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Evaluation of the trophic state in the littoral of Ohrid lake

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Abstract

Evaluation of trophic states in Ohrid Lake is based in biomonitoring of standing water, especially in epiphyte diatoms in the littoral part which is a tectonic lake. Littoral epiphytic diatoms appear to be good indicators of the fishpond water quality. The trophic and saprobic state is correlated with nutrient enrichment and organic pollution. This indicates that the structures of the communities reflect real environmental changes. Individual species of diatoms have specific preference to habitat and requirement for water chemistry. In this study, more epiphytic and oligotrophic species (such as *Cymbella* spp., *Gomphonema clevei*, *G. gracile etc*.) were appeared while more euplanktonic meso and/or eutrophic species toward sediment surface. Diatoms can be used as long-term indicators with high spatial resolution. The most abundant species were: *Cyclotella ocellata, C. meneghiniana; Achnanthes minutissima, Amphora fogediana, Cocconeis pediculus, C.placentula, Cymbella, microcepfala, C. affinis, C. caespitose, etc.,* Some of diatoms species were found rarely which included: *Stephanodiscus medius, Achnanthes lanceolata, Amphora montana, Cymatoplleura elliptica, Epithemia, sorex, Fragilaria capucina, Gomphonema clavatum, G. gracile, Navicula bryophyla, N. cuspidate* etc. The species of a favorable taxonomic group occupy all water covered substrates of the lakes and are present during the whole period. Our data highlights the floristic richness in water, its trophy and pollution state. An important role has the human impact in the nearby basin giving recommendation aiming to prevent environment impact regarding water quality..

Keywords: lake Ohrid; littoral zone; trophic state; diatom; ecological status.

1. Introduction

Biomonitoring methods have been used in water especially in fresh waters, to obtain information on the effects of pollution by waste waters or from the runoff from fertilized agricultural land on the biota. For biological monitoring we based at the Water Framework Directive [4, 7, 8, 16, 21, 24] which monitor the ecological status for water bodies. Benthic diatom is abundant and the most species- rich primary producers in fresh water, living in almost all habitats from the source to the mouth [5]. Diatoms fulfill these prerequisites, they are ubiquitous in lakes and rivers and frequent in the euphotic benthic zone throughout the year. The species of a favorable taxonomic group occupy all water covered substrates of the lakes and are present during the whole period. They are used to determine the water ecology because the cell wall is made from siliceous. They are easily sampled and preserved, hence providing a permanent record which allows the assessment of short or long-term changes. Usually, they are sensitive to changes in water quality and thus have been commonly used for the studies of Lake Environment and palaeolimnology [1, 6, 12, 31]. Diatom communities are a popular tool for monitoring environmental conditions, past and present, and are commonly used in studies of water quality.Several studies have clearly demonstrated that diatom community's change with increasing concentrations of both organic and inorganic load of substances, making them the preferred organism group for in situ biomonitoring studies in Europe, the USA and Asia [3, 10]. To identify the ecology of water in Ohrid lake, various indices have been calculated on the basis of nutrient preferences and relative frequencies of the full range of diatom such as Trophic Diatom Index [8, 9, 12, 12, 22, 23,25] the Saprobic Index [9, 12, 13, 22, 23], Shannon Index (H'), [12, 13, 27].

The paper describes the analyses of the diatom population and evaluation of trophic state from the littoral of Ohrid lake.

2. Material and Methods

2.1. Site sampling

The Ohrid Lake is situated in south-eastern Europe extends across the borders of Albania, Greece, and Macedonia. Lake Ohrid has 87.5 km of shoreline and covers an area of 358.2 km^2. Although the average depth of the lake is 164 m, it has a maximum depth of 289 m. Lake Ohrid is old and isolated by surrounding hills and mountains that a unique collection of plants and animals has evolved. These include a number of relict species, or "living fossils", and many endemic species, found only in Lake Ohrid. Benthic diatom samples were collected at shoreline of Ohrid lake in Albanian part. The sampling sites were from Tushemishti to Lin Cape of Ohrid Lake in Pogradeci. Diatoms were sampled at 9 sites: Guri i Kuq (T_1); Memelisht (T_2); Hudenisht (T_3); Hudenisht/Memelisht (T_4); Pojske (T_5); Verdova river (T_6); Pogradeci river (T_7); Tushemisht (T_8); Starova river (T_9) on summer 2011.

