

BENTHIC INVERTEBRATES SPECIES AS INDICATORS OF BENTHIC HABITATS HEALTH FROM SIUTGHIOL LAKE, ROMANIA

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Abstract: Siutghiol Lake is located in a heavily urbanized landscape of eastern Romania, in proximity to the cities of Constanta, Ovidiu, and the tourist resort of Mamaia, resulting in strong anthropogenic impacts on the lakes. Because the benthic domain represents an effective barometer for assessing the health of aquatic ecosystems, a study was conducted to identify the extent that invertebrates can be used as indicators of the spatial variation in ecological health of the lake. Benthic samples were collected from 18 sites in July 2009 from the center and shorelines of the lake, resulting in 54 integral replicate samples of benthos: sediment, rock and submersed vegetation, substrate with associated macro- and meiofauna. Sampling was carried out using van Veen bodengreifer and Ekman devices. Biological material was separated from sediment and macrofauna from meiofauna in the laboratory using sieves: mesh size 1mm (for macrobenthic invertebrates with size greater than 1mm) and 0.250mm (for meiofauna). Sorting and species identification was conducted under a stereomicroscope. Overall, macrobenthic invertebrates represent 5% and the meiofauna represents 95% of the numerical abundance of individuals. However, a net dominance of meiofauna compared to macrofauna (ratio by abundance of 6:1) in other areas of the lake appears to be associated with human impacts. Ten superspecific macrobenthic taxa with 18 specific taxa and 11 meiobenthic species were identified, including juvenile forms of macrobenthos. Typical meiobenthic taxa included representatives of 4 groups: Nematoda, Acarina, Ostracoda and Copepoda. The presence of Ponto-Caspian relict species is particularly important in coastal lakes. Listed relicts found in our samples include: *Cordylophora caspia* Pall. (Hydrozoa), Tricladid species from Turbellaria group, *Hypaniola kowalewskyii* Gr. (Polychaeta), *Pontogammarus robustoides* Sars. and *P. borcaea* Car. (Amphipoda), *Paramysis baeri bispinosa* Mart. and *P. intermedia* Cz. (Mysidacea), *Pterocuma pectinata* Sow. (Cumacea), *Iaera sars* Valk. (Isopoda). The relict species are found in habitats dominated by vegetated substrate on the western shore, littoral zone vegetation of the lake and around the Ovidiu Island. These habitat-species associations represent a community type similar to the original benthos of the lake prior to human impacts. Earlier reports mentioned the presence of relict species but with a much greater range than that reported here. However many of these species have broad ecological tolerances and thus can withstand relatively large variation of environmental parameters.

Keywords: benthic invertebrates, bioindicators, Siutghiol Lake, freshwater benthos

1. INTRODUCTION

The use of supra-individual biological systems to evaluate health status of aquatic ecosystems (especially population or benthic community parameters) is a priority supported by European Water Framework Directive through studies and European programs for monitoring, quality assessment and management of aquatic and coastal basins.

The concept of ecosystem health status assessment (Schaeffer et al., 1988; Schaeffer & Cox,

1992) has been adopted by more and more researchers (Ryder, 1990, Rozema & Verkleij, 1991; Regler & Cowel, 1972; Regler, 1992; Rapport, 1992a, 1992b). This is due in part to the need to characterize changes brought about by the development of socio-human system, and to find criteria, parameters that allow feedback on the health status of habitats and ecosystems. Suter (1990, 1993) believes that this concept of health status is a "metaphor" from the ecological standpoint because the emergence or proliferation of "unwanted

organisms" into an ecosystem. Assessment indicators can either represent a concrete "answer" to concrete action or state existing at a certain time (which may have a temporary nature). Alternatively, they can provide a "structural model" where the indicator-parameters identified are suitable for ecological analysis. There are numerous papers describing the criteria and characteristics of ecological indicators (Schaeffer et al., 1988; Kelly & Harwell, 1990; Liverman et al., 1989; Suter II, 1989), etc. Odum et al., (1979) and Odum (1985) have clearly outlined a hierarchy of the main categories that appear at the ecosystem level as a consequence of pressures generated by anthropogenic stress factors.

The structure of such supra-individual systems (e.g. populations, communities and ecosystems) is a state parameter often sought in monitoring activities for evaluating the health of aquatic ecosystems. We believe that the supra-individual structures of benthic invertebrates can be used to characterize the state of stress induced by human activities surrounding lakes on the Romanian Black Sea coast. For example, the response parameters that would characterize a state of stress or decline processes inside of an ecosystem include: (1) the dominance of small-sized benthic forms, to the extent that population growth (e.g. r-strategy) is favored, (2) the presence of short food chains, especially when detritus forms the primary trophic base, (3) a reduced number of species of predators, and (4) lower taxonomic diversity or species richness in parallel with increasing dominance of fewer species populations.

Lake Siutghiol (Sütgöl translates as "milk lake" in Turkish language) originated from a marine lagoon and is also known locally as the Great Lake or Mamaia Lake. It is surrounded to the east by the tourist resort of Mamaia (parallel with the Black Sea shoreline: N 44.25°, E 28.60°, Fig. 1), to south-east by "Ovidius" University Campus and a nautical Base. There is a connecting channel for water flowing between Lake Siutghiol and Lake Tabacarie. To the west are the localities of Palazu Mare and Ovidiu land to the north by Mamaia Village. It has a surface of 19 square kilometers (7.5 km in length, average width 2.5 km) and a maximum depth of 17 meters in a deep basing wherein are located two springs that feed the lake). In the southwest is the tourist destination, Ovidiu Island, with an area of two hectares comprised primarily of limestone.

