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DISTRIBUTION, MORPHOLOGICAL VARIABILITY, ECOLOGY AND THE PRESENT STATE OF *NITELLA* FROM LAKE OHRID AND ITS SURROUNDINGS

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Abstract - Our research into 52 profiles of the littoral zone of the Macedonian part of Lake Ohrid and numerous samples taken from its surroundings has resulted in a detailed picture of the composition of the Charophyta vegetation in the lake. The results of the research also include data regarding the species composition and present state of *Nitella*. The dominant species of *Nitella* is *Nitella opaca*, which is characterized by a specific distribution, morphological variability and ecology. The present state of *Nitella* is not steady, especially in the watershed of the lake, since in this area there are some permanent changes in the hydrology of the terrain. Therefore, there is a need to establish long-term and complex monitoring which will result in the prompt detection of risk factors and influences, thereby enabling a rapid reaction to a possible newly emerged negative state.

Key words: Lake Ohrid, *Nitella*, distribution, morphological variability, ecology, present state

INTRODUCTION

Lake Ohrid is a unique natural ecosystem of Tertiary age and oligotrophic character, which is characterized by a high level of biodiversity and endemism. The lake is located in the southwestern part of the Republic of Macedonia and in the eastern section of the Republic of Albania. Moreover, it is one of the most important centers of diversity of Charophyta in the Balkan region (Blazencic et al. 2006a; Blazencic et al., 2006b).

In Lake Ohrid, there are classified four zones of macrophytic vegetation, while the deepest, most developed and almost continuous belt along the lake is the belt of charophytes, which occupies an area of 10.49 km^2 and has an approximate total biomass of 10500 tons (Trajanovska, 2002; Trajanovska et al., 2004).

The Charophyta algae in Lake Ohrid and its surroundings are represented by a total of 21 species that are grouped into 4 genera: *Chara* with 14 species, *Nitella* with 5 species, *Nitellopsis* with 1 species and *Tolypella* with 1 species (Stanković, 1929; Jakovljević, 1936; Kostić, 1936 and Trajanovska, 2009).

In our research, *Nitella* was represented by the following species: *Nitella opaca* as a dominant species in the lake and *N. flexilis,* which was located only in one of the localities.

It should be noted that the changes in the Charophyta flora in Lake Ohrid and especially in its sur-

rounding are mostly due to an anthropogenic influence. Likewise, the lake's watershed is endangered, above all, by the rapid urbanization and increase of agricultural activities in the area. As a result, the greatest changes over the last years are noted in the species composition of the genus *Nitella*.

In order to determine the changes of distribution and the composition of the genus *Nitella* that occurred due to changes in the terrain (drying-off of some water-covered areas where they used to exist) in the last 80 years, samples were collected from localities and areas (canals, slumps, mud and alike), which were earlier recorded in the literature as habitats of this type of algae.

MATERIALS AND METHODS

The vegetation material was collected during the summer period from 2007 to 2010 from 52 different profiles along the Macedonian part of the lake (Fig. 1). Out of each of the researched localities, samples were collected from several depth points, depending on the width of the vegetation belt, characteristics and the slope of the lakebed.

During the collection of the material, we used a Van Veen grab (type spider). Collection was conducted in accordance with the standard limnological methods for the collection of macrophyte vegetation (Lind, 1986; Wetzel, 1975; Wetzel and Likens, 1979).

Charophyta species were identified with the following identification keys: Corillion (1957, 1975), Wood and Imahori (1964, 1965), Gollerbax and Krasavina (1983), Krause (1997) and Schubert and Blindow (2003).

RESULTS

During our research, two species from *Nitella*, *Nitella opaca* and *N. flexilis,* were found. *N. opaca* was the dominant species in the lake and it was recorded in 12 of the 52 localities. On the other hand, *N. flexilis* was found in only one locality and with very few sterile sample units (Fig. 1). Detailed information re-

