

# Phytoplankton Composition of Lake Prespa, Republic of Macedonia

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**Abstract:** Lake Prespa is an ancient lake located in the southeastern part of Europe. It is a transboundary lake shared by the Republic of Macedonia, Greece and the Republic of Albania. In order to study the phytoplankton composition, surveys in the Macedonian part of Lake Prespa were carried out at four sampling points in the littoral zone and two sampling points in the pelagic zone, during spring and summer period of 2013. Our results indicated that phytoplankton assemblages of Lake Prespa and their spatial and temporal distribution were typical of mesotrophic lakes. Bacillariophyta and Cyanophyta were the dominant divisions within the phytoplankton assemblage, showing distinct seasonal variations. Bacillariophyta predominated in spring, while Cyanophyta in summer. According to the trophic state index (TSI) based on chlorophyll *a* concentration, all sampling points at Lake Prespa indicated mesotrophic conditions.

**Key words:** Lake Prespa, phytoplankton, trophic state, pelagic zone, littoral

## Introduction

Phytoplankton species represent the most sensitive biological components of water ecosystems, which first respond to changes in nutrient concentrations. Regarding this fact, phytoplankton investigations are included in all monitoring programmes on aquatic ecosystems. According to the European Union (EU) Water Framework Directive (EU 2000), phytoplankton is one of the biological quality elements used in the assessment of the ecological state of surface waters.

In the second half of the 20th century, phytoplankton investigations in Lake Prespa were conducted only occasionally (KOZAROV 1959, 1960, 1972, MITIC 1996, MITIC et al. 1997). PATCEVA (2005) carried out comparative analyses of phytoplankton communities and studied the trophic state of lakes Ohrid and Prespa in the period from 2001 to 2003. The analyses of the qualitative and quantitative composition of the phytoplankton revealed significant changes in the phytoplankton composition compared to previous studies (PATCEVA 2005, PATCEVA & MITIC 2006).

Our aim was to study the qualitative and quantitative composition of phytoplankton and characteristics of phytoplankton community in the Macedonian part of Lake Prespa, in order to compare these parameters, as well as the trophic state of the lake to previous results.

## Materials and Methods

The surveys of the phytoplankton in the Macedonian part of Lake Prespa were carried out at four sampling points in the littoral zone and two sampling points in the pelagic zone. The water samples were collected at the following sites: Ezerani north-west (NW) (N41°00'131"; E20°56'683"), Ezerani north-east (NE) (N41°00'01"; E20°58'656"), Ezerani littoral (N41°00'197"; E20°57'741"), Oteshevo (N40°58'692"; E20°55'016"), and the pelagic zone (N40°57'949"; E20°57'513") – at depths of 0 m and 15 m.

The phytoplankton samples were collected during two sampling campaigns: in spring (April 2013) and in summer (July 2013). The weather in

spring was sunny with a light southern wind and temperatures of the surface water between 13.9°C and 16.5°C. The weather in summer was sunny and water temperatures of the surface water varied between 25.2°C and 25.6°C.

The samples were collected with a Niskin water sampler and preserved immediately at the sampling site by adding 4% formaldehyde.

The phytoplankton was analysed based on the following parameters: phytoplankton composition – phytoplankton taxa present; phytoplankton abundance – number of individuals per volume of water (cell/l); diversity of phytoplankton community – diversity index (Shannon-Wiener index); bloom metric – Pielou's evenness index; and dominant species. The identification of phytoplankton taxa and quantitative analyses (enumeration of individuals per volume of water) were done according to UTERMÖHL (1958), using an inverted microscope LW101–2 trinocular, with epillumination module and camera OmniVID, 8.0 MP.

The evenness index (bloom metric) and the diversity index were calculated according to PIELOU (1969) and SHANNON & WIENER (1949), respectively. The Trophic State Index (TSI) was calculated based on values of chlorophyll *a* concentration (CARLSON 1977). Chlorophyll *a* was analysed according to ISO 10260 (1992), using a spectrophotometer UV–VIS SPECORD 10 (Zeiss) after an extraction with 90% ethanol.