The Siutghiol-Tabacarie lake complex, although strongly impacted by tourism activities and development in the area, was declared Site of Avifauna Interest (SAI-Sit de Interes Avifaunistic) and Special Protection Area (SPA) because it hosts

important components of sedentary and migratory avifauna. Data characterizing qualitative and quantitative structure of aquatic communities in Siutghiol Lake are few, and the ecosystem is considered to be strongly degraded due to human activities, especially in the last five decades.

This paper draws from a series of studies conducted in the summer of 2009, conducted within the framework of an integrated project for the development of indicators for sustainable development and monitoring in coastal zones (https://pantherfile.uwm.edu/ehlinger/www/romania/NSF_IRES.html). With regard to the coastal lakes, major themes included: monitoring of nutrient loads, bacteria and water quality, chemical and ecotoxicological characterization of sediments, and benthic biodiversity. Faculty staff and students from "Ovidius" University of Constanta and University of Wisconsin-Milwaukee conducted the research. The objective of the work reported here was to evaluate whether benthic invertebrate species have the potential to serve as sensitive indicators of ecological health or benthic habitats in Siutghiol Lake.

2. MATERIAL AND METHOD

2.1. Sampling site description

Benthic biological samples (N=54 total) of macro- and meiofauna were collected from 18 locations; 9 locations in the shoreline zone (0-0.5 m depth, Fig. 1) and 9 locations in the central area of the lake, with depths of maximum 3.5 m; additionally samples were taken from around the Ovidiu Island: 4 were located on the western shore of the island (area of impact due to urban settlements Palazu Mare and Ovidiu) and the other four along the eastern shore of the island.

Samples were collected from different types of substrates: (1) phytal (especially reeds and rarely submerged vegetation dominated by *Potamogeton* and *Cerathophyllum*), (2) sedimentary (mostly dominated by clay and only occasionally with a clay/sand matrix that was encountered on the eastern shore of the lake) and (3) hard, rocky substratum (found along the shoreline of the lake and on north and east shores of Ovidiu Island).

2.2. Sampling methods

Benthos samples (substrata and biological material) were collected using three methods: (1) Eckman dredge, Van Veen type bodengreifer, or a dredge with a collection "cup" made of silk cloth with 0.2 mm mesh size were used to collect

sediment samples; (2) Plant material was collected just below the water surface within an area contained by a rectangular sample grid (22x20 cm), recording numerical abundance and dry plant biomass, and; (3) Stones collected with attached biological material were collected and measured so as to calculate collection surface area.

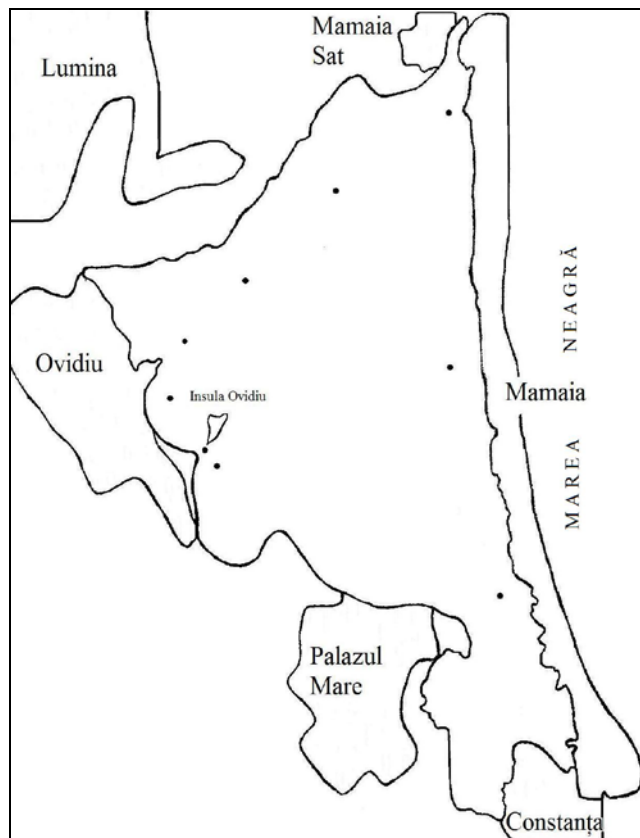


Figure 1. Siutghiol Lake location and placement of collection points for benthic sampling

2.3. Benthic fauna analysis

Biological samples were fixed immediately after collection with 4% formaldehyde and stored in labeled airtight plastic boxes, and transported to the laboratory. Sample processing involved separating biological material from the substrate using a set of sieves with mesh size of 1 mm and 0.250 mm. Similarly, the separation of benthic invertebrate fauna in two major categories was done first by serial sieving and retention of macrofauna and meiofauna.

Sorting and identification of organisms was conducted using a stereomicroscope and occasionally with a compound microscope. It was necessary to use vital dye Pink Bengal to facilitate sorting, especially with meiofauna because the samples had a large load of debris and plant material. Species determinations were made using keys by Godeanu (2002).