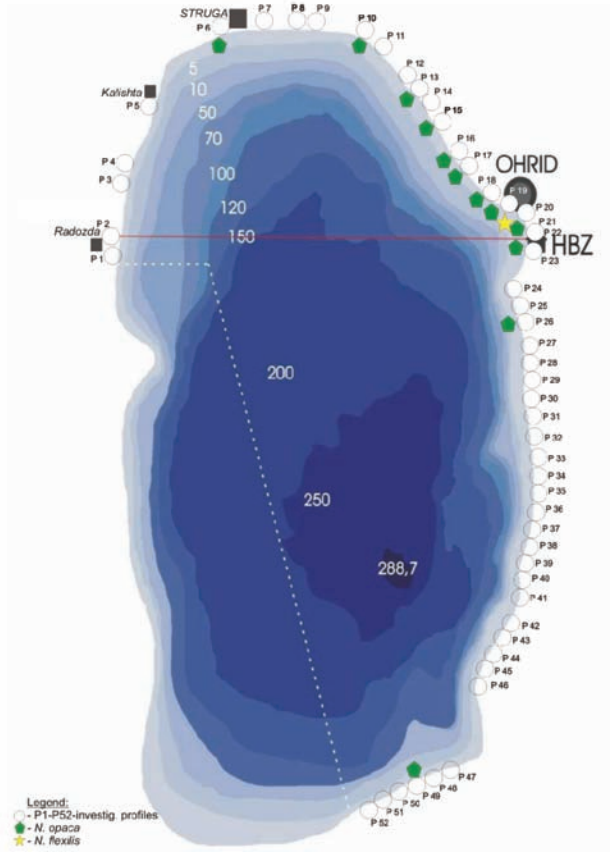

Fig. 1.Map of investigated profiles and distribution of *Nitella* species in Lake Ohrid and its surroundings.

lating to the morphological variability, distribution and ecology of the species *N. opaca in* Lake Ohrid is presented below.

Nitella opaca (Bruzelius) C. Agardh 1824
Morphological variability

Nitella opaca is the dominant species in Lake Ohrid (Fig. 2), with a size that is small to medium. It is fresh green in color with a characteristic incrustation in a shape of ring, which gives the species a zebra-like appearance. Branchlets are divided once into two or three top cells. The species is dioecious.

The length of the samples of *N. opaca*, as with all other charophytes, changes depending on the depth at which they are found. The lowest length of the

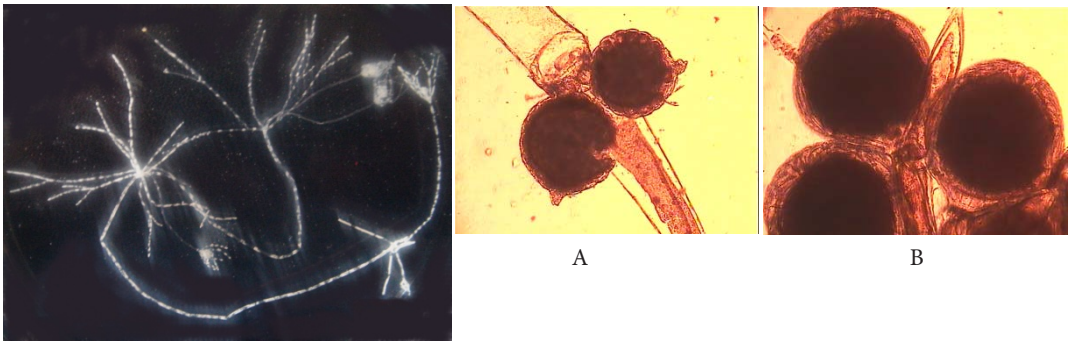

Fig. 2. *Nitella opaca* from Lake Ohrid (A – part of a female plant with oogonia; B – part of a male plant with antheridia).

collected samples was only 4.9 cm, found at a depth point of 0.5 meters. Thereafter, from the depth of 1 m to 7 m, an increase in length from 5 to 22.34 cm was noted. The length increased from 8 to 14 m and the largest sample of the species was found at a depth of 15 m, with the maximum length of 80.3 cm.

The diameter of the main axis was between 270 and 800 μm. Larger dimensions for the diameter of the main axis were found in the female samples compared to the those registered in the male samples of the species.

The length of the internodes differed in different parts of the plants (top, middle and basis). Hence, the length at the top of the plant was from 0.8 to 3 cm, in the middle 1.8 to 3.5 cm, the largest dimensions in the length of the internodes were at the base of the plant, i.e. from 2 to 7 cm.

There are 6 to 7 (usually 7) branchlets in a whorl with lengths from 0.5 to 3 cm (depending on whether they were from the top or from the base of the plant), while the diameter was from 151.23 to 300.58 μm. The length of the last segment of the phyloids was 70 to 79.18 μm. .

The reproductive organs were noted in five of the researched profiles. In profiles P13, P21 and P26 only male samples were registered, while in profiles P17 and P19 male and female samples were recorded at several of the researched depth points. The antheridia are large and their diameter varied from 220.40 μm (in profile P17 at a depth of 6 m) to 814.80 μm (P26 at a depth of 15 m). The oogonia were yellowish in color and ellipsoid or egg-like in shape. Their length varied from 231.81 to 647.67 μm and their width from 166.21 to 578.54 μm, depending on whether they were juvenile (underdeveloped) or adult and developed. The coronula was 26.67-98.73 μm in height and its width was 31.67-165.21 μm. The spiral cells of the oogonia formed 7-9 twists. The oospores were dark brown, about 320-465 μm long and 310-450 μm wide, with 6-8 ridges.

