distribution in the area, which have suggested favorable conditions for their growth and high survival rate. Dominant species by Copepods were *Acartia clausi*, together with its nauplius stages. The dominance of that species indicates deteriorated environmental conditions and it is well exploited as an indicator species of eutrophication [25].

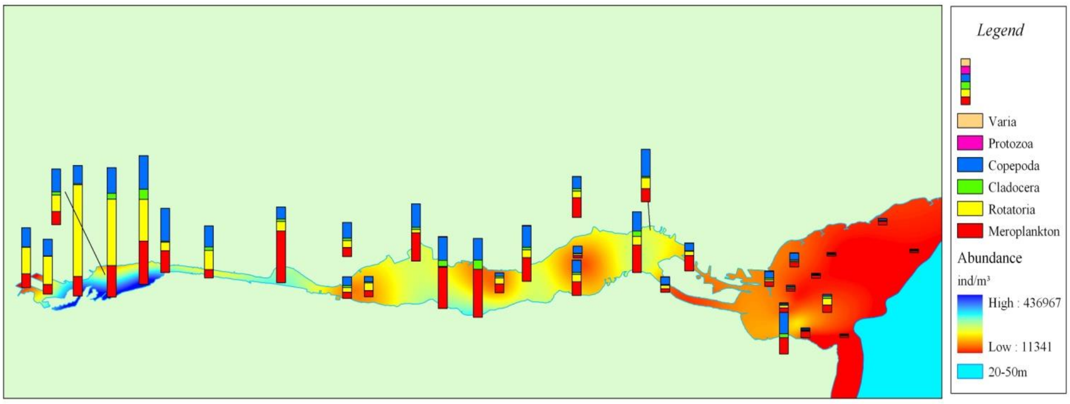

Fig.4. Average zooplankton abundance [ind.m^{-3}] in the system Beloslav-Varna Lakes-Varna Bay (1999-2002)

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The distribution of average zooplankton biomass demonstrated high values in the southern part of the lakes. The structure was dominated by benthic larva and copepods, both with high individual weights. Zooplankton total biomass fluctuated in a wide range (from 136.71 mg.m-3 to 4066.93 mg.m-3), as a result of patchy distribution of large species of copepods, Cladocera and Meroplankton (Fig. 5). The lowest values were registered at stations located to the Varna –West Port, Thermoelectric power stations and Sewage plant (station A1, station A6a). Species diversity (*B. rubens*, *A. clausi*, Cirripedia nauplii, *P. polyphemoides*) and quantitative parameters were low at the area most likely due to the great impact of plant functioning. The noteworthy part of small sized species and fine filtrates in the biomass structure may possibly suggest a high phytoplankton concentration.