Numerical abundance and biomass ascertained from samples were entered into a database from which a series of ecological indices were calculated. Benthic population abundance was used for calculating ecological density, frequency, dominance, diversity (H' - Shannon), and equity (E) indices.

3. RESULTS AND DISCUSSION

3.1. Benthic community

Seventeen taxa were identified to the species level: one species of sponges (*Spongilla lacustris* L.), two species of coelenterate (*Cordylophora caspia* Pall. and *Hydra*, **Hydrozoa**), two species of Polychaeta (*Hypaniola kowalewskyi* Gr, *Manayunkia caspica* Annenk.), one species of Hirudinea (*Erpobdella stagnalis* L. species cited as an indicator species for a mesosaprobic waters in saprobies system), three amphipods (*Pontogammarus robustoides* Sars., *P. borceae* Car. and *Gmelina aestuarica* Car.), three mysids (*Paramysis baeri bispinosa* Mart., *P. intermedia* Cz. and *Limnomysis benedeni* Cz.), one cumacean (*Pterocuma pectinata* Sow.), two isopods (*Asellus aquaticus* L. and *Iaera sarsi* Valk. and one species of bryozoan (*Plumatella* L.). Meiobenthic forms with size under 1 mm in the adult stage were identified to the supraspecific level (including: nematodes, bryozoans, hydracarian species, ostracod and copepod crustaceans). In total 17 supraspecific taxa were identified, of which 8 were not identified beyond supraspecific level (including: Turbellaria, Nematoda, Oligochaeta, Acarina, Ostracoda, Copepoda, Coleoptera and Diptera – Nematocera).

Comparison of macrobenthic and meiobenthic groups among the three habitat types (sedimentary, hard and phytal) revealed a consistent numerical dominance of meiobenthic forms (due largely to the abundance of nematodes). With regard to biomass, macrobenthic forms were dominant, due largely to the Nematocera dipterans from genus *Chironomus* (Fig. 2).

The qualitative structure of benthos communities is relatively simple, with two major groups of invertebrates dominating both numerically and by biomass. Dominant taxa included: Cironomidae (**Diptera** –Nematocera / **Insecta**) and vermiforms (**Nematoda** and **Annelida**, Fig. 3). From the relict Ponto-Caspian macrobenthic species the following were observed: *Cordylophora caspia* Pall. (**Hydrozoa**), *Hypaniola kowalewskyi* Gr., *Manayunkia caspica* Annenk. (**Polychaeta**), *Pontogammarus robustoides* Sars., *P. borceae* Car. and *Gmelina aestuarica* Car. (**Amphipoda**),

Paramysis baeri bispinosa Mart., *P. intermedia* Cz. (*Cumacea*), *Asellus aquaticus* L. and *Iaera sarsi* Valk (*Isopoda*), *Pterocuma pectinata* Sow. (*Cumacea*), *Asellus aquaticus* L. and *Iaera sarsi* Valk (*Isopoda*).

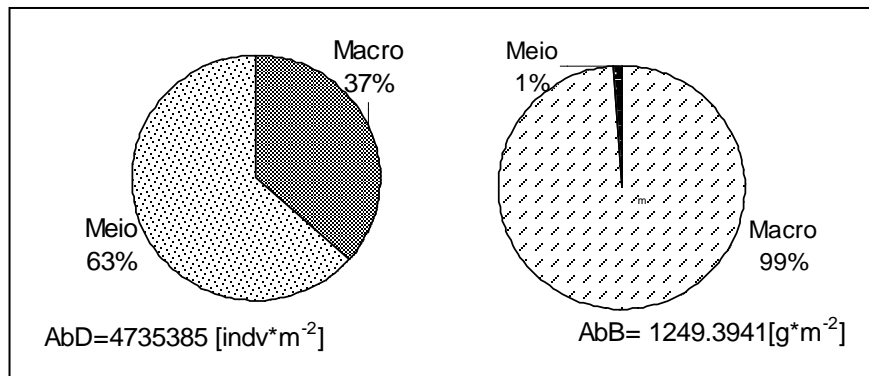


Figure 2. Ratio of macro- and meiobenthic invertebrate groups from Lake Siutghiol, July-August 2009 (by numerical abundance-AbD and biomass-AbB)