2.2. Biological investigation

The biological investigation was based on a microscopic examination of diatom communities growing over stones or other substrates (periphyton). Diatoms were sampled in 0.5 m from the shoreline by scraping the upper surface of selected rocks from riffle sections of the lake with a toothbrush and the resulting suspensions collected and preserved in 4% formaldehyde [7, 13, 14, 20, 26, 28]. The cleaning of diatom frustules was done boiling the material, first with HCl*cc* and then, after washing, boiling them again with H_2SO_4*cc*, adding during the last procedure some crystals of KNO_3, as described by [11, 15]. About 500 valves per slide were counted using 100 oil immersions, yielding a 95% confidence for the data on species composition [7, 15, 20]. Diatoms were identified using standard literature [2, 11, 19, 28]. Different taxa have specific tolerances and preferences for phosphorus, which are characterized by the trophic location (1–5) of each indexed species. The weighting of each species varies from 1 to 3, depending on the range of trophic state they can tolerate and exist within [22, 23].

3. Results and Discussion

Lake Ohrid represents a unique ecosystem even from microscopic algae point of view, especially diatoms. Most of the species in Ohrid Lake are oligotraphent [13, 17] growing up only in clean waters with low nutrients, like *Gomphonema lateripuncatatum, Diploneis ovalis, Nitzschia denticula*, *Achnanthes minutissima*, *Cymbella microcephala*, *Navicula cryptotenella*, *Nitzschia angustata*, *Gomphonema truncatum*, *G. parvulum*, *Fragilaria capucina*, etc., Hudenisht (T_3); Pojske (T_5); Tushemisht (T_8) or Starova river (T_9). Other species of highest vitality in stronger mesotrophic to eutrophic waters were observed, like: *Amphora pediculus*, *Cocconeis pediculus*, *Cymbella minuta*, *Diatoma vulgaris var. vulgaris*, *Epithemia adnata*, *E. sorex*, *Gomphonema pumilum*, *G. olivaceum*, *Gyrosigma accuminatum*, *N. menisculus var. grunowii*, *N. reinhardtii*, *Nitzschia dissipata*, *N. palea*, *Rhoicosphaenia abbreviate* etc., were found in Gur i Kuq (T_1); Memelisht (T_2); Hudenisht/Memelisht (T_4); Verdova river (T_6).

Table 1. Evaluation of ecological indexes in Lake Ohrid, 2011.

Sampling sites	T1	T2	T3	T4	T5	T6	T7	T8	T9
N	25	36	28	33	28	29	39	32	36
H'	3.28	3.49	2.32	3.28	2.65	3.89	3.56	2.94	2.1
TI_{DIA}	2.3	2.3	1.8	2	1.8	2.4	2.5	1.5	1.6

Trophic Classess	Eutroph	Eutroph	Mesotroph	Meso-eutroph	Mesotroph	Eutroph	Eutroph	Oligo-mesotroph	Mesotroph
SI	2	1.8	1.9	2	1.8	2.1	1.9	1.6	1.7
Saprobic classess	β- mesosaprobic	β- mesosaprobic	β- mesosaprobic	β- mesosaprobic	β- mesosaprobic	β- mesosaprobic	β- mesosaprobic	Oligosaprobic β- mesosaprobic	Oligosaprobic β- mesosaprobic

N – Number of species; H'- Diversity Index; TIDIA - Trophic Index; SI - Saprobic Index, (T1- Gur i Kuq; T2- Memelisht; T3- Hudenisht; T4- Hudenisht/ Memelisht; T5- Pojske; T6-Verdova River; T7 – Pogradeci River; T8-Tushemisht; T9 – Starova river).