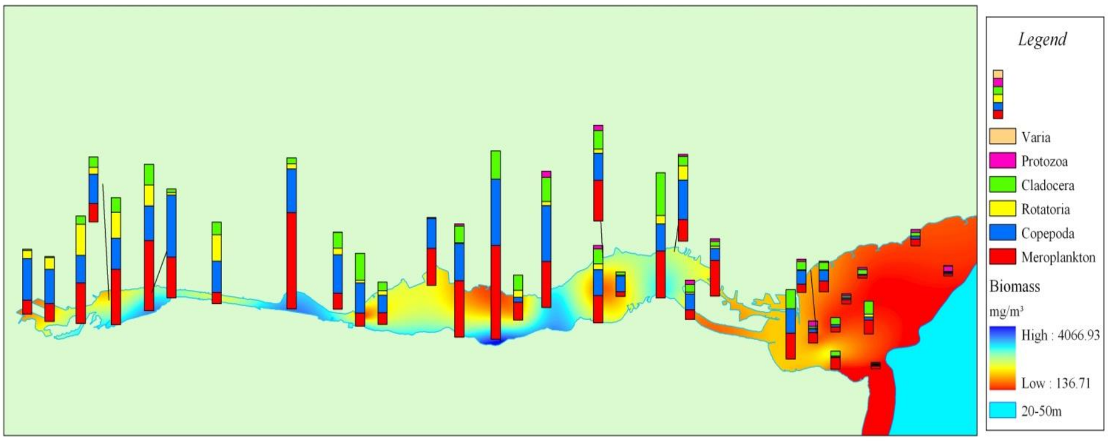
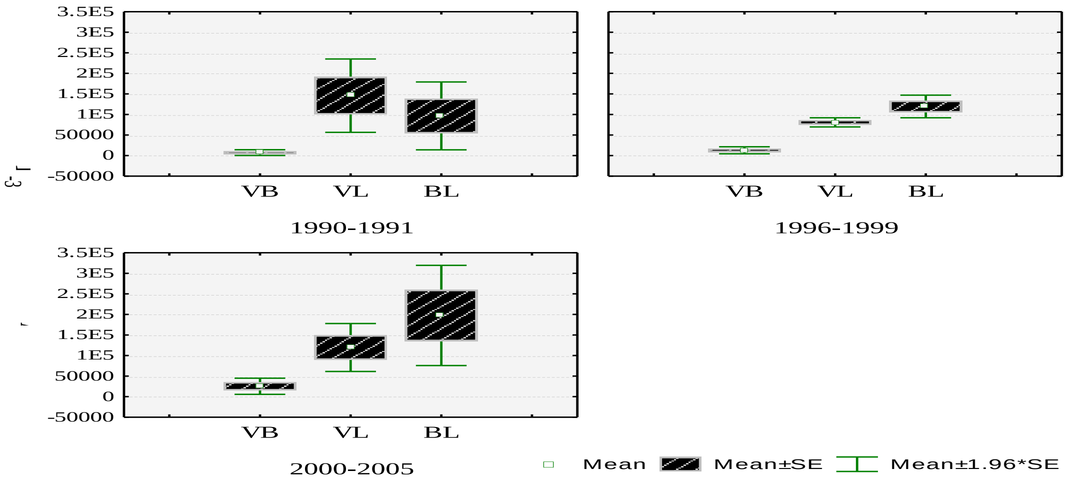


Fig.5. Average zooplankton biomass [mg.m^{-3}] in the system Beloslav-Varna Lakes-Varna Bay (1999-2002)

Wide ranges of quantitative metrics testify to extremely uneven spatial and temporal distribution of zooplankton abundance and biomass. Generally, the lower quantitative variables in Varna Bay compared to lakes demonstrated much less pronounced heterogeneity. A trend was a rise in the numbers and biomass of zooplankton approximately 3 times in Varna Bay from 1990 - 1991 to 2005. Inverse relationship was established for the Varna Lake, where the number and biomass decreased by 2 to 4 times (1990-1991 - 2551.58 mg.m^{-3} ± 1159.02 SE; 2000-2005 - 1372.9 mg.m^{-3}± 384.90 SE) while the values remained almost comparable in Beloslav lake (2065.07 mg.m $^{-3}$ ± 902.79 SE in 1990-1991 and 2129.18 mg.m $^{-3}$± 1089.12 SE) with a slight decline in the late 90s (Fig. 6 a, b). It was established a well pronounced increasing gradient of zooplankton abundance and biomass from the Bay toward the Lakes. Higher mesozooplankton average biomass in Varna Bay corresponded to the *M. leidyi* biomass reduction [26]. After *B. ovata* settlement changes occurred in the macrozooplankton structure. The share of *M. leidyi* in the western part of the Black Sea decreased to 29% of the amount of jelly plankton at the expense of increased Beroe and *Aurelia aurita* values [27, 28, 29, 30].



