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Microscopic algae from karst lakes of Dumre region (Central Albania)

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ABSTRACT: More than 90 karst lakes, often smaller than 1ha, and shallower than 10m, can be found sparse over limestone or gypsum in Albanian territory. The most famous are the lakes of Dumre, a zone that extends between Shkumbini and Devolli valleys (Elbasani district). These lakes do not have nor inflows or outflows, and are often filled by the rainfall; therefore, their water level oscillates drastically during the year. Sporadic samples of peryphyton or phytoplankton were collected in some of Dumre lakes (Belshi, Merhoja, Mulleza, Cepi). Moreover, one sediment core (ca. 38cm) was taken in Belshi lake, in June 2005; based on Pb^{210} and Cs^{137}, the sediments were the well laminated, dating only to the last 20 years (between 2005-1984), where alternated yellow and black layers might belong to one year. The calculated sedimentation rate was 1.76 cm/yr, considered relatively high, due to the strong erosion form the surrounding watershed.

The diversity of diatoms found in Dumre lakes can be considered high, despite the limited number of samples examined. About 220 taxa of microscopic algae, diatoms (*Bacillariophyta*), were found in all the collected samples, represented mainly from the genera *Navicula* (28 species), *Nitzschia* (23) and *Cyclotella* (17). More than 170 species were found in the littoral samples of different lakes, where the sample from Cepi, a shallow eutrophic pond was the richest with diatoms, more than 90 species. About 140 species were found in the core sample from Belshi lake, represented mainly from *Achnnathes minutissima, Cyclotella ocellata, C. stelligera, Gyrosigma acuminatum, Cymbella affinis, Gomphonema olivaceum* or *Hantzschia amphioxys*. Centric diatoms *Cyclotella ocellata* and *C. stelligera*, and the pennate *Achnanthes minutissima* were found also relatively abundant in the population community of each sediment layer. The calculated Trophic Index of Diatoms (TI_{DIA}) in each sediment layer oscillated from 1.2 (oligotroph) to 3.4 (polytroph), showing a moderate pollution with nutrients (phosphorous and nitrogen). Saprobic index seems to be more stable, oscillating from 1.5 (oligosaprob) to 2 (beta-mesosaprob), corresponding to scarcely polluted (I-II class) to moderately polluted water quality (II class). From the rare and interesting species of the karst lakes here were mentionioned *Caloneis* cf. *aerophila*, *Gomphonema augur*, *Neidium bisulcatum* var. *subampliatum*, *Nitzschia geitleri*, *N. lorenziana*, *Placoneis elginensis*, *P. clementioides*, *Sellaphora levissima*, *Surirella venusta*, *Surirella* cf. *tenera*. *Caloneis* sp. and *Surirella* sp. represent interesting or new species.

The terrigenous hilly relief, the typical Mediterranean climate characteristics combined also with poor land use activities (land denuding), can be the principal causes of the relatively high rate of sedimentation observed in Belshi lake. The decentralized management of wastewater is recommended to prevent the eutrophication processes, and protect the water quality of the lakes. Moreover, forestation activities especially in denuded area would restore the vegetation cover and decrease the erosion.

Key words: Albanian karst lakes; Belshi lake; sediment core sampling; Albanian diatoms

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INTRODUCTION

In most cases there is little or no reliable long-term data about the natural history of lakes. Paleoecological studies offer a way to address how a lake's water quality has changed through time as a result of watershed disturbances. It depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or washed from the watershed. The sediments of the lake preserve fossil remains that are more or less resistant to bacterial decay or chemical dissolution; it includes diatom frustules, cell walls of certain algal species and subfossils from aquatic plants, pollen grains and chironomids (Lowe *et al.* 1996; Little *et al.* 2000; Garrison & La Liberte 2007). The chemical characteristics of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. Using the fossil remains found in the sediment, one can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake. It plays an important role in reconstructing when the condition of the lake has changed, when did this occur, what were the causes, and what were the historical conditions of the lake.

Fig. 1: Geographical positon of Elbasani district (Albania)

Siliceous microscopic algae, diatoms (*Bacillariophyceae*), which were taken into consideration by us, are known to be very sensitive to changes in environmental variables such as trophic conditions and pH (Vos & De Wolf 1988).