The high abundance of *Fragilaria capucina gracilis* group in this lake, diatoms preferring oligo-mesotrophic waters [29] is probably related to these environmental conditions. In fact, this species has spread widely and become quite abundant in Ohrid Lake over the last few years [13, 18]. The ecological preference groups of diatoms reflected the chemical character of the different streams.

Such changes in diatom community structures suggest a change in environmental conditions such as, for example the deterioration of trophic status observed in Ohrid lakes.

In nine sampling sites of Ohrid Lake the number of diatom species oscillatet from 25 (Gur i Kuq) to 39 species in Pogradeci river (Tab. 1; Fig. 1). The poorest stations in species were Gur i Kuq (T_1); Hudenishti (T_3). The high number of species were found in Memelisht (T_2); Starova river (T_9) approxemately 36 species, and Pogradeci river (T_7) approxemately 39 species.

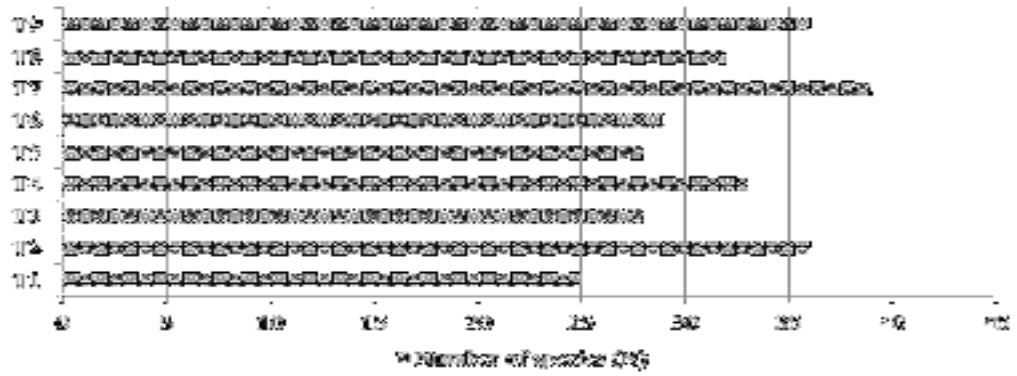

Figure 1. Number of species in nine sampling sites at sampling days on 2011, on Ohrid lake, 0.5 m. (T_1- Gur i Kuq; T_2- Memelisht; T_3- Hudenisht; T_4- Hudenisht/ Memelisht; T_5- Pojske; T_6-Verdova River; T_7 – Pogradeci River; T_8- Tushemisht; T_9 – Starova river).

Diversity index oscillated between 2.1 to 3,89 (Tab. 1; Fig. 2). Higher diversity values were observed in Verdova river (T_6) approximately 3.89 and 3.56 in Pogradeci river (T_7). The low value of diversity were obsereve in Starova river (T_9) approximately 2.1; in Hudenisht (T_3) 2.32; and 2.65 in Pojska (T_5). Low values of Diversity index (H') were the result of a small number of genera and a high abundance of a few common species.

Saprobic values oscillated from 1.6 (oligo- β-mesosaprob), in Tushemisht (T_8); Starova river (T_9); to 2.1 in Verdova river (T_6) (β-mesosaprob), [22]. The low value belong 1.6 which show the low value of organic matter and show clean water.

Based on Trophic Index in Ohrid Lake, trophic states oscillated from oligo-mesotroph to eutroph (Tab. 1; Fig 3). By Rott [23] average value of trophic diatom index oscillated from oligo-mesotroph (1.5) in Starova river (T_9); 1.6 in Tushemishtui (T_8) to eutroph from the interval 2.3 to 2.5 in Guri i Kuq (T_1); Memelisht (T_2); Verdova river (T_6); Pogradeci river (T_7), (2.7). Also the results show a relatively rich of inorganic matter and high level of different species of macrophytes vegetation. Most of them belong to hydrophilic or hygrophilic plant species.
Lake Ohrid also shows metal pollution near the sites of the old chromium, iron, nickel and coal mines outside Pogradeci town. Zones of pollution and habitat destruction along the lake shoreline because the littoral zone receives the direct impacts of the population living along the shoreline, it tends to be the most impacted environment in most lakes.