The fructification of this species in the lake is more intensive during the summer months (especially during July and August) and it is characterized with higher intensity in the plants which live in more shallow waters in comparison to those that live in deeper waters, which are usually sterile.

Distribution

Regarding the horizontal distribution of the species *N. opaca* in Lake Ohrid (Fig. 3), it can be noted that the smallest registered distance from the coast at which this species was recorded was 0.80 m (profile P10). The greatest distance from the coast in was 410 m (profile P26).

Nine of the researched profiles of this species occupies a certain area and forms a belt at the bottom of the littoral of the lake. The greatest width of the belt

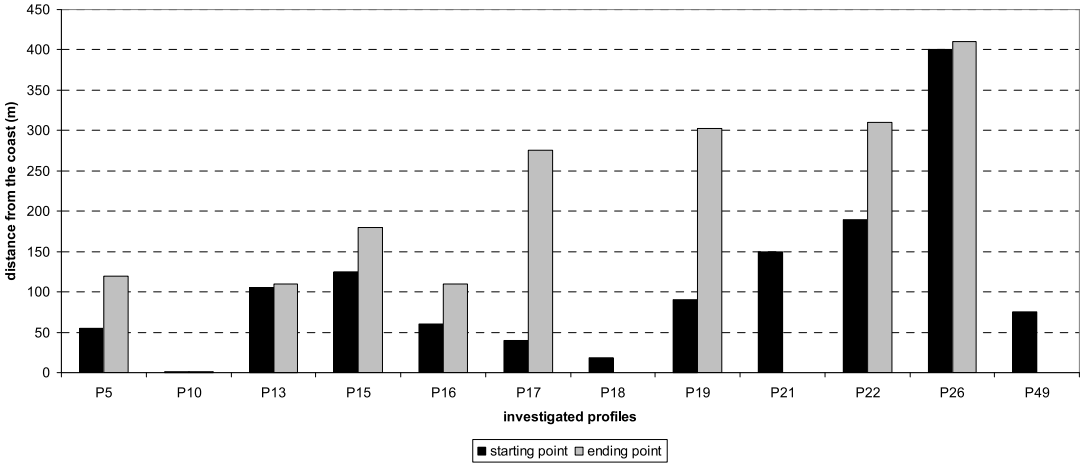

Fig. 3. Horizontal distribution of *N. opaca* from Lake Ohrid.

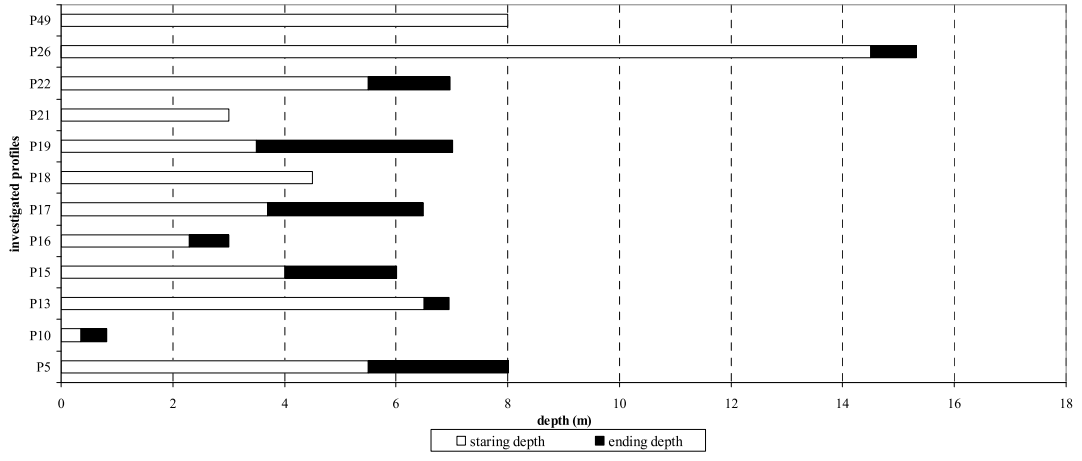

Fig. 4. Vertical distribution of *N. opaca* from Lake Ohrid.

was noted at P17 (236 m), while the smallest width was recorded at P10 and it is estimated to be 0.7 m. At P18, P21 and P49, *N. opaca* was present only in a certain depth and distance from the coast; hence, there can be no discussion about a belt of distribution of the species.