## Results and Discussion

### Phytoplankton composition

A total number of 56 phytoplankton taxa were collected in Lake Prespa during the spring and summer campaigns of 2013 (Table 1). The taxa belonged to six divisions: Cyanophyta, Bacillariophyta, Chlorophyta, Chrysophyta, Pyrrophyta and Euglenophyta. Most of the phytoplankton taxa identified belonged to Chlorophyta (24 taxa), followed by Bacillariophyta (12), Cyanophyta (8), Pyrrophyta (5), Euglenophyta (4), and Chrysophyta (3). The number of taxa was the lowest in the pelagic zone at 15 m depth (9 taxa) and at 0 m depth (19 taxa) due to the fact that the typically pelagic points are characterised by phytoplankton communities consisting mainly of euplanktonic species. The number of taxa at the littoral points was significantly higher because their phytoplankton communities contain littoral species and species that usually live on the bottom and on macrophyte vegetation. The highest number of taxa (43) was observed at the littoral sampling point Ezerani littoral, followed by Ezerani NE (32) (Table 1). These points abound with

macrophyte vegetation, especially reeds.

Our study showed distinct seasonal differences in the phytoplankton composition. Bacillariophyta was the dominant group in spring, contributing between 93% and 98% to the total phytoplankton abundance in the pelagic zone and between 76% and 84% to the total phytoplankton abundance in the littoral zone. An exception was the sampling point Ezerani NE, where the green algae (Chlorophyta) were the dominant group of algae in the spring period, contributing 84% to the total phytoplankton abundance (Tables 2 and 3). In the summer period, Cyanophyta (blue-green algae) was the dominant algal group at all sampling points, with the exception of samples at 15 m depth in the pelagic zone and Ezerani NE, where Chlorophyta (green algae) dominated, comprising 67% and 44% of the total number of individuals, respectively. The proportion of Cyanophyta was the lowest at 15 m depth in the pelagic zone, while it ranged from 21% (Ezerani NE) to 35% (Ezerani littoral) at the other sampling points (Tables 2 and 3). For comparison, during the period 2001–2003, a tendency of increased percentage presence of blue-green algae was observed in Lake Prespa: from 30.89% in 2001 to 31.71% and 55.6% in 2002 and 2003, respectively (PATCEVA 2005). Summer populations of phytoplankton vary in relation to the trophic state of lakes but can include either another diatom development in less productive lakes by late summer and early autumn or increases in nitrogen-fixing cyanobacteria in eutrophic lakes (WETZEL 2001).

The proportion of Pyrrophyta in summer was the highest at the surface level (35%) and the lowest in Ezerani littoral (2%) (Tables 2 and 3). This group of algae has the highest growth rates in summer at high temperatures and light intensity. In the previous studies (2001–2003), the average percentages of Pyrrophyta were 1.8% in 2001, 0.14% in 2002, and 3.3% in 2003 (PATCEVA 2005).

The proportion of Chrysophyta was generally very low (1 or 2%) (Tables 2 and 3). This taxonomic group is characteristic of oligotrophic lakes. During the period 2001–2003, this group of algae also contributed insignificantly to the total abundance: with average annual percentages of 2.16% in 2001, 0.93% in 2002, and only 0.3% in 2003. This is rather supportive argument of the notion that during the last decades in Lake Prespa, certain negative processes have occurred and resulted in aggravation of its trophic state (PATCEVA 2005). Our results also showed that the overall composition of the phytoplankton communities in Lake Prespa was typical for lakes that are in the process of eutrophication.