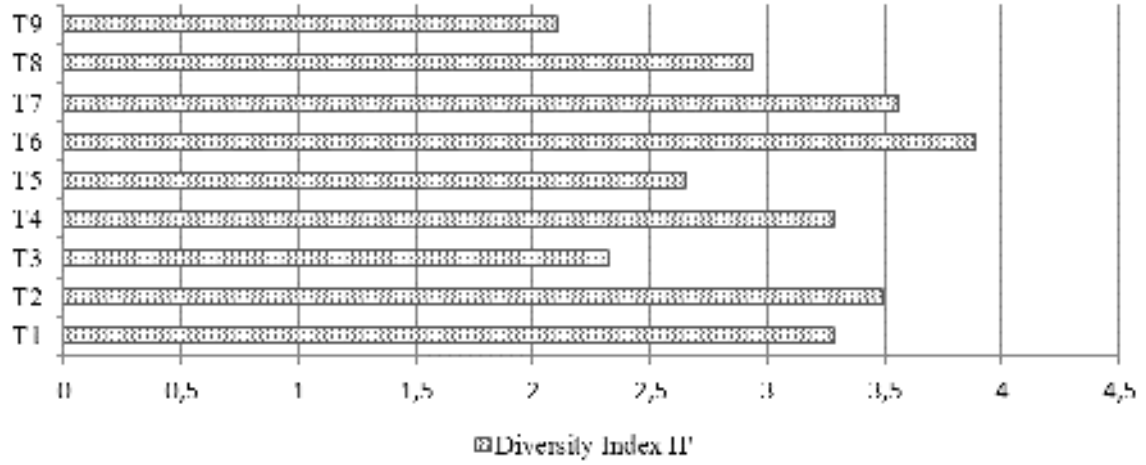

Figure 2. Shannon diversity index (H') in nine sampling sites at sampling days on 2011, in Ohrid lake, 0.5 m. (T_1- Gur i Kuq; T_2- Memelisht; T_3- Hudenisht; T_4- Hudenisht/ Memelisht; T_5- Pojske; T_6-Verdova River; T_7 – Pogradeci River; T_8-Tushemisht; T_9 – Starova river).

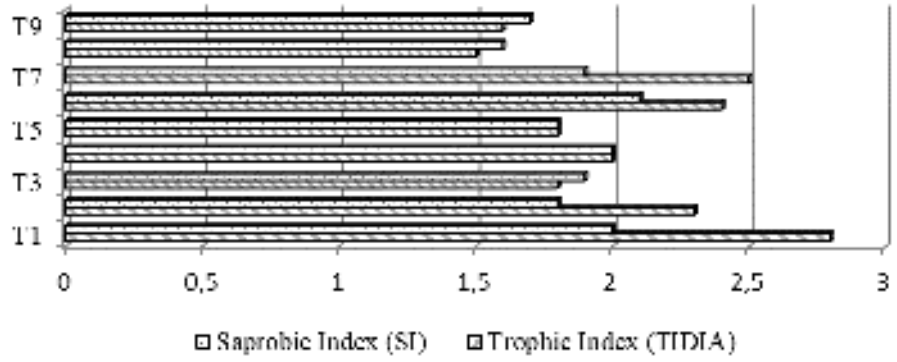

Figure 3. Saprobic index (SI) and trophic index (TI_{DIA} in nine sampling sites at sampling days on 2011, on Ohrid lake, 0.5 m. (T_1- Gur i Kuq; T_2- Memelisht; T_3- Hudenisht; T_4- Hudenisht/ Memelisht; T_5- Pojske; T_6-Verdova River; T_7 – Pogradeci River; T_8-Tushemisht; T_9 – Starova river).