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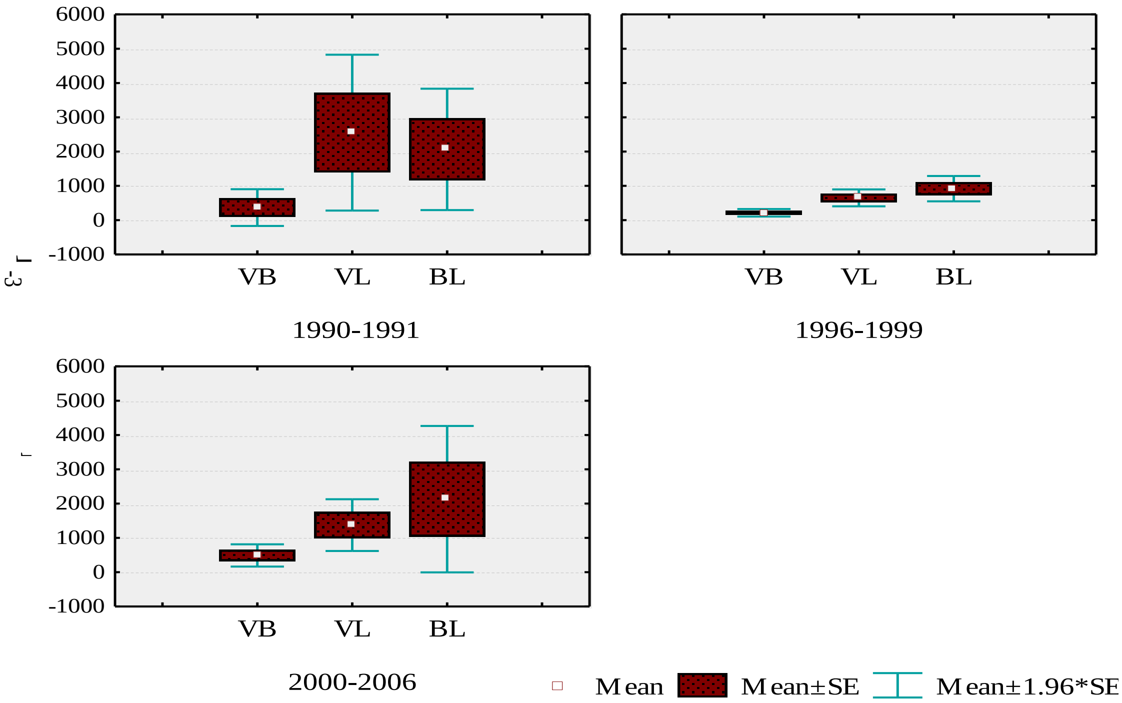


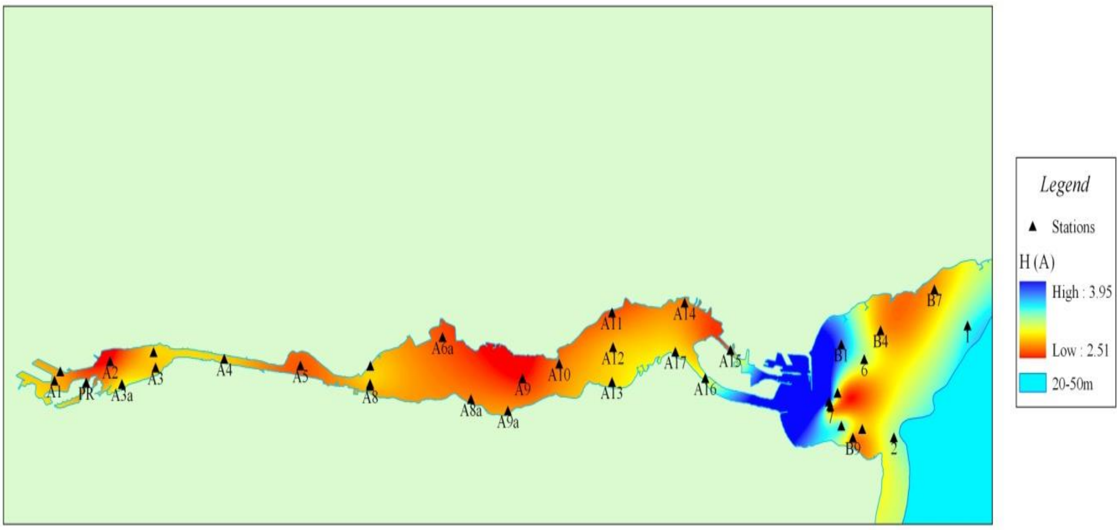
b)