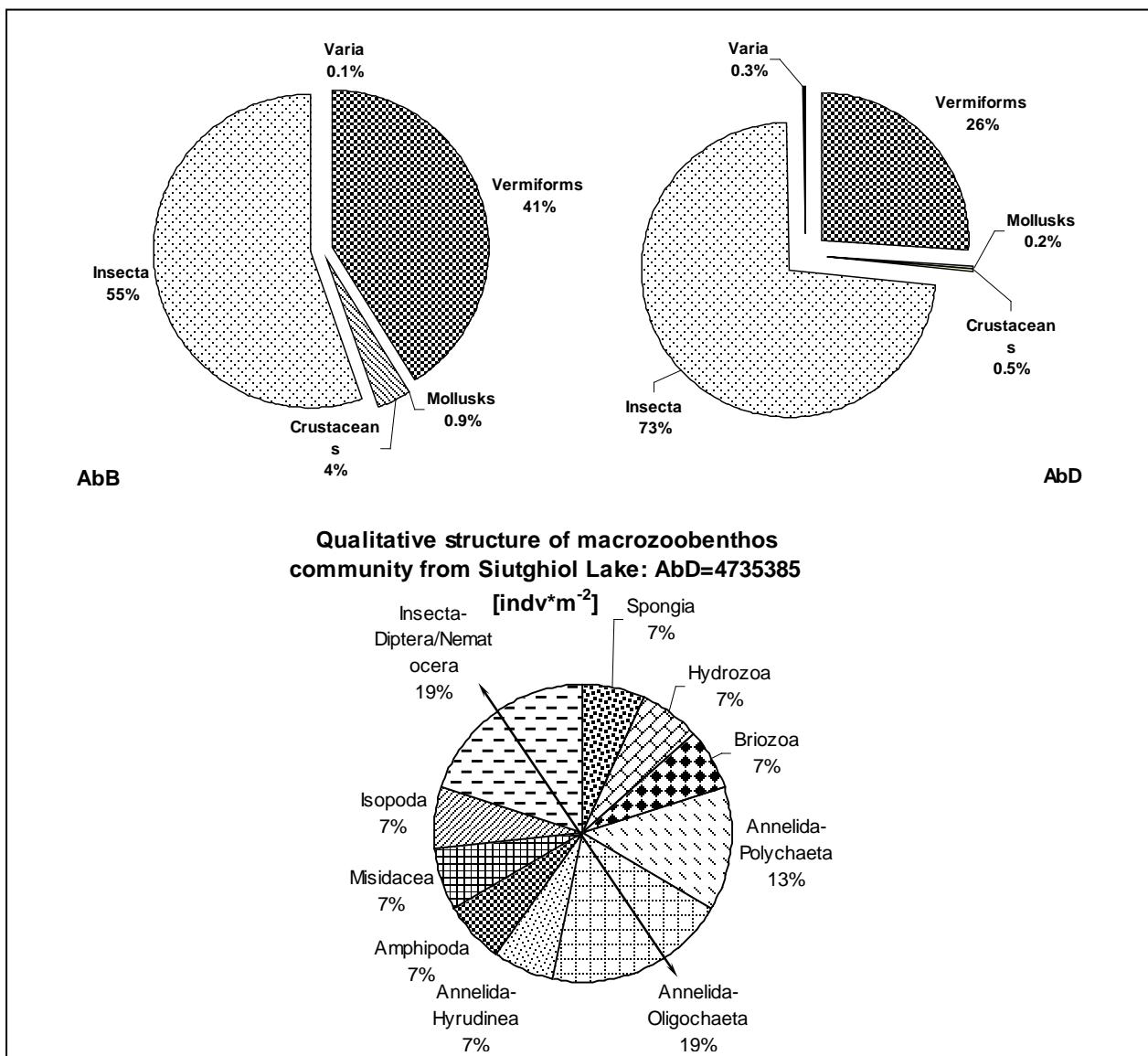


Figure 3. Ratio of the main groups of invertebrates in the benthos communities of Lake Siutghiol, July-August 2009 (by numerical abundance-AbD and biomass-AbB)

Crustaceans meet the highest number of relict species (9), in sedimentary habitats dominated by sand but also on vegetal-belt substrate; this is also confirmed by bibliographic data (Şerban et al., 2000, Şerban et al., 2001, Paraschiv et al., 2009) where all this group included a total of eight relict forms, all reported mostly in the vegetation belt, the most common are: amphipod *Echinogammarus warpachowsky*, two mysidae species (*Limnomysis benedeni* and *Paramysis kroyeri*, the latter one with 609 indiv. m⁻²) and two species of isopods (*Asellus aquaticus* and *Isopoda sarsi*). From the list of known Ponto-Caspian relicts (Mordukhai-Boltovskoi, 1964), in Lake Siutghiol benthos only 10% were encountered during studies conducted over the past 15 years.

Zoobenthos communities in studied habitats are dominated both numerically and by biomass by Diptera Nematocera and Oligochaeta populations (especially by biomass) and nematodes. The presence while in a small proportion (7%) of representatives of groups of crustaceans, Hirudinea, and Hydrozoa is due to their presence in small number and only in few habitats (especially on sandy substrate). Habitats with the lowest number of species and individuals were those with clay substrate with high organic matter content (with reduction processes), where besides nematodes and chironomids nothing else was encountered (especially along the eastern transect, Mamaia - Holiday Village). Benthic areas around Ovidiu Island and Palazu Mare, with sandy or silt substrate recorded the highest number of taxa (16, even though some species have been reported in a single location, as for polychaet *Hypaniola*, mysid and cumacean crustaceans).

Comparative analysis of main parameters-numerical abundance (A_bD), abundance by biomass (A_bB) and number of taxa of benthic communities in the three major types of habitat shows that the greatest differences are observed in numerical abundance (A_bD) from sedimentary habitats compared to the values of the same parameter calculated for communities associated to phytal and rocky substrate (Fig. 4). This is due to the large number of nematodes ($A_bD = 993\ 519\ \text{indv.m}^{-2}$).

Presence of nematodes in such increased numbers in sedimentary habitats is due to very high organic matter content (especially particulate, detritus) recorded and reported by chemical analysis conducted in parallel with biological determinations. The presence of detritivorous nematodes groups represents important information on benthos community structure (Wu et al., 2010). Nature of detritus and excess of particulate organic matter is

not only endogenous (resulting from processes at the level of every supra-individual biological system), much of it is of anthropic nature - reaching in different ways/processes to accumulate in the sediments.