About 90 karst lakes can be found sparse over limestone or gypsum in Albanian territory (Kabo 1990-1991). The most famous are the lakes of Dumre zone that extends between Shkumbini and Devolli valleys (Elbasani district, Central Albania; Fig. 1); their total surface is about 770 ha, where the most important are Cestija (98.6 ha), Seferani (87.5 ha), Merhoja (65.5 ha), Dega (37.4 ha), Rashta (29.9 ha), Paraska (27.4 ha), Belshi (26.9 ha) and Cerraga (18.8 ha); the others are often smaller than 1 ha. The karst lakes are generally shallow (to 10m); the biggest depth is measured in Merhoja (61 m). They do not have nor inflows or outflows, and are often filled by the rainfall; therefore, their water level oscillates drastically during the year. Scarce data were published related with their biodiversity especially aquatic flora and vegetation.

Palaeolimnological studies in the Albanian natural lakes are missing, despite of interest. The first approach was given by Kupe *et al.* (2008) for sediment cores taken in Shkodra Lake, a trans-boundary lake between Albania and Montenegro. Data about diatoms in Dumre lakes were reported for the first time by this preliminary approach, completing further the biodiversity of Albanian aquatic habitats. Belshi Lake, close to Belshi town, ca. 30 km south-west of Elbasani, will be taken as the most representative (Fig.1). Rough indications about the sedimentation rates of the last decades and human impact will be discussed, as precondition to their protection and restoration.

MATERIAL AND METHOD

One sediment core (ca. 38cm; Fig. 2a) was taken in Belshi lake, in June 2005. The core was taken at the highest depth (11m) with the aid of a manual core sampler. The sediment core was evidently laminated with alternated white and dark layers, which are drawn up in the Fig. 2b.

One diatom sample was collected in each sub-layer, 43 samples in total; moreover, 6 representative samples, respectively in 0-1, 1-5, 5-10, 10-20, 20-30 and 30-38cm, were collected for dating. In order to determine when the various sediment layers were deposited, the samples were analyzed for lead-210 (^{210}Pb), a naturally occurring radionuclide. Lead-210 is the result of natural decay of uranium-238 to radium-226 to radon-222. Since radon-222 is a gas it moves into the atmosphere where it decays to lead-210, which is deposited on the lake during precipitation and with dust particles. After Pb-210 enters the lake and it is in the lake sediments, it slowly decays, with the half-life of 22.26 years. It means that it can be detected for about 130-150 years (Garrison & LaLiberte

Table 1: Composition of diatom samples taken from the sediment core in Belshi lake, Dumre, Albania (date 12.06.2005; depth 11 m); B, black; W, white; S, spring; A, autumn

Diatom sample	Core depth, cm	Colour of layer	Core thickness, cm	Suspected year and season
1	0	B	2	2005 S
2	0.5	W	0.5	2004 A
3	1	B	0.5	2004 S
4	1.5	W	1.5	2003 A
5	3	B	0.3	2003 S
6	3.5	W	0.2	2002 A
7	3.8	B	0.3	2002 S
8	4	W	0.2	2001 A
9	4.5	B	0.5	2001 S
10	5	W	0.5	2000 A
11	6	B	1.5	2000 S
12	7.5	W	1	1999 A
13	8.5	B	0.8	1999 S
14	9.3	W	1.7	1998 A
15	11	B	0.5	1998 S
16	11.5	W	1.3	1997 A
17	12.8	B	0.2	1997 S
18	13	W	0.5	1996 A
19	13.5	B	1	1996 S
20	14.5	W	0.5	1995 A
21	15	B	0.5	1995 S
22	15.5	W	1	1994 A
23	16.5	B	0.5	1994 S
24	17	W	0.8	1993 A
25	17.8	B	0.2	1993 S
26	18	W	0.5	1992 A
27	18.5	B	1	1992 S
28	19.5	W	1	1991 A
29	20.5	B	0.5	1991 S
30	21	W	0.5	1990 A
31	21.5	B	0.5	1990S
32	22	W	3	1989 A
33	25	B	2	1989 S
34	27	W	1	1988 A
35	28	B	1	1988 S
36	29	W	1	1987 A
37	30	B	1.5	1987 S
38	31.5	W	1	1986 A
39	32.5	B	1.5	1986 S
40	34	W	2	1985 A
41	36	B	1	1985 S
42	37	W	1	1984 A
43	38	B	1	1984S