The littoral zone adjacent to the town of Pogradec is heavily impacted. Impacts are also apparent to the northeast, to Guri i Kuq, Memelisht, Memelisht – Hudenisht. In the region around Pogradec, the nutrients in the untreated sewage that is discharged directly into the Pogradeci and Verdova river and discharged directly in the lake. Evidence of the ecological impacts of human activities is apparent in both the aquatic plant community and the phytoplankton in the near shore waters. In the region of Pogradec, phytoplankton densities are much higher than elsewhere along the shoreline, and the submerged plant community has high densities of pollution tolerant taxa. In the mining area of Memelisht and Guri i Kuq, these plants show evidence of metal contamination and stunted growth. The

population in the Pogradec areas has been growing rapidly, and as this growth continues, the pressures on the lake will continue to increase. A coordinated approach that manages urban growth, agricultural impacts, and industry must be developed. Biomonitoring have been used in freshwaters to obtain information on the effects of pollution by waste waters or from the runoff from fertilized agricultural land on the biota, [14].

In this study, the Shannon Diversity Index is a good and widely used tool to compare organism communities independent of pollution effects. The Saprobic Index [22, 30] and Trophic Indices [23] describe, by definition, the capacity for two different biological processes, the degradation of organic material and the primary productivity, respectively. In case of aquatic systems with low organic load, as a result of an efficiently working WWTP. In contrast, the Saprobic Index (SI) based on the load of dissolved organic materials originating from untreated or insufficiently treated municipal wastewater. This indicates that the structures of the communities reflect real environmental changes.

4. Conclusions

- The shore line habitats in Lake Ohrid belonging to an environment oligo-mesotroph to mesotroph represented by species such as: *Cyclotella ocellata, Achnanthes minutissima* and *A. biasolettiana, Fragilaria capucina, Gomphonema pumilum, G. olivaceum*, etc., also has other species that dominate eutrophic habitats such as: *Amphora pediculus, Cocconeis pediculus, Cymbella minuta, Gomphonema minutum, Nitzschia dissipata*, etc.
- The waters of Lake Ohrid near Pogradeci town were dominated by *Amphora lybica, Cymatolpeura solea, Fragilaria ulna, Navicula cuspidata,* etc. Average value of trophic diatom index oscillated from 1.5 (oligo-mesotroph) in Tushemishti (T_8), 1.6 Starova river (T_9) to 2.5 (eutroph) in Pogradeci towon from Pogradeci river (T_7), Verdova river 2.4 (T_6); 2.3 in Guri i Kuq (T_1) and Memelisht (T_2).
- Average value of saprobic index oscillated from 1.6 (oligo- β-mesosaprob), in Tushemisht (T_8) and Starvova river (T_9) to 2.1 (β-mesosaprob), in all other sampling sites. Composition of diatoms show a slightely-slightely with organic matter (oligo- β-mesosaprob and β-mesosaprob) and slightly polluted with inorganic matter (mesotroph), esception of four sampling sites: Guri i Kuq (T_1), Memelisht (T_2), Verdova river (T_6), Pogradeci river (T_7) were polluted (eutroph state).
- As above, in all sampling stations nutrients were lower than the EC guide values for surface water. High values of nutrients were measured in Pogradeci town from Pogradeci river (T_7). The diatom index has an advantage of a short-term indicator and furthermore, the samples can be easily collected at the shore line, 0.5 m from depth. This is also an advantage of diatom sapling in other depth in the lake. To the northwest of Pogradec, there are a number of old mines that used to produce chromium, nickel, iron, and coal.
- Lake Ohrid is being fertilized by nutrients in detergents and human and animal waste, and by nutrients in runoff from the land. As a result, the lakes are becoming more eutrophic in some sampling sites. Historically, Lake Ohrid was known as an “oligotrophic” or clear water lake. It is likely that Lake Ohrid may have “aged” by thousands of years in just the last few decades because the actions of people have greatly accelerated eutrophication.
- Species that prefer oligotrophic conditions are becoming less abundant.
- These changes provide further evidence that the Lake Ohrid ecosystem is changing and underscore the need to reduce the phosphorus inputs to the lake.
- Population growth and socioeconomic pressures are leading to continued destruction of the reeds, especially in the areas around Pogradec and Tushemisht village. The importance of these environments for both wildlife and human welfare is still not reflected in economic planning and decision-making.

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