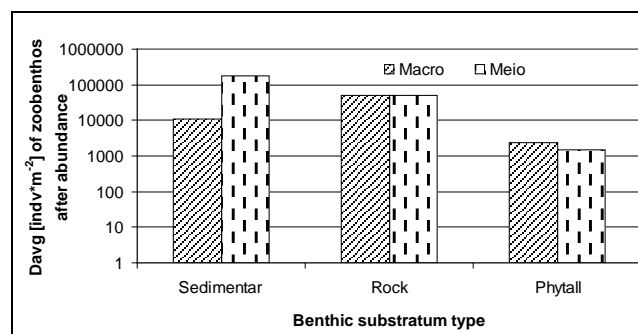


Figure 4. Comparative analysis of communities from examined types of habitat in relation to the value recorded for communities on hard substrate (with the lowest values).

Sedimentary habitats have the largest area of the lake, common not only in the deeper areas, but also frequently encountered in the shore area (e.g. along the entire eastern side of the lake where there is very little belt-vegetation). The dominance in our samples of sedimentophyll fauna can be explained on one hand by the extent of sedimentary habitats and on the other hand by trophic preferences: detritivores, filterer-detritivores, suspension feeding-detritivores from the water-sediment interface as well as from the interstitial water or sedimentivore of the most invertebrate species in these communities; the existence of high amounts of detritus and particulate organic substance is one of the important prerequisites for the development of opportunistic invertebrate populations, able to exploit these excess trophic resources. Thus, nematodes, annelids, many species of crustaceans and chironomid larvae among macrobenthic forms as well as the most part of the meiobenthic groups exploit this important trophic resource (Fig. 5). Increased values of average population density (over 1,000 indiv.m⁻² for macrobenthos or values increased by up to two orders of magnitude compared to the first category for meiobenthos) but also the occurrence frequency of these populations (between 80 and 100%) represents an important argument confirming this hypothesis.

Average macrobenthos population densities varied greatly among habitat types and showed different patterns compared to meiobenthos (Fig.6). Iliophilous fauna represents 36% of the total abundance of benthic fauna determined in this study; amphipod, mysid and cumacean crustaceans are absent in this type of habitat.