The vertical distribution of the species *N. opaca* in Lake Ohrid is given in Fig. 4. The minimum depth at which the species is evident was 0.35 cm (profile P10) while the maximum depth was estimated to be 15 m (P26). The species was usually recorded at depths from 3 to 6 m.

Ecology

N. opaca is present only in certain regions of Lake Ohrid, particularly in the areas of the lake littoral near to the inflows of the larger tributaries rivers, as in the case of profiles P13, P16, P17 and P49, which are near the inflows of the River Koselska, River Velgoska and River Cerava. It was usually found in areas where there are streams in the water layers and where there is a certain accumulated quantity of organic material. Likewise, this species was registered in areas where there are underground springs, such as the case of profile P5, i.e. the distribution overlaps with

Table 1. Comparative researches of *Nitella* species in Lake Ohrid and its surroundings.

No.	*Nitella* - species	Jakovljević (1936)	Kostić (1936)	our researches (2007-2010)
1	*Nitella opaca*	+	-	+
2	*Nitella hyalina*	-	+	-
3	*Nitella mucronata*	-	+	-
4	*Nitella syncarpa*	-	+	-
5	*Nitella flexilis*	-	-	+

the areas of cold-water streams, which occur because of the waters originating from the springs.

It mainly grows on muddy and sandy-muddy bottoms, with pH of 7.73-8.89 and water temperatures of 21-26°C during the summer period. The samples for our research were collected during this period.

N. opaca mostly grows together with other vascular submerged macrophytes in shallower waters, such as *Potamogeton perfoliatus, V. spiralis* and *Zannichellia palustris*. Of the charophytes, the most present in the community are *C. ohridana, C. denudata, and C. globularis,* with only one locality with *N. flexilis*. *N. opaca* in Lake Ohrid is the most present and forms pure populations, especially in deeper waters.

Table1 presents a short overview of the presence of species of the genus *Nitella* of research conducted in 1936 (Jakovljević, 1936; Kostić, 1936) compared to the results of our research conducted in the period 2007 – 2010. As can be seen, in 1936 4 species of *Nitella* were recorded, while in our research only 2 are recorded, one of which is present at only one locality, represented by a very few samples.

DISCUSSION

Concerning its distribution, *N. opaca* is a cosmopolitan species that has been recorded in North and South America, Africa and Asia. In Europe, it is also widely distributed, especially in the countries neighboring the Baltic Sea (Corillion, 1975). On the Balkan Peninsula the species is registered in almost all countries, including Serbia, Montenegro, Bosnia and Herzegovina, Croatia, Slovenia, Bulgaria, Albania and Romania (Blaženčić et. al., 2006 b; Trajanovska, 2009). In the Republic of Macedonia, the species was noted in Lake Ohrid (Jakovljevic, 1936), and the species *N. flexilis* is recorded for the first time in our research, but at only one of the researched profiles, at a depth of 3 m.

Furthermore, there is a risk of confusing *N. opaca* with the rest of the species from the genus *Nitella*. For instance, sterile samples of *N. opaca* cannot be distinguished from *N. flexilis*, but the difference is in the fact that *N. opaca* is dioecious. Moreover, in the samples of *N. opaca* there was an absence of mucous around the gametangia, a characteristic that makes the species different from *N. syncarpa*.

There are some differences between the dimensions of the diameter of the antheridia of *N. opaca* in our research and those of some research conducted in the past. In fact, according to our results the diameter of the antheridia varies within the interval of 220.40-814.80 μm, while in other similar research these dimensions are quite different, e.g. Krause (1997) – 650-700 μm, Moor (1986) – 500-700 μm, and Golerbah and Krasavina (1983) – 650-775 μm. These differences are presumably due to the repetitive measuring conducted in different parts of the plan, but also due to the different stages of development of the samples. This difference occurs in the dimensions of the oogonia, too.

Ecological circumstances influence the morphological differences of *N. opaca*, which were registered between the forms existing in deeper waters and those found in shallower waters. Actually, the forms

found in deeper waters are stretched, branched, with less heads and they have longer phyloids, darker in color and less fertile. Then again, the forms located in shallower waters have greater density, are compact, more incrustated, forming more heads and are much more fertile.

Generally, by analyzing the results of comparative studies of the species of *Nitella* conducted in 1936 and in the period 2007 – 2010 (Table 1), the question arises as to the reasons for such a difference in the species composition of *Nitella* at the mentioned periods. This is especially important when the state of the genus *Nitella* in the lake and its surroundings is discussed.

