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Diatom assemblages comparison of lakes located in three discrete nearby cirques, the Rila Mts., Bulgaria, in the condition of climate change and human activity

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Abstract

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A comprehensive research into three groups of mountain lakes located in three discrete nearby cirques in the north-western Rila Mts., was carried out in order to compare the community composition of diatoms and to add the anthropogenic change and climate change into context. In total, 170 diatom taxa belonging to 51 genera were found. The number of the diatom species in the investigated lakes ranged from 40 to 71. The minimum species number (40) was recorded in the Dolno Chanakgyolsko Lake. The Shannon-Weaver Index for the 14 lakes varied between 3.67–4.95. The most diverse diatom epilithic flora was observed in the lakes: Urdino 1 and Urdino 4. In order to a generalization of base tendency in variation of species composition and establishment their distribution among the sites was used ordination method – Principal Component Analysis (PCA).The climate change serves as the main driving force for all studied lakes, while human activities are the primary driving forces for the lakes within cirque "Seven Rila Lakes". The main results will be employed as a case model to quantify the impact of climate change and human activities in this realm.

Keywords: diatoms; mountain lakes; environmental factors; multivariate analyses; climate changes; human activity

Introduction

The Rila Mountains (Southwest Bulgaria) is the highest massif on the Balkan Peninsula (Mousala peak – 2925 m. a. s. l.). The total area of the range is estimated at about 2393 km^2, i. e. 2.2% of the total land area of Bulgaria (Zypkov & Naidenow, 2000). There are 140 lakes within the Rila Mts (Ivanov et al., 1964).

The study area is situated in north-western Rila Mts. and comprises three discrete nearby cirques including three groups of lakes (Fig. 1). The lakes from group of the cirque "Seven Rila Lakes" originate of the Dzerman River, left tributary of the Struma river, which is part of the West Aegean Sea River Basin. The lakes from the other two groups – Chanakgyolski Lakes and Urdini Lakes, originate tributaries of the Iskar River, which runs into the Danube River, which is part of the Black Sea River Basin. All these lakes are of glacial origin. They are considered to be at age of 13 000÷14 000 years when the ice masses, covering the high altitudinal zones during Neopleistocene began to thaw (Zyapkov & Naidenow, 2000).

Some geographical, morphometric, catchment and physical characteristics are given in Table l. All the studied lakes are above the timberline and their altitudes range from 2205

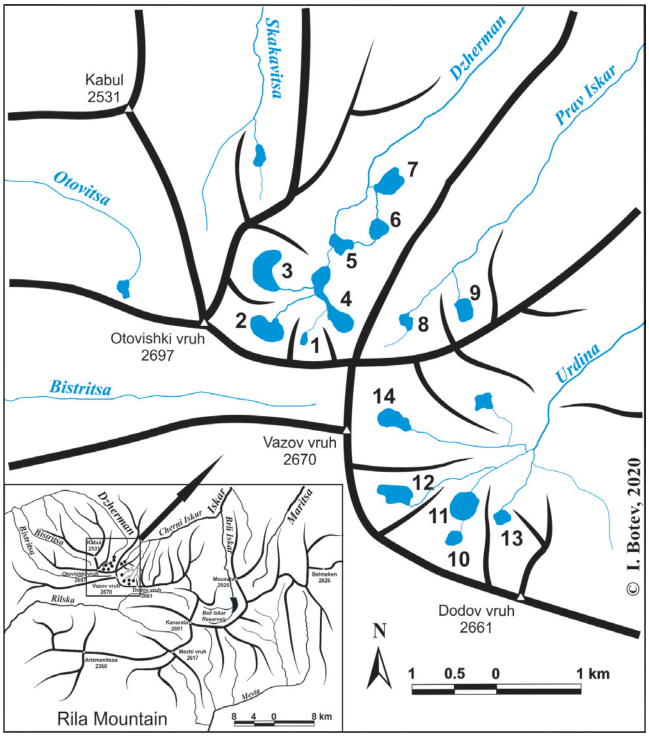

Fig. 1. Map showing the location of the study lakes
About the number and names of the lakes see Table 1

to 2535 m a. s. l. The maximum depth of Lake Okoto (1) is 37.5 m and it is the deepest high mountain lake in Bulgaria. Lake Bubreka (3) ranks third among high mountain Bulgarian lakes with regard to water volume (1.170 million m^3).

A lot of results obtained on benthic diatoms and water chemistry in the lakes within cirque "Seven Rila lakes" were published previously (Ognjanova-Rumenova et al., 2006, 2009a, 2009b, 2011, 2019; Catalan et al., 2009; Camarero et al., 2009a, 2009b; Ognjanova-Rumenova, 2012). Our latest study includes seven more lakes located within discrete nearby cirques – Chanakgyolsko and Urdino. Until now, there is no data on their benthic diatom flora.