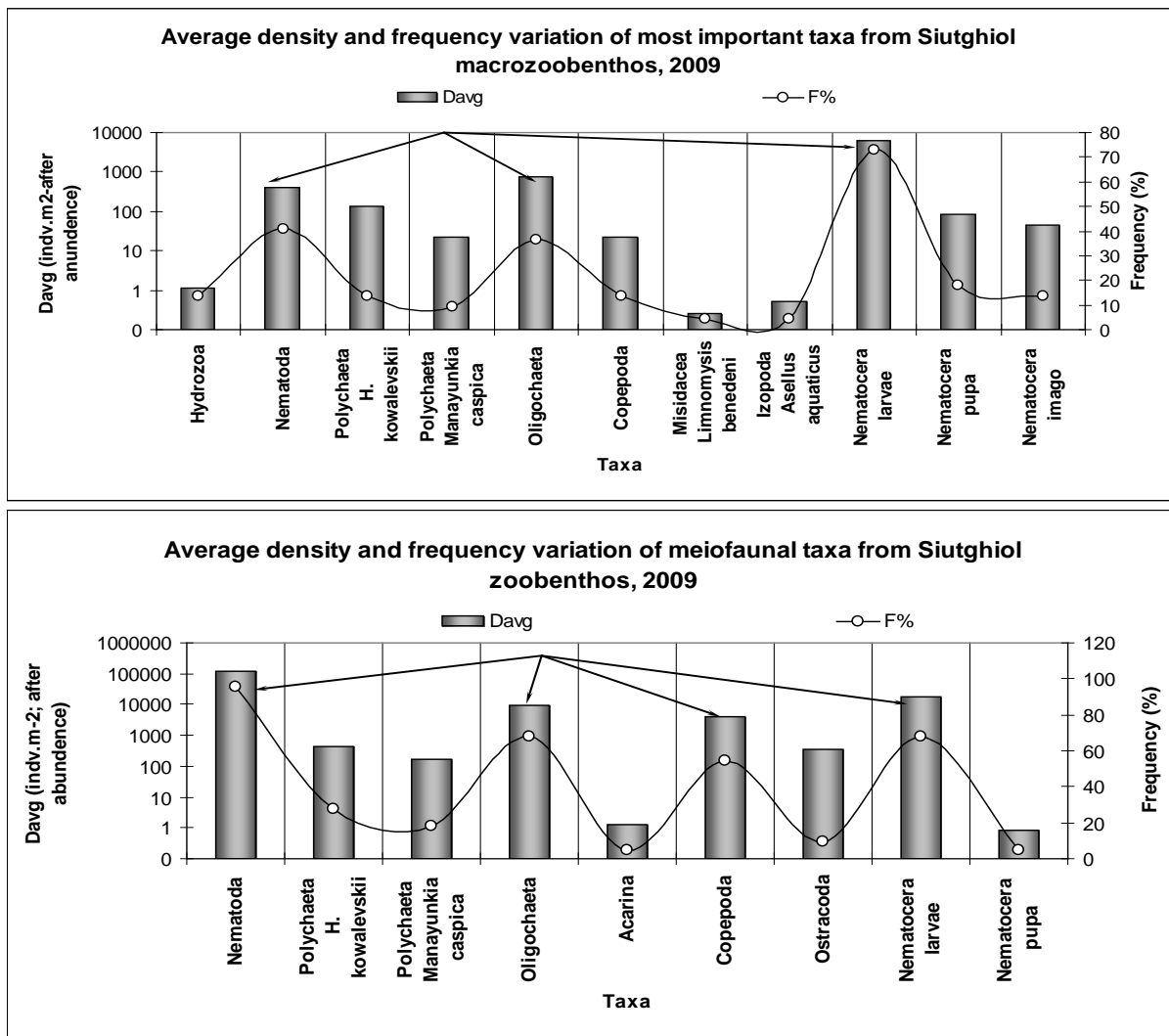


Figure 5. Average density and frequency of the main benthic populations from communities associated to sedimentary habitats in Siutghiol Lake, July-August 2009

Numeric abundance of copepods was much lower compared to the sedimentary habitats, in turn increasing the numerical abundance of hydracarian populations (over 22,000 indv.m⁻²). Average density value for iliophyll populations is 50 570 indv.m⁻² (compared to 10,302 indv/100g dry biomass, recorded value for phytophyll communities with dominant macroforms, Fig. 6A), representing a half of the value recorded by sedimentophyll benthofauna. Chironomids (Diptera Nematocera) are dominant for this type of substrate, which explains the close values of macro- and meiobenthic population densities (Fig. 6B). Since rocky and phytall substrate biotopes are mostly found on the shoreline, their associated fauna share similar species that are typically found in near shore. In case of sedimentary habitats we found an almost identical distribution of invertebrate taxa in both the shore area and lake center (Fig. 6). The lowest values of average density were recorded for macrobenthic populations from the phytal substrate in Mamaia 1 station (180

indv./100g dry biomass, Fig. 6) and from sediments taken from the connection channel between Siutghiol and Tabacarie Lake (808 indv.m⁻²). This channel crosses a tourist complex and the sediments are heavily contaminated with hydrogen sulphide and Pb and Hg (229, 507 and 0.29 µg/g respectively). The highest values were recorded for all benthos communities associated with the three types of substrate at Ovidius University Nautical Base station (77,550 indv.m⁻² iliophyll populations, Fig. 6).

Interestingly, the same average density values are recorded for both macrobenthic and sedimentophylic meiobenthic populations from the lake shore until about 4 meters in depth; we explain this situation as being due to the fact that in all sedimentary habitats, constantly dominant were only the representatives of groups: Nematoda, Oligochaeta and Diptera-Nematocera (chironomids), groups with pronounced affinities for sedimentary habitats with significant load in particulate organic matter.