The first issue that has to be taken into consideration is that there are some differences in the collecting of the charophyte material in our research compared to that undertaken in 1936. These differences mainly include no overlapping of the researched localities (in the research conducted in the past there were fewer research profiles), but also the changed terrain, which is mostly visible in the surroundings of the lake and in its littoral zones.

However, the most important question to emerge from the comparative studies is in regards to the species *N. syncarpa*, *N. hyalina* and *N. mucronata*, which were detected by Kostić (1936), but which our research did not been register in the lake. *N. syncarpa* was recorded in 1936, mainly in the northwestern region of the lake, especially in Radozda and Struga, i.e. on the left side of the outflow of the River Crn Drim. In addition, it was found in the surroundings of the town of Struga, and also in the hunting spots Strusko and Kalisko, as well as in Gumnisce, Pestani and Rajca. During the collection of the material for our research, we tried to overlap the localities with those where the species had been found in the past, but unfortunately we did not record it. The area near Struga, which is known as the hunting spot of Strusko and Kalisko, used to be mainly swampy, with numerous canals, but nowadays has dried-off and is known as Strusko Field and used for wheat cultivation.

N. mucronata was also registered in 1936 in two forms: f. *heteromorpha* and f. *rubistior*, but it was not found in our research. *N. mucronata* f. *heteromorpha* has been found in Podmolje (on the road Ohrid – Struga) in a swampy part that does not exist nowadays. In fact, the entire part in this region, which used to be a swamp, today is overgrown with terrestrial plants and bushes. *N. mucronata* f. *robustior* has been found in Gorica, i.e. in a canal that is located between Ohrid and Gorica. This canal does not exist today, having been dried-off for a long time.

N. hyalina was recorded in the mentioned research from 1936 in the hunting grounds Strusko and Kalisko, which, as has been noted above, do not exist anymore and have been dried-off and transformed into Struško Field with large arable areas. In addition, this species was registered in Radožda and Gumnišće in 1936 (we collected samples there, as well), but we did not found any sample of this species.

Furthermore, Lake Ohrid, as has been noted above, belongs to the group of oligotrophic lakes. The anthropogenic influence is certainly present, but the capacity of the lake for resistance to this influence is still quite high, partly due to the measures undertaken for its protection, but mainly due to the hydrology and morphology of the lake's basin and its capacity of self-purification. However, the watershed, unlike the lake, is endangered. The rapid urbanization, as well as the increased level of agricultural activities, has resulted in a decrease in the quality of the rivers and land in the watershed.

Since the early 1970s, the shoreline of the lake has been permanently affected by an anthropogenic influence. Because of the processes of melioration, urbanization and agricultural activities, many swampy regions near the lake have vanished while others are very close to vanishing. Ohrid Blato, Struga Blato (in the part where there used to be the hunting grounds Struško and Kališko), the numerous canals and puddles that have dried up along the road Ohrid – Struga, near the lake are classical examples of the direct impact of the anthropogenic factor. In this particular case,

the building of military objects, a dendrological center and in particular, the building of numerous beaches and other types of infrastructure, are typical manifestations of the mentioned anthropogenic influence. The drying of these swampy parts, as well as many puddles and canals, has resulted in the destruction of living habitats of numerous flora and fauna species.

The changes in the status of the Charophyta flora, especially in the composition of the genus *Nitella*, occurred mainly due to such long-term attacks on the water accumulations in the surroundings of the lake. However, it should be noted that there is an increase in the disturbances of the littoral zone of Lake Ohrid as well (the building of private hotels with beaches near the lake, the building of parking places drying-off the littoral parts of the lake, especially in the region of Struga). This is negatively affecting the charophytes that live in such shallow littoral zones.

Lake Ohrid is classified as a trans-boundary lake. It belongs to two neighboring countries, i.e. Republic of Macedonia and Republic of Albania. Moreover, the watershed of Lake Ohrid includes Lake Prespa as its sister lake, which is shared among three countries, i.e. Macedonia, Albania and Greece. The undertaking of long-term monitoring and prevention measures for the entire watershed of the lake depends on equal contributions of all three countries. Unfortunately, the political, social and cultural differences among these countries are seeing an increase in the so-called invisible barrier that is obstructing the process of harmonization of the legislative in an adequate manner, resulting in a lack of protection. In this regard, the elevation of the science over this barrier would result in the countries working together in the field of prevention and restoration of the endangered ecosystems, or at least some parts of them. The intensification of attempts in mutual research for the complex protection of the lake and its surroundings is the only realistic possibility for the continuation of the existence of the special environment of the lake, including the charophytes that inhabit these regions.

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