The objectives of this study were: 1) To explore the relative abundance and diversity of diatom flora; 2) To examine the relationship between diatom flora and major environmental factors; 3) To compare the community composition of diatoms in all studied lakes located in three discrete nearby cirques and to add the anthropogenic change and climate change into context.

Materials and Methods

Water chemistry was sampled from the surface (0.5 m, by means of one litre Friedenger sampler) at each site. Conductivity, pH, dissolved oxygen, and temperature were measured *in situ* by instruments and electrode type WTW Conductometer 3110 Set 3, Electrode KLE 325, WTW pH Meter 3210 Set 2; Electrode SenTix 41 and WTW Oxi Meter 3210 Set 3, Electrode DurOX 325-3, without stirring during measurements. Secchi depth transparency was measured *in situ* as well.

A total of 22 epilithic diatom samples were collected in all surveyed lakes in July, 2016. Methods for epilithon sampling followed those described by Cameron (1997). The samples were cleaned, according to the standard methods described by Battarbee (1986). A minimum of 300 valves was counted in every sample (Renberg 1990). In general, nomenclature followed Krammer & Lange-Bertalot (1986–1991), Round et al. (1990), Lange-Bertalot & Metzeltin (1996), and Hofmann et al. (2011). The spectra of physico chemical tolerance of the identified diatom taxa were based mainly on Lowe (1974), Van Dam et al. (1994), and Hofmann et al. (2011).

Principal component analysis (PCA), based on a correlation matrix by centring and standardization, was used to summarize the major patterns of variation within main environmental data (pH, alkalinity and conductivity). For the purpose of multivariate analysis, diatom species were expressed as relative abundance (% total diatoms) and only those taxa exceeding 2% in any single sample were retained.. Ordinations were implemented by the CANOCO statistical package (Ter Braak & Šmilauer 2002).

Results and Discussion

The diversity of recent epilithic diatoms from fourteen lakes, situated in three discrete nearby cirques was analyzed. In total, 170 diatom taxa belonging to 52 genera were found. The number of the diatom species in the investigated lakes ranged from 40 to 71. The minimum species number (40) was recorded in the Dolno Chanakgyolsko Lake. The Shannon-Weaver Index for the 14 lakes varied between 3.67–4.95. (Fig. 2) The most diverse diatom epilithic flora was observed in the lakes: Urdino 1 and Urdino 4. There is a decreasing in the values of the Shannon-Weaver Index and species richness in the diatom assemblages over the last 20 years in the lakes in cirque "Seven Rila Lakes" (i.e. Lake Okoto, $\overline{H} = 3{,}67$) (Ognjanova_Rumenova et al., 2019).

Relationship between diatom flora and major environmental factors

Biogeographical information was available for 120 (76% of the total) taxa. The diatom flora was mainly composed of cosmopolitan species (67.5%). 25.8% of the

Table 1. Geographical, morphometric, catchmet and physical characteristics of the 14 lakes investigated in July 2016

№ on the map	Name of the Lakes	Samplig site coordinate	Altitude*	Catchment area*	Surface area*	Water volume*	Max. depth*	Water Temperature	Conductivity
		degrees	m. a. s. l.	$10^6.m^2$	$10^4.m^2$	$10^3.m^3$	m	ºC	µS/cm
				Group of Seven Lakes					
1	Sulzata	N 42.19736 E 23.31120	2535	0.18	0.70	15.0	4.5	10.4	15.8
2	Okoto	N 42.19867 E 23.30824	2440	0.36	6.80	860.0	37.5	6.5	23.1
3	Bubreka	N 42.20318 E 23.30819	2282	0.56	8.50	1170.0	28.0	13.6	22.0
4	Bliznaka	N 42.19806 E 23.31824	2243	2.10	9.10	590.0	27.5	12.5	25.2
5	Detelinata	N 42.20542 E 23.31863	2216	2.28	2.60	54.0	6.5	13.5	24.5
6	Ribnoto	N 42.20556 E 23.32250	2184	2.73	3.50	38.0	2.5	13.4	25.3
7	Dolnoto	N 42.21066 E 23.32382	2095	3.00	5.90	240.0	11.0	16.5	19.3
				Group of Chanakgyolski Lakes					
8	Gorno Chanakgyolsko	N 42.19943 E 23.32480	2238	0.53	1.01	–	5.5	12.5	18.0
9	Dolno Chanakgyolsko	N 42.20029 E 23.33006	2205	0.56	3.75	–	–	12.6	11.8
				Group of Urdini Lakes					
10	Urdino № 1	N 42.17472 E 23.32961	2375	0.49	0.86	16.0	4.7	11.4	25.9
11	Urdino № 2	N 42.17826 E .23.32952	2278	0.79	2.53	89.5	6.6	14.8	23.0
12	Urdino № 3	N 42.17934 E .23.32408	2339	0.55	2.34	59.5	4.6	12.8	39.2
13	Urdino № 4	N 42.17562 E .23.33159	2336	0.13	1.26	54.5	7.6	14.6	26.0
14	Urdino № 5	N 42.18612 E 23.32606	2338	0.86	1.65	19.0	2.4	12.2	25.3

