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ABOUT ECOLOGICAL STATE IN SHKODRA LAKE

Përmbledhje: Në artikull është vlerësuar gjendja ekologjike në Liqenin e Shkodrës bazuar në cilësinë e ujit dhe eutrofikimin. Cilësia e ujit është vlerësuar me metoda kimike dhe shkalla e eutrofikimit nga prania e biotës. Impakti i ujërave të zeza në brigjet është vlerësuar si një faktor me impakt të lartë në cilësinë e ujit dhe në biodiversitetin e Liqenit të Shkodrës. Paraqitet dhe potenciali biotik i popullatave bimore dhe lidhja e tyre me gjendjen ekologjike të liqenit. Është vlerësuar gjithashtu dhe diversiteti i zinxhirit ushqimor dhe varianca e biodiversitetit.

Fjalë kyçe: *Liqeni i Shkodrës, eutrofikimi, cilësia e ujit, biodiversiteti, biota*

Abstract: It was evaluated the ecological state in Shkodra Lake based on water's quality and eutrophication. The quality of water is evaluated with chemical methods and the eutrophication scale on biota's presence. The impact of sewage waters on the shores is evaluated as a factor with a high impact in the water's quality and biodiversity in Shkodra Lake. It was presented the biotic potential of plant populations and their relation with the ecological state of the Lake. The diversity of food chains and variance of biodiversity is evaluated too.

Key words: *Shkodra Lake, eutrophication, water quality, biodiversity, biota*

INTRODUCTION

Shkodra Lake is located in a karst terrain in the outer part of the southeastern Dinaric Alps (Fig. 1). The lake waters level also varies seasonally from 4.7–9.8 meters about sea level. The total surface is about 370 km^2 and one third approximately 142 km^2 lies in Albania. Synoptic surveys established the difference in water masses in the northern lake and showed the importance of the importance of inflowing river water, especially the Moraca. Several physical factors greatly influence the movements of water, water quality and the distribution and abundance of all life associated with the lake. The lake is large and its surface area plus its shallowness make it especially susceptible to wind activities. Shkodra Lake has an outlet, the Bojana River,

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Figure 1. Map of Shkodra Lake

yet it received the inflow of a number of rivers. This condition plus the rainfall comes mostly in a few months leads to flooding of the flatlands on the northern and northeastern shores.

The flooding greatly increases the size of the lake and greatly increases possibilities for nutrient exchange, increases the number of habitats for lake organisms, and provides extensive spawning and feeding areas for fish and aquatic birds.

In subsequent sections the inflowing river waters have a big influence on the turbidity, temperature and the chemistry of the lake important to the biota. Shkodra Lake also receives a large inflow of spring water from the numerous okos, a feature of its karst topography. Water temperature remains uniform throughout the year in those okos and this condition attracts a large number of fish.

MATERIALS AND METHODS

Bibliography survey and chemical analyses in water and sediments.

DISCUSSION AND RESULTS

The geology of Shkodra lake basin is closely tied to the orogenic activity of the Balkan Peninsula. Mayor orogenic activity occurred during the late tertiary and early quaternary period to form the Dynaric Alps. The Lake basin is situated in one of the tectonic depressions paralleling the mountain range at the foot of the Dynaric Alps (Lasca *et al.*, 1981)

Hydrology

The direct drainage of Shkodra Lake basin is 5490 km^2, of which 4460 km^2 are in Montenegro and 1030 km^2 are in Albania. According Lasca *et al.*, 1981 under some ecological conditions, the direct drainage basin is augmented by water from the drainage basins of Drini and Buna River, which drains parts of Albania, Greece, Macedonia and Montenegro. The annual precipitation in Shkodra Lake basin is 2238 mm, but 20 % is lost due to evapotranspiration. The remains 80% reaches the lake and leaves the lake through its only outlet Buna River at an average of 332 m^3/ second. The lake is supplied with water from precipitation over the lake and over its catchment area. The largest inflow is from Moraca River, which provides more than 62% of the lakes water. Besides the Moraca River, Shkodra Lake receives water from the following Urelja, Grabovica, Velika Mrka, Mala Mrka, Pijavnik, Gostiljska Ri-

jeka, Zetica, Plavnica, Tara, Crnojevica Rijeka, and from Rrjoll and Vrake rivers in Albania. A portion of Lake's water is received from a series of both temporary and year-round karstic springs around its shorelines and from a number of sublacustrine springs (okos). The lake is reservoir in which river (surface) and oko (ground-water) mix. Therefore a complete understanding of the influxes both in water quality and quantity, are necessary if the relationships between the biological and geological systems and the carbonate cycle are to be understood. The chemical carbonate cycles behaves differently at each water influx point and should produce local variations in biological communities and the biological system.