Fig.6. Zooplankton abundance (a) and biomass (b) dynamics in Beloslav - Varna Lakes – Varna Bay in the periods 1990-1991, 1996-1999, 2000-2005.

c) Shannon-Weaver community diversity:

The Shannon-Weaver index H' was much lower in the areas where great amount of zooplankton has been recorded. The values of the index were from 1.9 to 3.97 (Fig. 7). The quantitative parameters (abundance, biomass) were particularly high in Beloslav Lake and in the Western part of Varna Lake, providing arguments for a high secondary production and disturbed ecological state of the zooplankton community in those areas. Low index H' at the outermost stations in Varna Bay was a result of the *P. polyphemoides* and Cirripedia nauplii dominance in the zooplankton structure.

The fairly better zooplankton state of the inside Varna Bay area (station B1, st. B2, st. B3) was probably related to the high species richness and the high evenness of species distribution (Pielou's evenness close to 1).



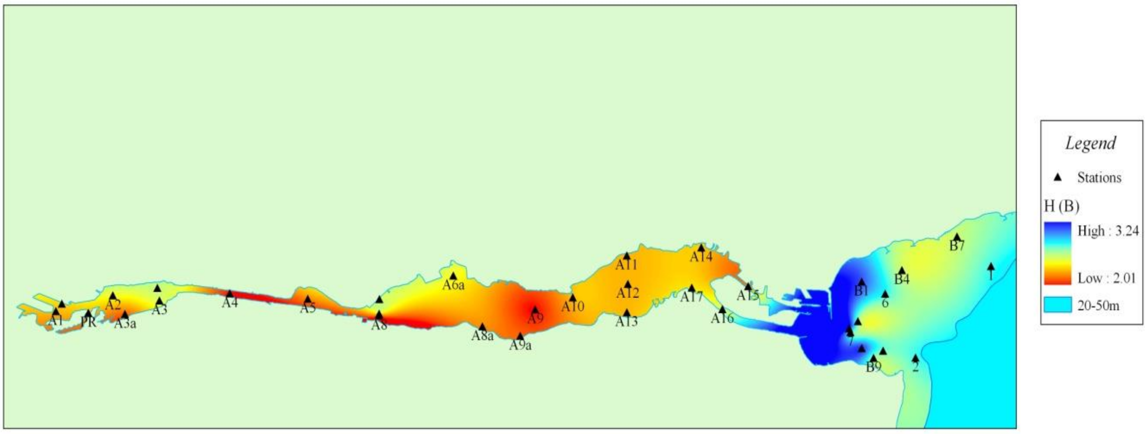


Fig.7. Spice-time distribution of Shannon-Weaver diversity index H (A) (upper plot) and H (B) (lower plot) in Beloslav -Varna Lakes - Varna Bay (1999 to 2002)

IV. CONCLUSION

The WFD ecological status assessment addresses more than the aspect of eutrophication alone, but the Document does not require Member States to take into account the plankton fauna as a qualitative assessment parameter for monitoring. However, it has been proposed to monitor suitable biological quality elements as part of the determination of ecological status. The discussed zooplankton characteristics (taxonomic composition, contribution of key-groups, indicator species, abundance and biomass) could be used as additional complementary indicators of the indirect eutrophication effects, respectively for a water quality assessment and undesirable disturbances of the coastal ecosystem.

The correspondence of the main community characteristics at the three sites (both lakes and Varna Bay) argues zooplankton taxonomic structure similarity of the area, and find out a relatively stability of the plankton fauna in the investigated area. On the contrary, the greatest quantity of zooplankton in Beloslav and Varna Lakes, most likely revealed a higher rate of reproduction as a response to the disturbed environmental conditions in comparison to the Varna Bay.

According to Shannon-Weaver index, plankton fauna's diversity is low which could suggest a "low" ecological potential of the zooplankton community especially in Beloslav and Varna lakes. Both lakes could be classified as "problem areas", showing an increased degree of nutrient enrichment due to Devnya and Provadiiska rivers inflow, ferry port, Sewage Plant and Thermoelectic power station. Further, Varna Bay could be classified as "potential problematic area" or a sensitive.

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