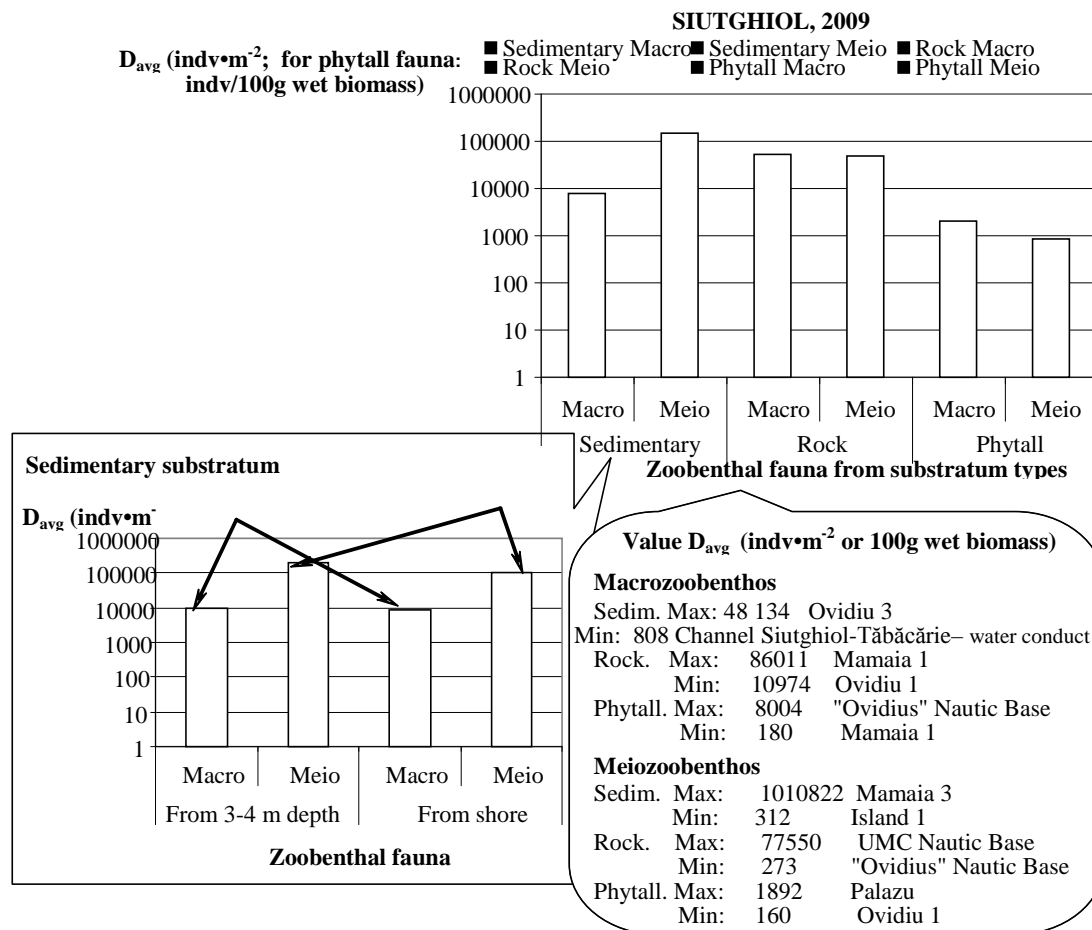


Figure 6. Distribution of benthic populations from Siutghiol Lake biotopes, July-August 2009 (D_{avg} is the average density of organisms; Macro - macrofauna; Meio - meiofauna).

3.2. Benthic Indices

The qualitative and quantitative determinations of living status parameters in conjunction with ecological indices calculated based on flora and fauna determinations were the basis for achieving several indices for assessing the health of ecosystems; however, often times these measurements are dependent upon the degree of representatives, the tools used, the methodology adopted for analysis and processing of biological material and especially upon the degree of repeatability in space and time of the determined parameters and indices values. Adoption of a biotic index for assessing the health status of aquatic ecosystems represents the method through which one may refer to ecosystem functionality at a time and in the particular determined conditions. Assessment by biodiversity indices is one of the most common methods used for a good period of time, but the resulting information does not provide much insight about the extent of human intervention or trophicity levels or even pollution levels reached by the aquatic ecosystem.

We believe that in order to obtain as

realistic information as possible on ecosystem health it is required to corroborate information about the state of water quality and substrate (especially sedimentary one - through active processes undertaken at its level, Lenat, 1993), about the structure and dynamics of superindividual ecological systems and not least about identification and assessment of the sources which can cause imbalances (even episodic) in ecosystems. All this information will form the basis for hypotheses regarding the evolution/dynamics of ecological systems, identification of underlying causes of this development and the measures necessary to maintain aquatic systems in certain self-regulation and dynamic equilibrium parameters.

We have proposed in this paper to achieve a health status analysis for Siutghiol Lake habitats using benthos invertebrate species that populate these habitats; for this we took into consideration the fact that a high diversity of invertebrate trophic groups in benthos communities represents a parameter that characterizes an equilibrium state of supraindividual ecological systems; the abundance