Climate

Shkodra Lake is a subtropical body of water lying in an area that has an extremely evaporation rate. The large amount of precipitation, coupled with high summer temperatures contribute to chemical weathering and the development of karst landscape area. The yearly annual precipitation in Shkodra Lake during the last then years varies from 1850–3200 mm depending on location in an average year. The average air temperature during these years is 15,4^{0}C and range from a monthly average low of 4,2^{0}C to a monthly average high of 28,5^{0}C. The monthly hours of sunshine during the years are 2443–2655 hours per year (Dhora, 2005) with monthly average 88 hours in winter and 369 hours in summer months. The average number of cloudy day is 82 days.

Bathymetry

The lake s maximum length is 44 km along the straight line connecting the Shkodra outlet with the mouth of Crnojevica River. The dimension may be not significant as a causeway at Vraninja divides the lake in two separate bodies of water connected only by a narrow opening 50 meters wide, this results in disruption of the natural lake-water circulation pattern, and creates two circulation systems within the lake. These caused different biological communities to develop in the two separate, but adjacent parts of the lake. The length of the lake in a straight line from Shkodra outlet to the causeway is 38 km (Lasca *et al.*, 1981). Lake of Shkodra where included in determination of lake shore line is e parameter of a considerable in that it reflects a potential for greater development of littoral communities in proportion to the volume of the lake. All available data strongly suggested that Moraca River in flow is the major factor in the physical limnology of northern Shkodra Lake. Its in flow is obvious importance and thermal conditions and transparency. (Karaman *et al.,* 1981) The transparency of Shkodra lake waters as measured by Secchi disc ranged from 2–3 meters in the summer and increased to as much as 5 meters in November and December (Karaman *et al.,* 1981; Dhora, 2005; Rakaj *et al.*, 2009)

There is no question transparency measured by a Secchi disc is also a measurement of turbidity. The term turbidity, however, is all inchosive and offers little insight as to real causes of increased or decreased transparency. The rivers waters are turbid and affect the transparency of the water, plankton are less abundant in areas affected by inflow; consequently turbidity caused by plankton is reduced when large amounts of river water are present.

Chemistry of Shkodra's lake's water

The chemical characteristics of the waters of Shkodra Lake are the result of in flow of the major tributaries, in flow from the sub-lacustrine springs exchange between the sediments and over-lying waters, the extensive floating of the terrestrial environment and the chemical exchange between the waters and the extensive beds of aquatic macrophytes. The waters of the Lake are characterized by high dissolved-oxygen content and a relatively low content of dissolved salts. The lake is a bicarbonate lake; the other anions have much lower concentration. Calcium is the main ion. The nutrient content is low, especially in the pelagial waters.

Analyses of water and sediments of Shkodra Lake show that the physicochemical conditions in the pelagial differ from those of the littoral, especially when the aquatic macrophytes are growing (Bekteshi, 2004).

The sediment water interface is oxidized as a consequence of the high dissolved-oxygen concentration in the overlying waters. The condition effects chemical conditions in the sediments for example the transfer of phosphorus from sediments to the water. Shkodra Lake is characterized by frequent and numerous winds all year around. Under completely mixed conditions relatively rapid release of phosphate occurs probably under aerobic conditions of lake sediments. (Karaman *et al.,* 1981)

Higher concentration of phosphorus in the sediments in some littoral areas is due to high local inputs, but it was discovered that the macrophytes can contribute the phosphorus to the sediments by serving as a transport mechanism.

The available information on nutrient concentration and plankton production in the pelagial indicate that the lake is not suffering from excessive nutrient loading. Apparently the use of agricultural fertilizers and detergents has affected the lake. Analyses for various possible pollutants show that generally the quality of water is satisfying, although there are some disturbing data on concentration of PCB in benthic organism (Rastall *et al.,* 2004).

High trace metal content in water is associated with high trace metal content in the sediments. By analyzing lake sediments it is possible to determine the origin, distribution and also the possible hazards of metal contamination (Rastall *et al.,* 2004).