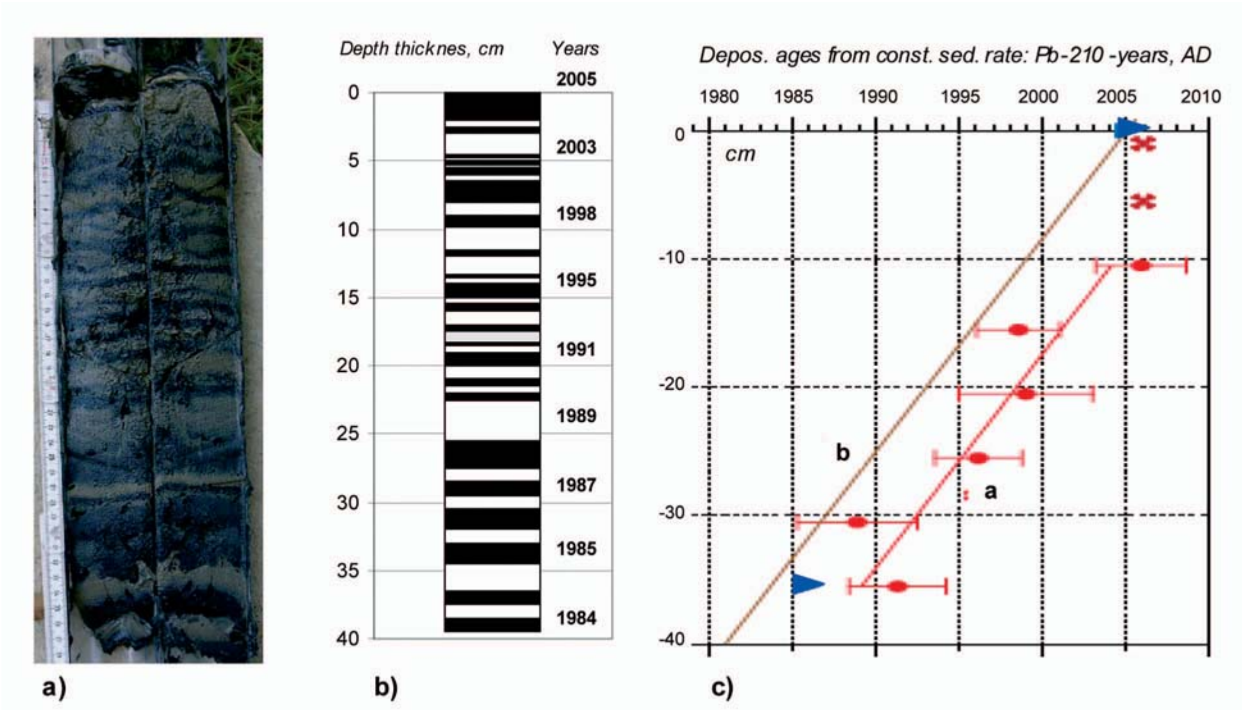

Figure 2: a) Photo of the sediment core taken in Belshi Lake, Dumre – dt. 12.06.2005, depth 11m (photo by L. Shuka); **b)** Profile of layer depths in centimeters and their alternated color; **c)** Dating Model: constant sedimentation below a mixed surface layer. Sedimentation line (b) parallel to line (a) in figure 1c start at 2005, the year of coring; arrow ► shows speculated Cs-137 dating in agreement with Pb-210-dating. Sedimentation rate (line a) is the linear regression, using the age errors as weights: 1.76±0.43 cm/yr (unweighted: 1.67±0.13 cm/s) Pb-210 ages refer to 100 Bq/kg total initial activity and 10 Bq/kg supported activity (data form Dr. H. Erlenkeuser, Universitety of Kiel, Germany).

2007). Sediment age for the various depths of sediment was determined by the 'Constant-Fraction-Model' (Appleby *et al.* 1992) (Fig. 2c).

Moreover, five samples of peryphyton or littoral phytoplankton were collected sporadically in some of Dumre lakes, in Cepi, Merhoja, Mulleza (in June 1993), in Belshi (June 2006) and Merhoja (September 2006).

The diatom communities in each sublayer were examined microscopically. Diatom frustules were cleaned by boiling the material in HCl_{conc} followed by boiling in H_2SO_{4conc} with addition of a few crystals of KNO_3 (Krammer & Lange-Bertalot 2005). Microscopic slides were prepared using Naphrax (index 1.69) and examined with a LEICA DML microscope (objective 100x). Microscopic photos were done using a Leitz-Diaplan Leica optivc microscope, using an 63x objective. Species determinations were made following the keys of Krammer & Lange-Bertalot (1986-2005). To get reliable data (confidence 95%) more than 400 valves were counted. The Trophic Index of Diatoms (TI_{DIA}; ROTT *et al.,* 1999; 2003) and Saprobic Index (SI; Rott *et al.* 1997) was calculated using the formula of Zelinka & Marvan (1961). In addition, the Diversity Index (H'; Shannon & Weaver 1949) was calculated. Permanent slides and photos were deposited in the Lab of Botany, Tirana University.

