

# Macrophyte-based Assessment of Nutrient Pollution of Lake Prespa, Republic of Macedonia

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**Abstract:** Macrophytes are one of the basic biological quality elements used in the assessment of ecological status of aquatic ecosystems. In this study, we analysed the macrophytes in three transects at four sites from the littoral of the Macedonian part of Lake Prespa. A total of 15 macrophyte species were found. The macrophyte community was characterised by the presence of emergent and submerged species. In order to assess the nutrient pollution, the macrophyte index for each site and transect was calculated. The results showed that the nutrient pollution was mainly moderate-immense, immense and massive. The pollution was found to be heavy and very low only at single sites.

**Key words:** Macrophyte index, ecological status, Lake Prespa

## Introduction

Macrophytes as relatively long-lived organisms are one of the basic biological quality elements used together with phytoplankton, macrozoobenthos and fish in the assessment of the ecological status of lakes (SOLIMINI et al. 2006). Macrophytes in the littoral zones of lakes have two fundamental properties, which make them useful and attractive as limnological indicators: 1) they react slowly and progressively to changes in nutrient conditions (MELZER 1999); and 2) the littoral zone may experience patterns of nutrient (and pollutant) concentrations caused by natural or artificial inflows, as well as by diffuse, non-point sources (DAVE 1992, DRAKE & HEANEY 1987 in MELZER 1999, PENNING et al. 2008) and rooted submerged macrophytes may reflect this patchiness. Therefore, macrophyte indices reflecting nutrient pollution have been developed in Europe for both lakes (MELZER 1999) and rivers (SCHNEIDER et al. 2000, SCHNEIDER & MELZER 2003).

In the littoral zone of Lake Prespa, the composition of the macrophyte vegetation varies

depending on water depth. Emergent and floating macrophytes grow at smaller depths and closer to the coastline, while submerged macrophytes grow in deeper water (TALEVSKA et al. 2009). During the past decades, Lake Prespa has been under great anthropogenic pressure, which drastically affected the ecosystem, resulting in a decline in the water level and an increase in the trophic status (PAMBUKU et al. 2014)

Our main aim was to study the macrophyte composition and determine the level of nutrient pollution in the littoral of the Macedonian part of Lake Prespa through calculations of the macrophyte index, as it was not done before for this lake.

## Materials and Methods

Lake Prespa is a transboundary lake shared between the Republic of Macedonia, the Republic of Albania, and Greece. The lake is located at 849 m a.s.l., has a surface area of 254 km<sup>2</sup>, a catchment area of 1,300

km<sup>2</sup>, a maximum water depth of 48 m, a mean water depth of 14 m, and a volume of 3.6 km<sup>3</sup> (WAGNER et al. 2010).

The sampling of the macrophytes was conducted in the summer period during 2015.

The macrophytes in Lake Prespa were monitored at the following sampling sites: Oteshevo (MV1), Ezerani (MV2), Krani (MV3) and Nakolec (MV4). At each site, macrophytes were surveyed by three transects from the upper littoral to the lower vegetation limit according to the WISER method, which is recommended by the European Committee for Standardisation (Comité Européen de Normalisation, CEN) (BIRK et al. 2010). The WISER method consists of establishing transects perpendicular to the lake shoreline with a length covering the complete depth range of macrophyte occurrence. At each site, a central transect was selected (first of the three transects per site). The other two transects were located to the left and right of the first transect, respectively. The minimum inter-distance between two transects per site was 5 m. The transects were subdivided into 1 m depth zones (1 m depth intervals).

In shallow water, the entire plants were collected manually. In deep water, the plants were collected by the Van-Veen grab.

The collected material was identified to species level, using different floras and keys for vascular macrophytes (HAYEK 1924–1933, JORDANOV 1963–1970, JOSIFOVIĆ 1970–1977, TUTIN et al. 1964–1980), and charophytes (CORILLION 1957, 1975, WOOD & IMAHORI 1964, 1965, GOLERBAH & KRASAVINA 1983, KRAUSE 1997, SCHUBERT & BLINDOW 2004).