The total evaluation of the chemistry of water of the lake include the following components analyses made in water: dissolved oxygen, carbonates, bicarbonates, pH, calcium, magnesium, alkalinity, conductivity, consumption of MKO 4, ammonium, nitrates, sulfates, chlorides, total inorganic and organic phosphorus, iron and manganese, water temperature. (Sokoli, 2008)

Oxygen – soluble oxygen in water depends on the atmosphere, photosynthetic activity in water and the metabolic activity in sediments. Data for respective DO is 6,7 mg/l and of DO % is about 61.85.

Carbonate – carbonate content ranged between 2 and 19 mg/l CO_3^{2-}. This range of values is due to composition und uptake of bicarbonates as a result of photosynthetic activity. Bicarbonates varies from 76.8–234 mg/l HCO_3^-

Alkalinity – during the period of study alkalinity varied from 1.56–2.82 mval/l.

pH – the pH values varies around 7.85 but most often they ranged within the interval 8–8.4. Alkaline water of Shkodra Lake contains mostly bicarbonates.

Calcium – the water is characterized by high quantity of calcium 47.8 mg/l Ca. The maximum values occurred during the high water level.

Phosphates – the recorded values of orthophosphates in the pelagial ranged usually between 0,002–0,005 mg/l P. The unpurified waste water coming from rivers increase the quantity of phosphates in the littoral parts of the lake.

Total phosphate in unfiltered lake water ranged from 0,004–0,040 mg/l P. The high concentration of phosphorous in the littoral areas causes ample growth of the macrophytes vegetation. It is fact that the densest growth is found in the part of the Lake strongly affected by rivers, Moraca River etc.

Nitrate – nitrate concentration ranged in the pelagial from 0.013–1.300 mg/l NO_3. Nitrate concentration varied greatly seasonally. In the macrophyte vegetation zones nitrate values decreased at times to zero.

Nitrites – the values ranged from 0,012 -0,034 mg/l N. they were higher in the littoral than in the pelagial.

Ammonium – the values were higher in the littoral than in the pelagial. They vary in winter around 0, 27 mg/l N and 0,075 mg/l N in summer.

Chloride – chloride concentrations ranged from 1.8–4.3 mg/l.

Magnesium – the concentration of magnesium varies around 6.7–9.5 mg/l Mg.

Sulfate – concentration ranged from 4–32 mg/l SO_4.

Organic matter – the content of organic matter in the sediments is important both from biological production and the organic pollution of waters. Organic carbon ranged from 1.9–2.8% in the peagial and from 4.4 -5.6 in the littoral. Total nitrogen content to the sediments was about 0.4%.

During the last decades the anthropogenic pollution is going to be significant in this area. The Moraca River, the main tributary of the lake, brings most pollutants into the lake from Aluminium Company (KAP), agricultural plantations complex Podgorica landfill, the city drainage collector *etc*. A number of OCPs and PCBs have already been detected in the waters and tributaries of Lake Shkodra/Skadar using conventional sampling and extraction methodologies (Misuroviç, 2002).

The concentration of heavy metals in both water and sediments, in general, is still within the permissible limits of the EU standards. The high concentration of Cr and Ni in samples of Drini River is a result of existence of mines in North Albania and geological structure of sediments (Neziri & Gössler, 2006) The toxicologically relevant HOPs including EROD-inducing and potentially estrogenic compounds are widely distributed in the lake and readily available for uptake by aquatic biota (Rastall *et al.,* 2004).

By application of Chemcatcher passive sampler for heavy metals dissolved forms content in lake Shkodra there were identified a number of bioavailable forms of heavy metals concentrated in the collecting chelating (EmporeTM) disk as Cu, Mn, Zn, Fe, Co, Cr, Cd, Pb. The results are reported as absolute content (μg/disc) (Neziri & Lazo, 2008).

The chemical analyses of the sediments and water in the Lake of Shkodra have shown that there are differences for the majority of the chemicals analyzed. The near shore zone is not isolated body water from the open waters of the lake.

Is it known that the rate of biological productivity of a great number of lakes is governed to a great extent by the rate of phosphorus cycling in relation to the input loading of phosphorus from external sources. The exchange of phosphorous between the sediments and overlying water is the major component in the phosphorous cycle in natural waters. The near shore waters have greater concentration of phosphorous by the tributaries is especially characteristic of the rivers and particularly evident in the localities near the mouth of rivers.

The macrophytes large amounts of phosphorous and nitrogen produce at the same time nutritive substance for bacteria causing their mass development which accelerates the regeneration of nutrient salts, and mineralization of organic matter.