RESULTS AND DISCUSSIONS

From the dating model reported in the Fig. 2c, it was concluded that the core might belong to the last 20 years; alternated yellow and black layers might represent one year: the black layer might represent the late summer season, probably with high content of organic matter, from the intense growth of phytoplankton, and the white one might belong to rainy season: late autumn-winter. The measured layers reported in Fig. 2b and Tab. 1 show that there are differences on the sedimentation rate, oscillating from 0.5cm to 1.7cm (autumn 1998) in each layer, or from 1cm to 2.3cm per year (in autumn 1998). The calculated sedimentation rate (line a in Fig. 2c) is the linear regression, 1.76±0.43cm/yr, which can be considered relatively high, showing relatively strong erosion form the surrounding watershed.

About 140 species of diatoms were found in all examined core layers (43 subalyers); only about 10 species belong to centrics, the rest were pennate. *Achnnathes minutissima* was the most frequent species, found in 93% of the layers, followed by the centric diatoms *Cyclotella ocellata* (76.7%), *C. stelligera* (62.8) and *Asterionella formosa* (46.5%), then by other pennate species, like *Amphora lybica* (34.9%), *A. montana* (32.6%), *A. ovalis* (27.9), *Cymatopleura*

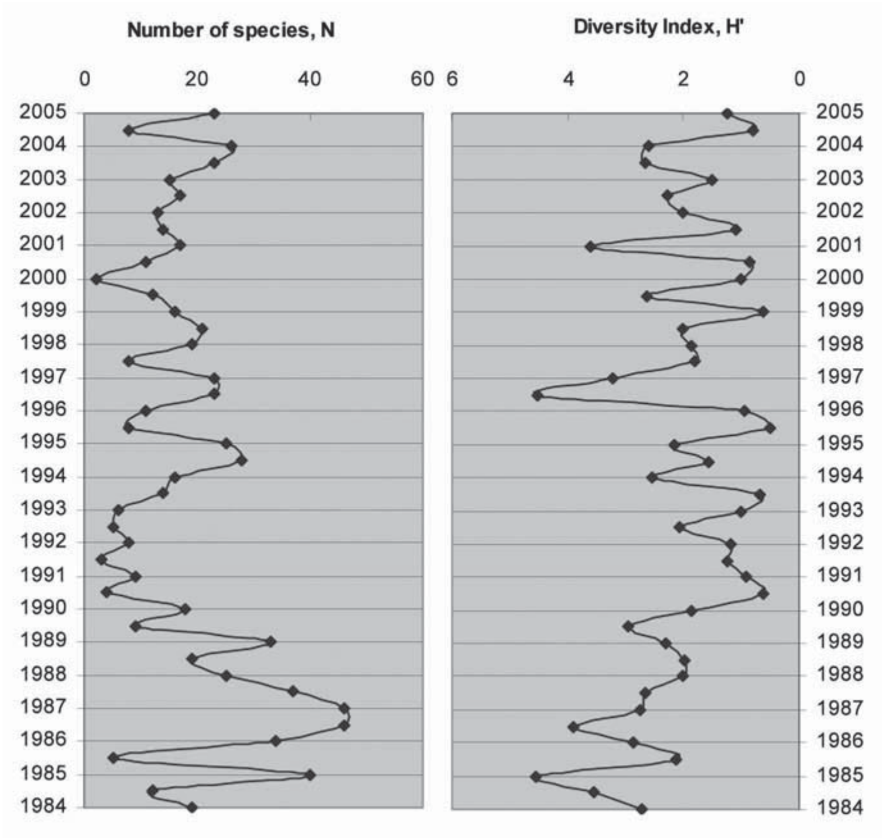

Fig. 3: Profiles of species number (N) and the related diversity index (H') in Belshi lake

solea (48.8%), *Cymbella affinis* (51.2%), *C. amphicephala* (20.9%), *C. minuta* (20.9), *C. silesiaca* (27.9), *Diatoma tenuis* (60.5%), *Fragilaria acus* (41.9%), *F. capucina* sp. *diverse* (16.3-27.9%), *Gomphonema olivaceum* (51.2%), *G. parvulum* var. *exilissimum* (32.6%), *Gyrosigma acuminatum* (74.4%), *Hantzschia amphioxys* (62.8%), *Fallacia pygmaea* (37.2%), *Navicula oligotraphenta* (25.6%), *N. reichardtiana* (27.9%), *N. trivialis* (20.9) and *Nitzschia palea* (46.5%).