**Table 1.** List of identified phytoplankton taxa in the Macedonian part of Lake Prespa, in 2013

TAXA		Pelagial 0 m	Pelagial 5 m 15mm m15m	Ezerani NW	Ezerani littoral	Ezerani NE	Oteshevo
CYANOPHYTA							
1	<i>Anabaena flos-aquae</i> Bréb.	+		+			
2	<i>Anabaena solitaria</i> fo. <i>planctonica</i> (Brunn.) Komárek	+		+	+	+	+
3	<i>Aphanizomenon flos-aquae</i> (L.) Ralfs	+					
4	<i>Chroococcus limneticus</i> Lemm.	+		+	+	+	+
5	<i>Chroococcus minimus</i> (Keissl.) Lemm.				+	+	+
6	<i>Lyngbya limnetica</i> Lemm.	+	+	+	+	+	+
7	<i>Merismopedia glauca</i> (Ehr.) Näg.				+		
8	<i>Gomphosphaeria lacustris</i> Chod.	+			+		
BACILLARIOPHYTA							
9	<i>Amphora ovalis</i> Kütz.					+	
10	<i>Aulacoseira</i> sp.		+				
11	<i>Cocconeis pediculus</i> Ehr.			+	+		
12	<i>Cyclotella ocellata</i> Pant.	+	+	+	+	+	+
13	<i>Cyclotella</i> sp.	+	+	+	+	+	+
14	<i>Cymbella</i> sp.				+		
15	<i>Fragilaria crotonensis</i> Kitton	+					
16	<i>Fragilaria ulna</i> (Nitz.) Lange-Bertalot				+		
17	<i>Fragilaria</i> sp.		+	+	+	+	+
18	<i>Gomphonema</i> sp.				+		
19	<i>Navicula</i> sp.			+	+	+	+
20	<i>Stauroneis</i> sp.				+		
CHLOROPHYTA							
21	<i>Ankistrodesmus falcatus</i> (Corda) Ralfs					+	
22	<i>Ankistrodesmus lacustris</i> Ostenf.		+	+	+	+	
23	<i>Chlamydocapsa planctonica</i> (West & G. S. West) Fott	+	+	+	+	+	+
24	<i>Chlamydomonas</i> sp.	+		+	+	+	+
25	<i>Closterium acutum</i> var. <i>variabile</i> Krieger	+	+	+	+	+	+
26	<i>Cosmarium phaseolus</i> Bréb.				+		
27	<i>Dictyosphaerium pulchelum</i> Wood.			+	+	+	
28	<i>Eudorina elegans</i> Ehr.			+	+	+	
29	<i>Mougeotia</i> sp.				+		+
30	<i>Nephrocystium aghardhianum</i> Nägel						
31	<i>Oocystis lacustris</i> Chod.	+	+	+	+	+	+
32	<i>Oocystis rhomboides</i> Fott	+		+	+	+	+
33	<i>Pandorina morum</i> (Muell.) Bory			+	+	+	+
34	<i>Pediastrum boryanum</i> (Turp.) Mengh.					+	
35	<i>Pediastrum duplex</i> Meyen			+	+		
36	<i>Pediastrum simplex</i> Meyen				+	+	
37	<i>Scenedesmus quadricauda</i> Bréb.				+	+	
38	<i>Scenedesmus acuminatus</i> (Lag.) Chod.				+	+	
39	<i>Scenedesmus arcuatus</i> Lemm.				+		
40	<i>Scenedesmus obliquus</i> (Turpin) Kütz.			+	+		+
41	<i>Sphaerocystis shroeteri</i> Chod.					+	+
42	<i>Spirogyra</i> sp.						+
43	<i>Staurastrum paradoxum</i> Meyen				+		
44	<i>Staurastrum paxilliferum</i> G. S. West				+		+
CHRYSOPHYTA							
45	<i>Dinobryon bavaricum</i> Imhof				+		
46	<i>Dinobryon divergens</i> Imhof				+		
47	<i>Dinobryon sociale</i> var. <i>stipitatum</i> Lemm.			+	+	+	
PYRROPHYTA							
48	<i>Gymnodinium mirabile</i> var. <i>rufescens</i> Penard.			+			
49	<i>Gymnodinium</i> sp.	+		+	+	+	
50	<i>Peridinium cinctum</i> (O. F. Müll.) Her				+	+	
51	<i>Peridinium cunningtonii</i> Lemm.	+		+	+	+	+
52	<i>Peridinium</i> sp.					+	+
EUGLENOPHYTA							
53	<i>Euglena viridis</i> Ehr.			+			
54	<i>Euglena</i> sp.				+	+	
55	<i>Phacus</i> sp.			+	+	+	
56	<i>Trachelomonas</i> sp.				+	+	

**Table 2.** Percentage of algal divisions of the total number of identified taxa in the Macedonian part of Lake Prespa, during the spring sampling campaign in 2013

	Pelagial 0 m	Pelagial 15 m	Ezerani littoral	Ezerani NW	Ezerani NE	Oteshevo
Cyanophyta	3%	1%	1%	–	1%	–
Bacillariophyta	93%	98%	76%	81%	8%	84%
Chlorophyta	4%	1%	17%	18%	84%	14%
Chrysophyta	–	–	–	–	–	2%
Pyrrophyta	–	–	6%	1%	7%	–

**Table 3.** Percentage of algal divisions of the total number of identified taxa in the Macedonian part of Lake Prespa, during the summer sampling campaign in 2013

	Pelagial 0 m	Pelagial 15 m	Ezerani littoral	Ezerani NW	Ezerani NE	Oteshevo
Cyanophyta	31%	18%	35%	34%	21%	23%
Bacillariophyta	12%	15%	40%	36%	20%	41%
Chlorophyta	21%	67%	21%	19%	44%	15%
Chrysophyta	1%	–	1%	1%	–	–
Pyrrophyta	35%	–	2%	9%	12%	21%
Euglenophyta	–	–	–	1%	3%	–