Based on the values it can be concluded that the waters of the lake are between the low and medium level of mineralization. From the sanitary aspects waters of some sites are very polluted by organic matters.

Aquatic macrophytes

Submersed and emergent aquatic macrophytes are a conspicuous feature of Shkodra Lake littoral. The shallow mean summer depth of the Lake 5.1 m has permitted the extensive development of macrophyte communities. The submersed macrophytes of the lake presumably play an important role in nutrient cycling, and provide shelter for animals as well as substratum for *Aufwuchs* communities of attached microflora and microfauna. The macrophyte communities range from relatively conspicuous emergent and floating-leaved communities dominated by *Phragmites communis, Scirpus lacuster, Nuphar luteum, Nymphea alba* and *Trapa natans*, through submersed communities dominated by *Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton lucens, Potamogeton perfoliatus, Potamogeton crispus,* and *Ranunculus aquatilis*, to inconspicuous submersed communities with *Vallisneria spiralis, Najas marina* and *Charophytes*. The aquatic vegetation of Shkodra Lake can be considered to be composed of communities which are dominated by a small number of species, while at the same time many species are present in very small numbers. This is also true for the surrounding marshlands and terrestrial vegetation of the general region (Adams, 1981; Rakaj, 2008; Kashta, 2005; Sokoli, 2008).

The north and the northeast coasts are quite different. The northen shoreline slopes gradually into the lake as a consequence of the fluvial sediments brought by a number of inflowing rivers, forming a broad, shallow littoral region often covered by very dense macrophyte vegetation. Both macrophyte associations mentioned above occur together from the littoral to the pelagic region of Shkodra Lake. However, they do not exhibit a regular pattern of distribution due to a number of factors: the configuration of the terrain, the composition of the bottom sediments, and the inflow of a large number of small rivers (Rakaj *et al*., 2009).

Spatial distribution of algae

Algae populations within Shkodra Lake are not uniform in distribution and may generally bi discussed in terms of pelagic populations and benthic – epiphytic populations, and latter including epiphytic forma of algae living on the aquatic macrophytes in the littoral zone of the lake. Of the 685 species known, 235 are classed as plankton forms and roughly twice as many, 450 species are benthic – epiphytic living primarily on the macrophyte population. (Rakaj & Miho, 2005)

It has been recognized for some time that the very extensive growth of macrophytes were very important to the productivity of Shkodra lake.

The northern part of the Lake macrophytes cover about 38 km^2. The other major concerns were over the role of macrophytes in the phosphorous cycle of Shkodra Lake, especially of the aspect of whether the littoral macrophyte communities serve as a trap for allochthonous nutrients or as a source. The influence of aquatic macrophytes on chemical characteristics of the waters is shown by the results of the experiments where macrophytes were enclosed in plastic bags.

Karaman *et al*., 1981; Rastall *et al*., 2004; Rakaj, 2006 conclude that these macrophytes are physiologically adopted for photosynthetic use of bicarbonates with a resulting deposition of carbonate and decreases in alkalinity and conductivity.

Zooplankton

The investigations of the zooplankton and microfauna of Shkodra Lake extended from the end of last century until now. They have been primarily descriptive and taxonomic studies without a systematic approach (Petkoviç, 1981)

A taxonomic list of all forms of zooplankton and microfauna was established consisting of 355 species and forms classified into 11 divisions: *Rotatoria* (205), *Claodocera* (54), *Copepoda* (29), *Protozoa* (50), *Lamellibranchiata* (1), *Ostracoda* (9), *Bryozoa* (2), *Gastrotricha* (1), *Branchyura* (1), *Hydrozoa* (2), and *Spongia* (1). No doubt there is still a lot of work to be done in order to enrich this list (Dhora, 2005).

CONCLUSIONS

1. The waters of the Shkodra Lake are characterized by high dissolved-oxygen content and a relatively low content of dissolved salts. The lake is a bicarbonate lake, Calcium is the main ion. The nutrient content is low, especially in the pelagial waters.

2. Based on the values it can be concluded that the waters of the lake are between the low and medium level of mineralization. From the sanitary aspects waters of some sites are very polluted by organic matters.

3. Moraca River in flow is the major factor in the physical limnology of northern Shkodra Lake. Its in flow is obvious importance and thermal conditions and transparency.

4. Aquatic macrophytes are influencing the chemical characteristics of the waters in the Lake. The very extensive growth of macrophytes is very important to the productivity of Shkodra Lake.

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