The species occurrence was registered at each transect and depth zone, and the abundance of each species was estimated according to a five degree scale (TÜXEN & PREISING 1942 in MELZER 1999): 1 = very rare, 2 = infrequent, 3 = common, 4 = frequent, 5 = predominant (abundant).

A catalogue of nine indicator groups of macrophyte species (MELZER & SCHNEIDER 2001), exhibiting different sensitivity towards nutrient enrichment, was used to calculate the macrophyte index (MI), ranging from 1 to 5, with higher values indicating nutrient enrichment. Species belonging to indicator group 1 are restricted to oligotrophic conditions, whereas those belonging to indicator group 5 mainly occur in eutrophic, nutrient-rich lakes or sections of lakes. The remaining seven groups range from 1.5 to 4.5 and represent transitions between these two extremes. In order to compare the results from the shallow and deeper water, the MI of each sampling point was determined.

The macrophyte index was calculated according to the formula described by MELZER (1999) but with updated indicator values and class boundaries as described by MELZER & SCHNEIDER (2001):

where:

$MI$  = Macrophyte index

$I_i$  = Indicator value of  $i$ -th species

$Q_i$  = Plant quantity of  $i$ -th species

$n$  = Total number of species with an indicator value.

To calculate the macrophyte index each abundance value was cubed ( $y = x^3$ ) since the correlation between abundance and plant biomass is not linear (MELZER 1999). According to the calculations, the macrophyte index was divided into seven classes, each representing different degrees of nutrient enrichment. Different colours were assigned to each of these seven classes to allow a clear illustration of the results: very low nutrient enrichment (dark blue); low (light blue), moderate (dark green); moderate-immense (light green); immense (yellow); heavy (orange); and massive (red).

## Results and Discussion

During the summer sampling campaign, at the sampling sites Oteshevo, Ezerani, Krani and Nakolec, a total of 15 representatives of macrophyte vegetation (three emergent species and 12 submerged species) were determined. At all studied sites, there were no floating species recorded (Table 1). In the littoral, the macrophytes were distributed in different zones (belts).

The dominant emerged plant species at the sampling sites in the Macedonian part of Lake Prespa was the reed *Phragmites australis* (Cav.) Trin. ex Steud., which formed a natural discontinuous belt. The other present emerged plants were *Typha angustifolia* L. and *Typha latifolia* L., which were present in the belt of reed as pure associations. However, these species were rare, while the submerged macrophytes were the most frequent. The dominant submerged macrophytes at the sampling sites were the representatives of the genus *Potamogeton*: *Potamogeton perfoliatus* L., *P. pectinatus* L., *P. lucens* L., *P. pussilus* L., *P. crispus* L., and *P. trichoides* L. Present were also the species: *Zannichellia palustris* L., *Myriophyllum spicatum* L., *Ceratophyllum demersum* L., *C. submersum* L., *Vallisneria spiralis* L., and *Najas marina* L. (Table 1).

The greatest number of macrophyte species was registered at the sampling sites Oteshevo (13 species) and Ezerani (12 species). This was possibly due to the great amount of different organic and inorganic

**Table 1.** The list of all identified macrophytes at each sampling site and transect in the Macedonian part of Lake Prespa, in summer 2015; MV1, MV2, MV3, MV4 – site codes

	SPECIES	Oteshevo MV1 central	Oteshevo MV1 left	Oteshevo MV1 right	Ezerani MV2 central	Ezerani MV2 left	Ezerani MV2 right	Krani MV3 central	Krani MV3 left	Krani MV3 right	Nakolec MV4 central	Nakolec MV4 left	Nakolec MV4 right	Total number of sites
1	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	+	+	+	12
2	<i>Typha angustifolia</i> L.		+	+	+	+	+				+	+		7
3	<i>Typha latifolia</i> L.				+	+	+		+	+	+	+		7
4	<i>Potamogeton perfoliatus</i> L.	+	+	+	+	+	+	+	+		+	+		10
5	<i>Potamogeton pectinatus</i> L.	+		+	+		+		+		+	+	+	8
6	<i>Potamogeton lucens</i> L.	+		+	+	+	+							5
7	<i>Potamogeton pusillus</i> L.			+	+						+			3
8	<i>Potamogeton crispus</i> L.	+	+		+	+								4
9	<i>Potamogeton trichoides</i> L.	+												1
10	<i>Myriophyllum spicatum</i> L.	+		+	+			+			+			5
11	<i>Ceratophyllum demersum</i> L.	+	+		+		+							4
12	<i>Ceratophyllum submersum</i> L.		+											1
13	<i>Vallisneria spiralis</i> L.	+		+							+			3
14	<i>Najas marina</i> L.				+	+							+	3
15	<i>Zannichellia palustris</i> L.	+			+				+		+		+	5
	Total number of species:	10	6	8	12	6	8	3	5	2	9	5	4	