**Table 4.** Species number, diversity index (H) and evenness index (J) at six sampling points in the Macedonian part of Lake Prespa, during the spring sampling campaign in 2013

	Pelagial 0 m	Pelagial 15 m	Ezerani littoral	Ezerani NW	Ezerani NE	Oteshevo
Species number	6	6	16	6	11	8
Diversity index (H)	0.41	0.11	1.36	0.79	0.98	0.86
Evenness index (J)	0.23	0.06	0.49	0.44	0.41	0.41

**Table 5.** Species number, diversity index (H) and evenness index (J) at six sampling points in the Macedonian part of Lake Prespa, during the summer sampling campaign in 2013

	Pelagial 0 m	Pelagial 15 m	Ezerani littoral	Ezerani NW	Ezerani NE	Oteshevo
Species number	17	7	36	25	26	16
Diversity index (H)	2.02	1.21	2.06	2.15	2.58	1.80
Evenness index (J)	0.71	0.62	0.58	0.67	0.79	0.65

**Table 6.** Dominant species in the phytoplankton community in the Macedonian part of Lake Prespa, during the two sampling campaigns in 2013

Sampling points	Spring sampling campaign	Summer sampling campaign
Pelagial 0 m	<i>Cyclotella ocellata</i> Pant.	<i>Peridinium cunningtonii</i> Lemm. <i>Lyngbya limnetica</i> Lemm.
Pelagial 15 m	<i>Cyclotella ocellata</i> Pant.	<i>Closterium acutum</i> var. <i>variabile</i> (Lemm.) Krieg.
Ezerani littoral	<i>Cyclotella ocellata</i> Pant.	<i>Cyclotella ocellata</i> Pant. <i>Lyngbya limnetica</i> Lemm.
Ezerani NW	<i>Cyclotella ocellata</i> Pant.	<i>Cyclotella ocellata</i> Pant. <i>Lyngbya limnetica</i> Lemm.
Ezerani NE	<i>Chlamidomonas</i> sp.	<i>Chlamydocapsa planctonica</i> (West & G. S. West) Fott
Oteshevo	<i>Cyclotella ocellata</i> Pant.	<i>Cyclotella ocellata</i> Pant.

### Phytoplankton indices

During the summer period, the number of phytoplankton taxa was significantly higher than in spring at all sampling points. Likewise, diversity and evenness indices were also higher in summer compared to the results in spring (Tables 4 and 5).

The lowest diversity and evenness indices were observed in the pelagic zone at 15 m depth (Tables 4

and 5). The low values were due to a low number of taxa and the predominance of one species *Cyclotella ocellata* Pant., which accounted for 98% of the total phytoplankton abundance. The highest diversity and evenness indices were found at Ezerani NE in the summer period, which was due to the large number of taxa (26), the dominant abundance of the green alga *Chlamydocapsa planctonica* (West & G. S.

West) Fott and approximately uniform abundance of other taxa (Tables 5 and 6).

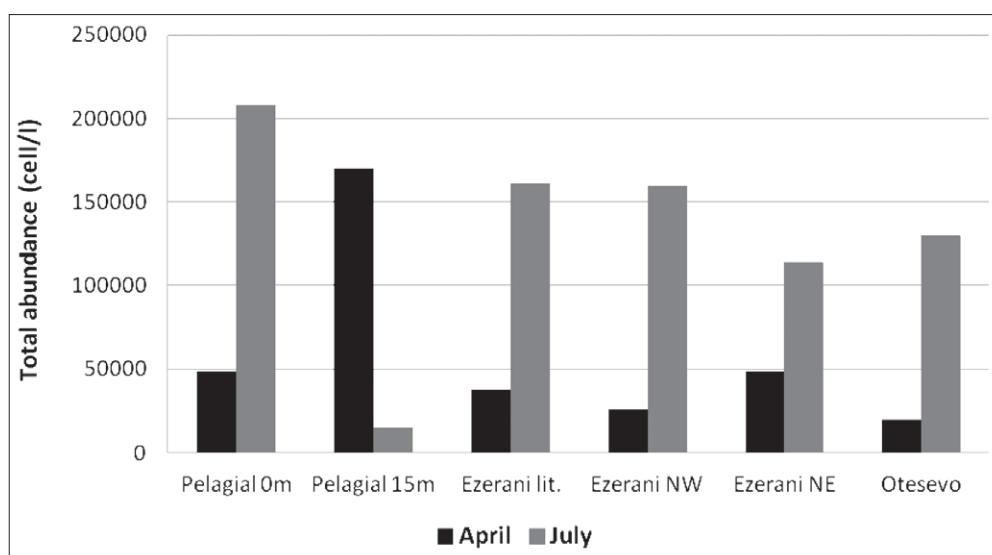
Generally, at all points, the diversity and evenness indices were higher in summer (Tables 4 and 5) owing to the higher number of taxa, higher abundance and lesser domination of a single species. The opposite was true in spring when both indices were lower due to the lower number of taxa and absolute dominance of the diatom species *C. ocellata* at all points, with the exception of point Ezerani NE, where the dominant was *Chlamidomonas* sp. (Tables 5 and 6).