**Data after Ivanov et al. (1964)*

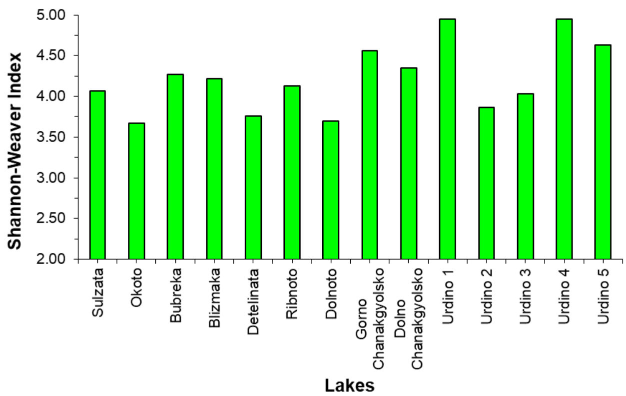

Fig. 2. The Shannon-Weaver diversity index in the studied epilithic diatom samples

taxa were classified as “nordic-alpine”, and only 6.7% as “boreal”. In regards to general and specific habitats (Van Dam et al. 1994; Hofmann et al., 2011), periphitic species dominated the flora (70%), but there were several (10.8%) planktonic and euplanktonic species: *Aulacoseira alpigena* (Grun.)Krammer, *A. italica* (Ehr.)Sim., *Hannea arcus* (Ehr.)Patrick, and *Fragilaria ulna* (Nitzsch)Lange-Bert. There were a few taxa, “mainly occurring in wet and moist, or temporarily dry places” (Van Dam et al. 1994), i.e. *Diadesmis perpusilla* (Grun.)Mann and *Hantzschia amphioxys* (Ehr.) Grun. Most of these species had lower relative abundance in the diatom association. Among pH-indicator species alkaliphilous (44.3%) and pH-indifferent (25.4%) diatoms clearly predominated, while 26.2% were acidophilous species with pH optima ranging between 5.4 and 6.9.

According to the halobion system, the indifferent oligohalobous taxa predominated, there were 25.2% of halophobous taxa. Four halophilous species were determined, but some of them had high abundance, such as: *Brachysira neoexilis* Lange-Bertalot.

Results of the Principal Component Analysis (PCA)

In order to a generalization of base tendency in variation of species composition and establishment their distribution among the sites was used ordination method – Principal Component Analysis (PCA). (Fig. 3).

The first principal component (axis 1) accounted for 33.8% of the variance in total data reflects a gradient of more acidophilous species *Achnanthidium minutissimum* (Kütz.) Czarnecki*, Tabellaria flocculosa* (Roth)Kütz., *T. fenestrata* (Lyngb.)Kütz.*, Gomphonema truncatum* Ehr.*, G. acuminatum* Ehr.*,* and *Brachysira neoexilis* (with loadings on this axis 0.9075, 0.7942, 0.7644, 0.7860, 0. 7370, and 0.6970 respectively), dominated in sites Do, De, R and to some extent U2, as *A. minutissimum* dominated in all four lake while the rest species only in Do and De.

The second principal component (axis 2) accounting for 23.5% of variance, largely represents a gradient from sites S, GCh and in some measure DCh (positive end), plotted at the top of the diagram to the group of mostly deep, nonacidified lakes – O, Bl, at the bottom (negative end).