substances present in the lake water as a result of untreated water from the hotel and tourist camp at Oteshevo, and the inflow of the Golema River into the lake at Ezerani. Thus, favourable conditions are provided for the growth and development of submerged vegetation, which is dense and high, with flowers on the water surface, forming meadows at the bottom of the lake. At these sampling sites the reed *P. australis* was dense and high, and the reed belt was wide and continuous.

At the other two sampling sites Krani and Nakolec, the number of macrophyte species was lower. This was most likely due to the low amount of substances in the lake water because of sedimentation of the sand from the rivers Kranska and Brajcinska flowing into the lake near the studied sites (VELJANOSKA-SARAFILOSKA 2014). Therefore, at these sampling sites the conditions were unfavorable and the number of submerged species was very low and they were less developed. This was especially evident at the sampling site Krani, where the lowest number of submerged species (6) was recorded and

the reed was also less frequent and lower than at the other surveyed sampling sites.

The algae *Cladophora* sp. were registered at almost all studied sites.

The macrophyte index (MI) at the studied sites and transects in the Macedonian part of Lake Prespa varied from very low to massive nutrient pollution (Table 2). At one of the sampling transects the value of the MI indicated very low pollution, at three of the transects – moderate-immense nutrient pollution, at other three transects – immense pollution, while at one of the transect the nutrient pollution was heavy, and at three of the transects it was massive.

The number of registered species differed not only at different transects but at the different depth points from the same transects. These differences were consequently reflected in the values of the macrophyte index. Thus, a greater number of species, i.e. higher species richness, did not *per se* mean higher values of the abundance or higher values of the macrophyte index. In other words, there was no positive (regular) correlation between the species

**Table 2.** Macrophyte index (MI) calculated at each sampling site and transect in the Macedonian part of Lake Prespa, in summer 2015, and corresponding classification of nutrient pollution

Sampling sites	Macrophyte index (MI)	Nutrient pollution
Oteshevo MV1 central	3.94	Massive (red)
Oteshevo MV1 left	3.88	Heavy (orange)
Oteshevo MV1 right	3.37	Immense (yellow)
Ezerani MV2 central	2.01	Very low (dark blue)
Ezerani MV2 left	3.22	Moderate-immense (light green)
Ezerani MV2 right	3.49	Immense (yellow)
Krani MV3 central	3.00	Moderate-immense (light green)
Krani MV3 left	4.00	Massive (red)
Krani MV3 right	0	
Nakolec MV4 central	3.39	Immense (yellow)
Nakolec MV4 left	3.00	Moderate-immense (light green)
Nakolec MV4 right	4.5	Massive (red)

richness and the abundance, as well as the values of the macrophyte index.

The data obtained during our study cannot indicate the nutrient pollution of entire Lake Prespa, since the number of sites and transects was limited. Also, some of the recorded macrophyte species are not included in the list of the macrophyte indicator groups (MELZER & SCHNEIDER 2001). Therefore, we can recommend a modification of the existing table with groups of indicator species in accordance with the presented macrophyte species from the lake in the future. The advantage of the macrophyte index over traditional metrics in assessing the ecological status has been successfully proved by the previous studies undertaken and completed in Lake Ohrid (SCHNEIDER et al 2014, TRAJANOVSKA et al. 2014).

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