Number of the species oscillated evidently between layers (Fig. 3), from 3 in 1991 (autumn) to 46 in 1986 and 1987. Slight decrease of species number and diversity was observed from the past years (1984) to the most recent years (2005). Generally, the white layers seem to be richer in species than black ones. Centric diatoms *Cyclotella ocellata* and *C. stelligera* were found also relatively abundant in the population community of each layer, respectively up to 86% (year 1993, *C. ocellata*) and up to 57% (1987, *C. stelligera*). From the pennatae diatoms, *Achnanthes minutissima* was found the most abundant in population community, up to 94% in year 2005, 90% in 1991 and 85% in 2004.

The population structure of diatoms help to give a better view of the average quality of the water. The Trophic Index of Diatoms (TI_{DIA}), calculated by us, classify the environment quality in seven classes, from ultra-oligotroph (TI_{DIA}, ≤1) to poly-hypertroph (TI_{DIA}, >3.4); to these classes would match up an increasing quantity of nutrients, especially phosphor and nitrogen (Rott *et al.* 1999). Where as the Saprobic Index (SI) takes into consideration the organic pollution, classifying the environment in 7 classes, from oligosaprob (SI, 1-1.5) to polisaprob (SI, 3.5-4) (Rott *et al.* 1997). It is worth to evidence that the TI_{DIA} and SI were drawn up for the periphyton communities, and are not well significant in diatoms found in core sediment layers, which are mainly of plankton origin. Therefore, our calculations have only an indicative value. Nevertheless, the TI_{DIA} oscillate from 1.2 (oligotroph, in years 1991, 1992, 2002) to 3.4 (polytroph, in year 1985) (Fig. 4). Saprobic index seems to be more stable, oscillating from 1.5 (oligosaprob) to 2 (beta-mesosaprob). The calculated indexes correspond to the water quality scarcely polluted (I-II class of quality) to moderately polluted (II class).

More than 170 species of diatoms were determined in the littoral samples of different lakes, where 14 species belong to centricae the others were pennatae. The sample from Cepi, a shallow eutrophic pond was the richest with diatoms, more than 90 species, followed by that in Mulleza (87) and in Merhoja (62). The diversity index was also high in Cepi sample (4.5). The most widespread species among the centric diatoms were *Cyclotella stelligera* and *C. ocellata*; among the pennate diatoms, the most widespread among the examined samples were *Cymbella*

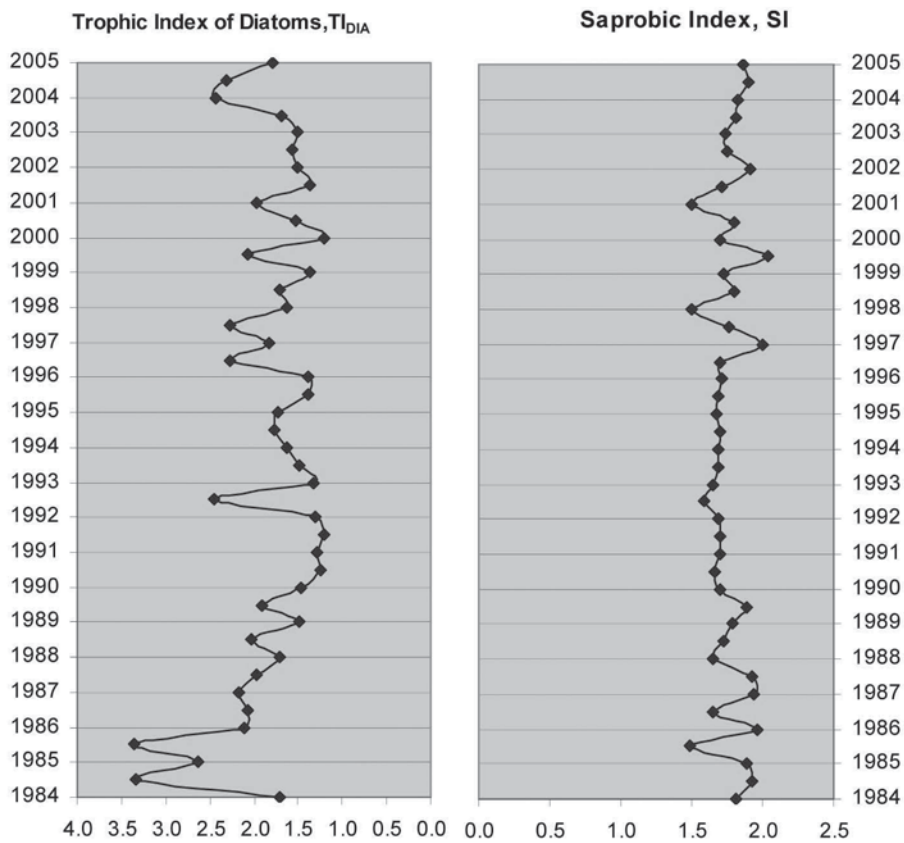

Fig. 4: Profiles of trophic index of diatoms (TI_{DIA}) and Saprobic index (SI) in Belshi lake