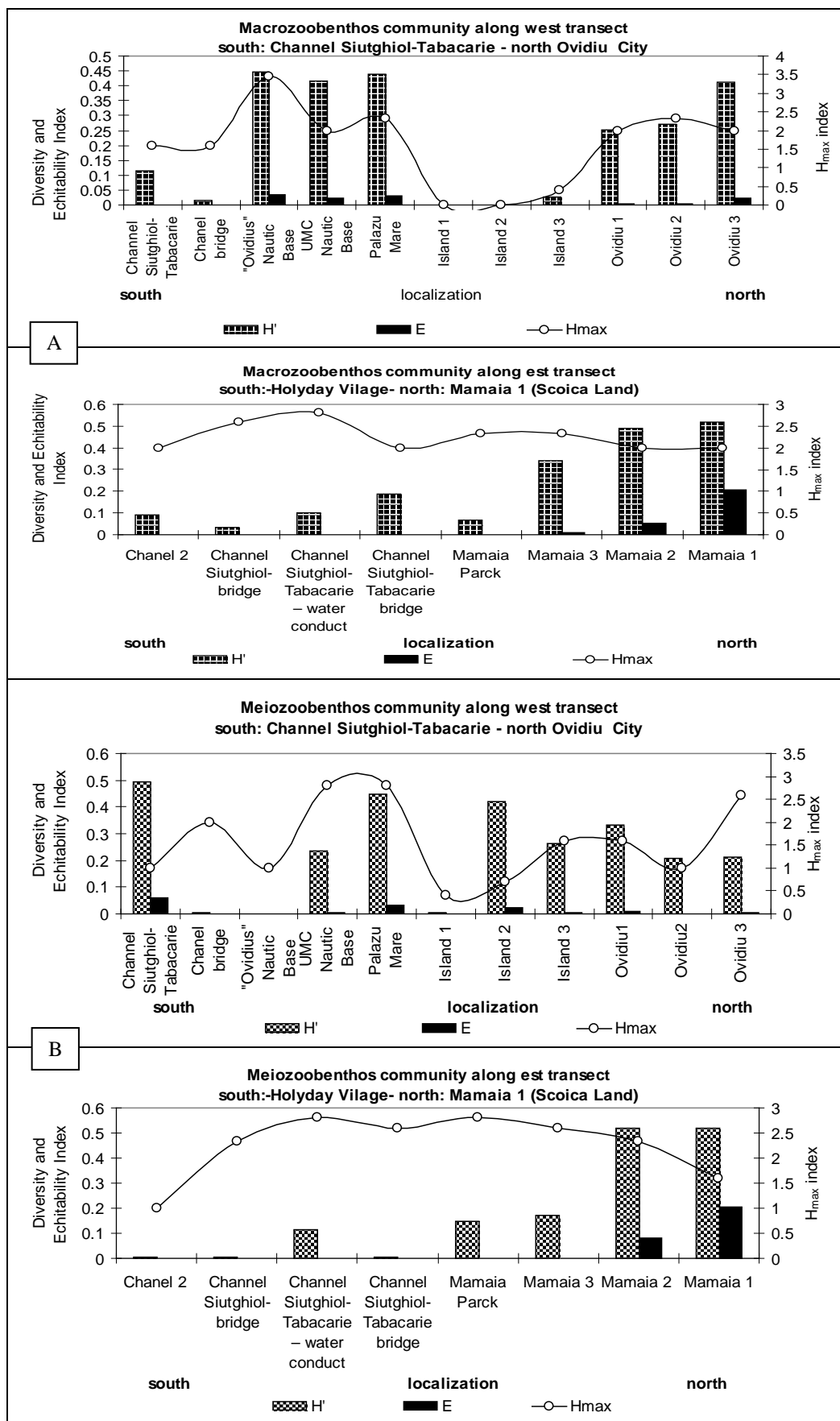


Figure 7. Variation of diversity and equitability indices calculated for macrobenthic (A) and meiobenthic (B) communities in western and eastern transects of Siutghiol Lake, 2009

or dominance only of groups with a certain type of feeding provides concrete information about the state of ecosystems functionality in correlation with the available trophic base. Dominance of detritivore populations (especially of nematodes, oligochaetes as well as of some chironomid species) is considered as having an extremely important ecological role in the movement of organic matter through benthic food chains (Abebe et al., 2006).

Indices of diversity (H') and equity (E) were calculated, and compared along two transects (north to south), parallel to the eastern and western shore of Siutghiol Lake. Sites along the eastern transect are subject to human impact generated by activities carried out in Mamaia tourist resort, while sites on the western side and especially around the Ovidiu Island are less affected, being subject to human impacts generated only by urban settlements: Palazu Mare and Ovidiu. Variation of H' and E indices within macrobenthic communities shows the southeastern area (near the channel connecting Lake Siutghiol to Lake Tabacarie) as having low values of the indices. This discontinuity in the variation trend for equitability (E) is due to a pronounced human impact through the input of organic matter from Holiday Village, Mamaia resort, Nautical Base of "Ovidius" University and Neptune Mamaia pier (Fig. 7A). Only groups with detritivore and sedimentivore trophic regime were found at high density in these locations.

The highest diversity and equity values of these indices were recorded for sites in the northwest extremity and around Ovidiu Island. All benthic Ponto-Caspian relict species reported by us were found in these areas of the lake, suggesting that these habitats provide a refuge for these species, due perhaps to a lower human urban impact. In the case of meiobenthic communities, in which detritivores and nematodes are the dominant groups, the discontinuity point of the trend curve for the indices in question is observed in sites in where macrobenthic groups are dominant with a more diverse trophic regime (Fig. 7B).

4. CONCLUSIONS

The need to develop monitoring indicators that are sensitive to human-induced stressors in aquatic systems is increasing. Beyond monitoring, the extent that indicators can incorporate ecological functionality better allows for their interpretation in formulating management and restoration plans. This paper compares several ecological indices and demonstrates that the functional status of grouped by trophic preferences of benthic macro and meiofauna covaries with the qualitative degree of human impact

in a coastal paramarine lake. Although the abundance ratio of macrobenthic to meiobenthic taxa also covaried with levels anthropogenic urban impact, it does not provide an informational indicator of the level of ecological functionality. Some of the taxa observed are specialist, stenobiotic relict species relict species (e.g. *Cordylophora caspia* Pall., *Hypaniola kowalewskyi* Gr. or most mysid species). However many more taxa are generalist, euribiotic relict species that are able to survive and develop increased effectiveness even in conditions with elevated levels of organic matter and periodic hypoxia.

Because of this, we consider that criteria for grouping by trophic regime and benthofauna type to be more relevant for linking environmental parameters. For example, the ratio between the density of macrobenthic populations (consisting of filterers and phytophagous taxa) relative to meiobenthic populations (consisting mostly of detritivores) represents a parameter that provides important information on ecosystem trophic structure. The quantity of nutrients in aquatic ecosystems such as Siutghiol Lake is high enough to generate phytoplankton blooms, and organic matter build-up in benthos is significant. This fosters the development of opportunistic groups that exploit these resources. Overall, the number of taxa is low in Siutghiol Lake with very few populations exhibiting high densities (e.g. nematodes, oligochaetes and chironomids). This contributes to low equity index values.

The diversity of the benthic fauna was lower in the southeastern part of the lake under increased anthropogenic impact due primarily to tourism activities developed in Mamaia Resort. The benthos zone situated near the channel linking Siutghiol Lake to Tabacarie Lake is also an area where there is no circulation of water due to the conformation of the shoreline which does not provide enough oxygen for the benthic domain and accumulates particulate organic matter.

We believe that the evaluation of the functionality status (or health status) of aquatic ecosystems based on ecological indices grouped by trophic preferences of benthic macro and meiofauna represents an appropriate way to estimate the degree of human intervention on the lake and it allows the assessment of its evolution trends.

Acknowledgements: The project was supported by National Science Foundation IRES award #0623474 to University of Wisconsin-Milwaukee

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Received at: 31. 03. 2013

Revised at: 12. 10. 2013

Accepted for publication at: 15. 10. 2013

Published online at: 21. 10. 2013