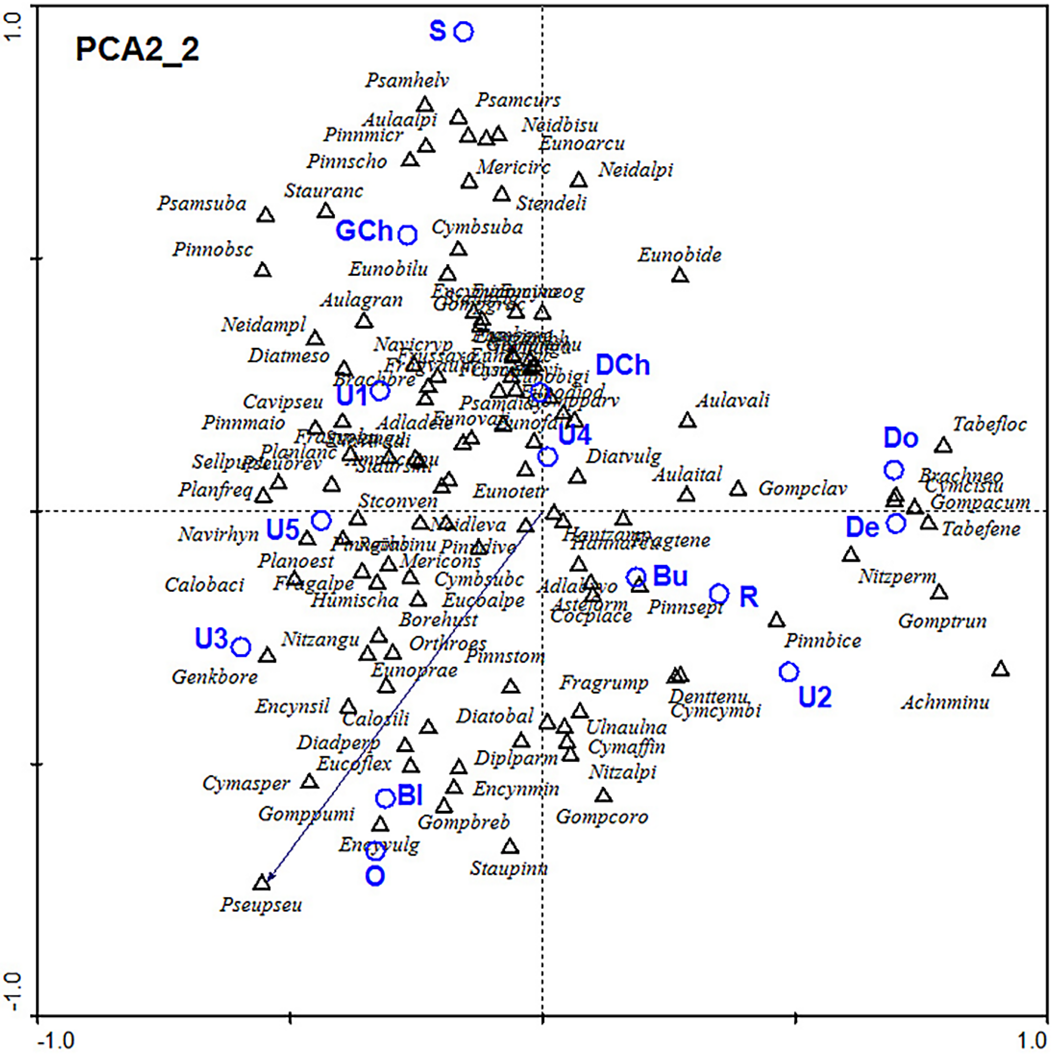

Fig. 3. The results of the PCA showed that the first three principal components (λ1 = 0. 338, λ2 = 0.235, λ3 = 0.128) together accounted for 70.1% of total variance of our data

About the names of the lakes see Table 1

The third principal component (axis 3) accounting for 12.8% of variance, represents a gradient from *Encyonema minutum* (Hilse)Mann, *Gomphonema minutum* (Ag.)Ag., and the rare *Diatoma vulgaris* Bory (with loadings on axis 3 7268 and 0.6058 0.5082) to *Staurosira construens* var. *venter* (Ehr.)Hamilton, (-0.6661) and rare *Cymbella cistula* (Ehr.)Kirchner (0.5387). *E. minutum* occurs in all Urdini lakes besides in some of others and *Staurosira construens* var. *venter* dominated in U3.

Conclusions

Our study synthesis the knowledge on diatom biodiversity in fourteen lakes located in three discrete nearby cirques in Rila Mts. The lakes within cirque "Seven Rila lakes" hold not only esthetic and recreation value, but also spiritual value. Every year, in August, thousands of people gather to perform their secret dances around the lakes. In the more alkaline deep lakes – "Okoto", "Bubreka" and "Bliznaka", several benthic *Fragilaria* s.l. species are identified, especially *Pseudostaurosira pseudoconstruens* (Marciniak)Williams et Round, *Staurosira construens* var. *venter* and *Staurosirella pinnata* (Ehr.) Williams et Round, as well as the indifferent species *Encyonema minutum*. In the highest lake – "Sulzata", the planktonic north-alpine species *Aulacoseira alpigena* is dominant. In the three shallower lakes – "Detelinata", "Ribnoto" and "Dolnoto", the biodiversity index is lower due to the active anthropogenic activity affecting this part of the cirque "Seven Rila lakes", as well as the abundant distribution of macrophytes. The climate change serves as the main driving force for all studied lakes, which is evidenced by the increasing percentage of planktonic species and their dominance in the diatom assemblages. The main results will be employed as a case model to quantify the impact of climate change and human activities in this realm.

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