microcephala, Rhopalodia gibba, Cymbella minuta, Achnanthes minutissima, Navicula oligotraphenta, Nitzschia fonticola, Sellaphora pupula, followed then by *Achnanthes lanceolata, Cymatopleura solea, Cymbella affinis, C. silesiaca, Fragilaria acus, F. crotonensis, F. tenera, F. ulna, Gomphonema parvulum, G. sarcophagus, G. truncatum, G. acuminatum, N. cryptocephala, Nitzshia palea, Pinnularia microstauron* and *Stauroneis smitthii*. The most abundant species in their respective communities were *Achnanthes minutissima* (up to 58.7% in Belshi lake, June 2006) and *Cyclotella ocellata* (up to 33.3% in Merhoja, June 1993).

CONCLUSIONS

The results of this first tentative with the plaeoecological studies in Albania confirm that high diversity of diatoms were found in Dumre lakes, despite the limited number of samples examined. About 220 taxa of microscopic algae were found altogether, diatoms (*Bacillariophyta*), were found in all the collected samples, represented mainly from the genera *Navicula* (28 species), *Nitzschia* (23) and *Cyclotella* (17). In Plates I and II are reported 26 microscopic photos that represent 23 species, which are the most common and/or rare and interesting species. From the rare and interesting species of the karst lakes we can mention *Caloneis* cf. *aerophila* Bock (Plate 1: Fig. 8), *Gomphonema augur* Ehrenberg (Plate I: Fig. 1), *Neidium bisulcatum* var. *subampliatum* Krammer (Plate I: Fig. 14), *Nitzschia geitleri* Hustedt (Plate II: Fig. 5), *N. lorenziana* Grunow (Plate II: Fig. 6), *Placoneis elginensis* (Gregory) Ralfs (Plate I: Figs. 3-5), *P. clementioides* (Hustedt) E.J. Cox (Plate I: Fig. 6), *Sellaphora levissima* (Kuetzing) D.G. Mann (Plate I: Fig. 11), *Surirella venusta* Østrup (Plate II: Fig. 2), *S. gracilis* (Plate II: Fig. 3). Grunow *Surirella* cf. *tenera* W. Gregory (Plate II: Fig. 4). The small *Caloneis* sp. (Plate I: Fig. 7), found in the small karst pond of Cepi, represents an interesting or even new species that requires further information; it was found also in Borshi spring (Southern Albania). *Surirella* sp. (Plate II: Fig. 1), a rare specimen found in Mulleza lake represents also an interesting or possibly new species, too.

Almost all the lakes are situated in an agricultural area, where in several villages spread out through their watersheds the main activity is the traditional agriculture and livestock. The zone is hilly, with typical undulated relief, shaped by karst topography. Nevertheless, soft erosive formations build up their slopes; the original forests have been drastically disappeared so far, and the natural vegetation is represented mainly from Mediterranean shrubs that grow up nowadays only in limited areas. Those characteristics combined also with poor land use activities, more evident during past decades, are the cause