### Phytoplankton abundance and dominant species

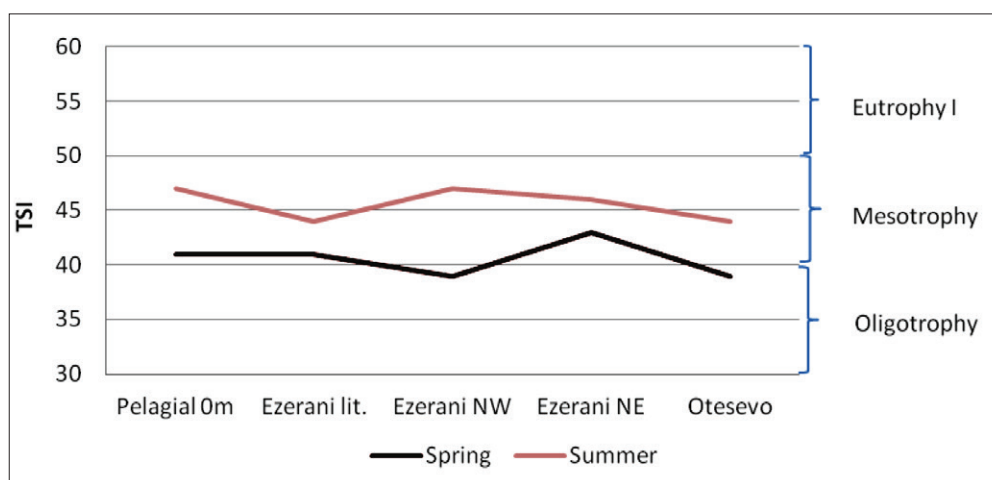
The total abundance of phytoplankton was considerably higher in summer than in spring, except for the pelagic zone at 15 m depth, at which the abundance was higher in spring (Fig. 1), with *C.*

*ocellata* as the dominant species (Table 6).

During the summer campaign, the highest total abundance of phytoplankton was found in the pelagic zone at 0 m depth (Fig. 1). The dominant species were *Peridinium cunningtonii* Lemm. (Pyrrophyta) and *Lyngbya limnetica* Lemm. (Cyanophyta). At the same time, the total abundance was the lowest at 15 m depth. In the littoral zone, the highest abundance was recorded in summer at Ezerani littoral and Ezerani NW, with the domination of *C. ocellata* (Bacillariophyta) and *L. limnetica* (Cyanophyta). Significant difference in the dominant species was observed at the locality Ezerani NE, where *Chlamidomonas* sp. (Chlorophyta) was identified as dominant in the spring sampling campaign and *C. planctonica* (Chlorophyta) was found as dominant species in the summer sampling campaign (Table 6).



**Fig. 1.** Phytoplankton total abundance (cell/l) at six sampling points in the Macedonian part of Lake Prespa, during the two sampling campaigns in 2013



**Fig. 2.** Trophic state index (TSI) based on chlorophyll *a* concentration in the Macedonian part of Lake Prespa, during the two sampling campaigns in 2013

During our study, there were no significant differences between the phytoplankton abundance and trophic state index (TSI) at different sampling points in each season, respectively (Figs. 1 and 2). The values of the TSI were higher in summer compared to spring, at all of the sampling points. The TSI at the two sampling points Ezerani NW and Oteshevo during the spring sampling campaign were within the limits of oligotrophy (Fig. 2).

According to the trophic state index (TSI) based on chlorophyll *a* concentration, all sampling points at Lake Prespa indicated mesotrophic conditions. Therefore, our results confirmed the results of PATCEVA (2005) and PATCEVA & MITIC (2006) and showed a continuous process of deterioration of the trophic state as a result of the increased anthropogenic pressure.

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