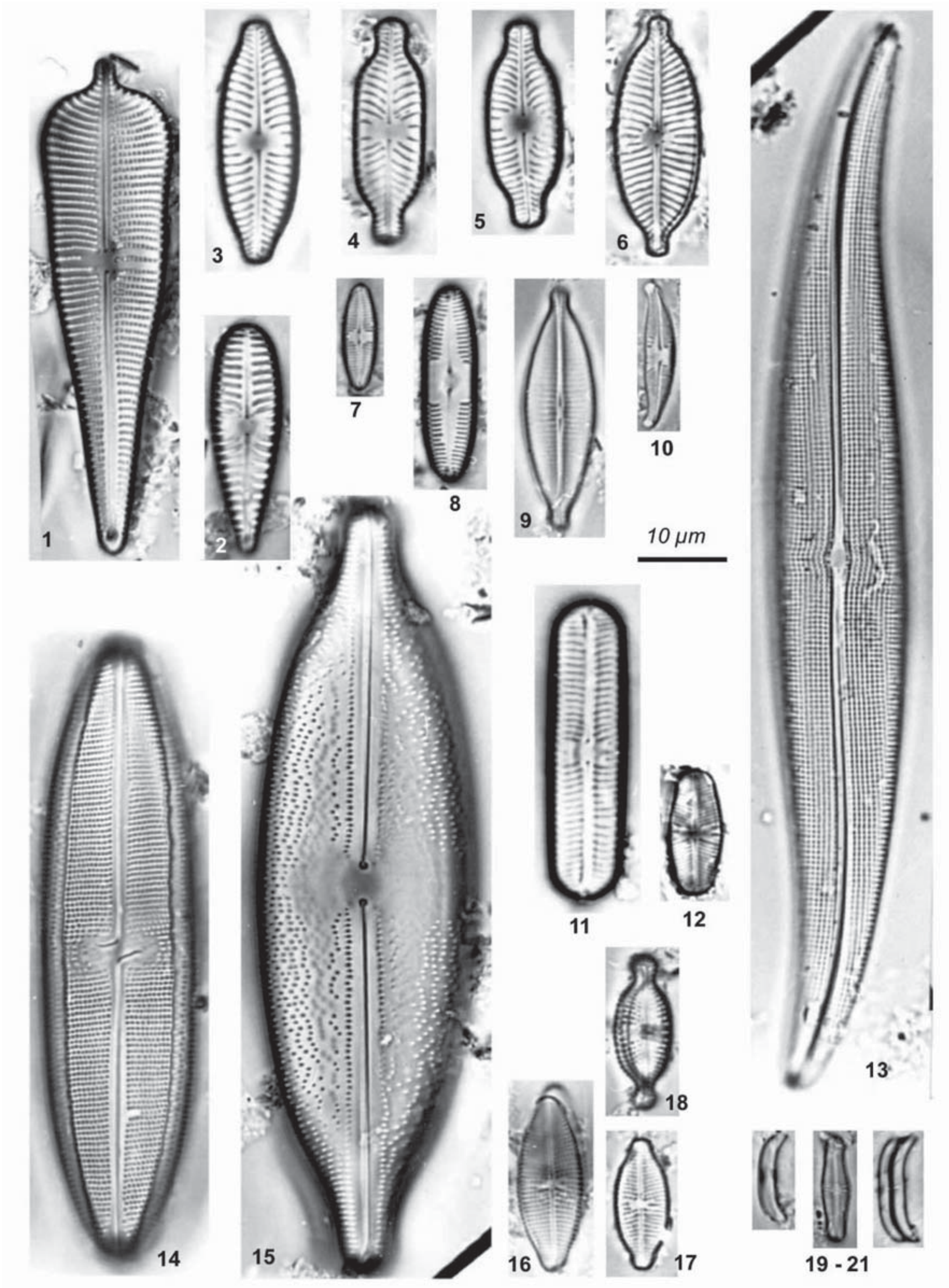

PLATE I: Fig. 1. *Gomphonema augur* Ehrenberg var. ?; **Fig. 2.** *Gomphonema olivaceum* (Hornemann) Brebisson var. *olivaceum*; **Figs. 3-5.** *Placoneis elginensis* (Gregory) Ralfs; **Fig. 6.** *Placoneis clementioides* (Hustedt) Cox; **Fig. 7.** *Caloneis* sp.; **Fig. 8.** *Caloneis* cf. *aerophila* Bock; **Fig. 9.** *Craticula accomoda* (Hustedt) Mann; **Fig. 10.** *Amphora montana* Krasske; **Fig. 11.** *Sellaphora levissima* (Kuetzing) Mann; **Fig. 12.** *Sellaphora pupula* (Kuetzing) Mereschkovsky; **Fig. 13.** *Gyrosigma acuminatum* (Kuetzing) Rabenhorst; **Fig. 14.** *Neidium bisulcatum* var. *subampliatum* Krammer; **Fig. 15.** *Anomoneis sphaerophora* (Ehrenberg) Pfitzer; **Figs. 15-16.** *Luticola kotschyi* (Grunow) Mann; **Fig. 17.** *Luticola muticopsis* (Van Heurck) Mann; **Figs. 19-21.** *Achnanthes catenata* Bily & Marvan.

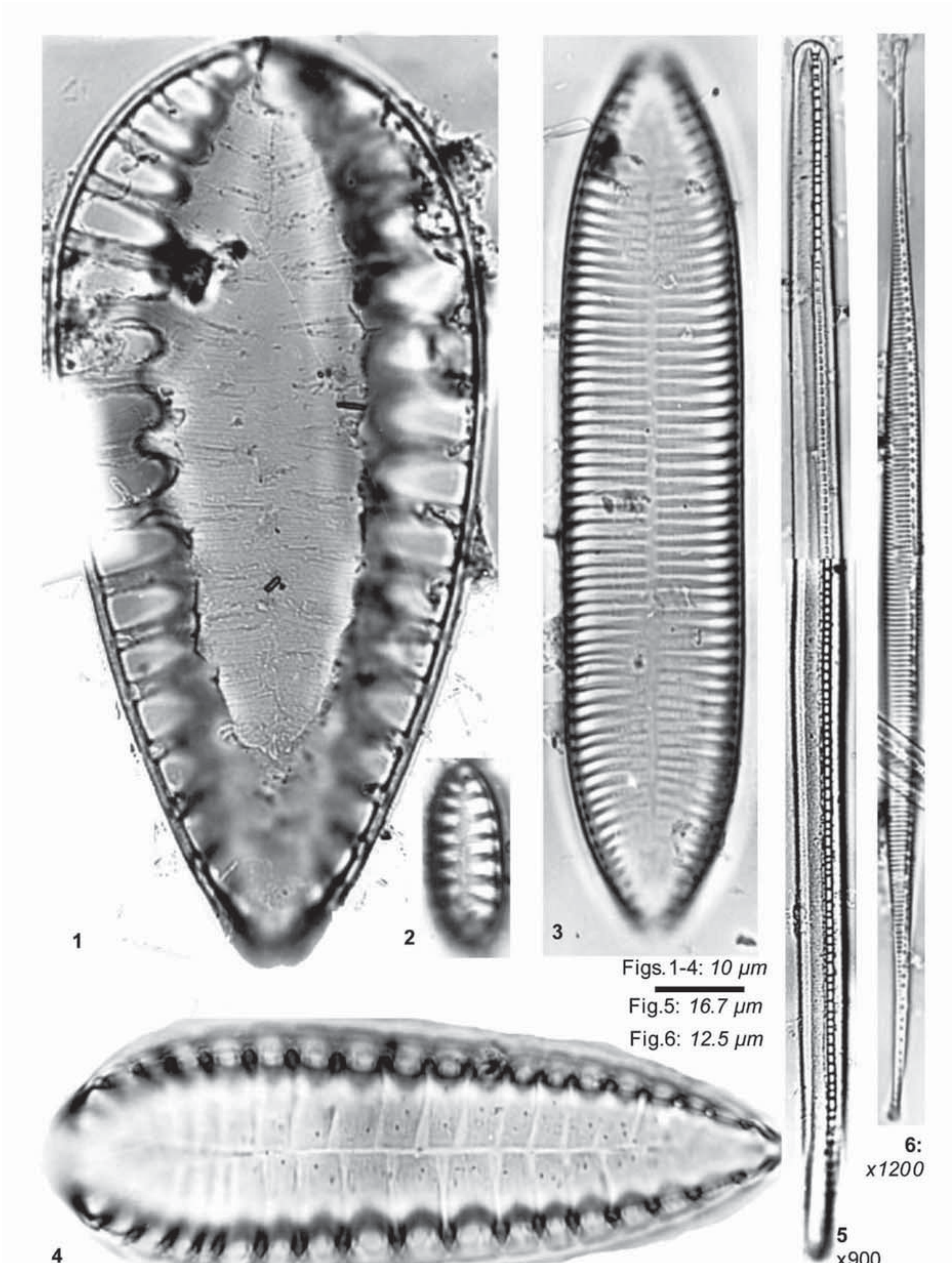

PLATE II: Fig. 1. *Surirella* sp.; **Fig. 2.** *Surirella venusta* Østrup; **Fig. 3.** *Surirella gracilis* Grunow; **Fig. 4.** *Surirella* cf. *tenera* W. Gregory; **Fig. 5.** *Nitzschia geitleri* Hustedt; **Fig. 6.** *Nitzschia lorenziana* Grunow.

of the relatively high rate of sedimentation observed even form our preliminary sampling in Belshi lake, phenomena observed even elsewhere in Albania (Miho *at al.* 2005, 2009). Moreover, poor management of waste was evident in the zone. The poor management of wastewater discharge, especially in Belshi lake, close with Belshi town can enhance the eutrophication processes. Also, other lakes suffer from the surrounding villages and their livestock, that decrease the beauty values of the zone, but they may cause health disturbances as well. The decentralized management of wastewater is recommended in each case. The erosion and as the consequence the sedimentation in the lakes could be prevented restoring the vegetation cover, through forestation activities, especially in denuded spots, i.e. in abandoned fields.

Acknowledgements – The core was taken with the aid of a manual core sampler, brought in Albania from Prof. B.W. Scharf, Muenster University, Germany. Dating was carried on in cooperation with Dr. H. Erlenkeuser, University of Kiel, Germany. The preparation of diatom samples was carried on by the former student of Biology B. Hoxha, under the assistance of Prof. A. Witkowski, using the facilities of the Department of Paleooceanology, Institute of Marine Sciences, University of Szczecin, Poland. To all of them the authors express the highest gratitude.

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REZIME

Mikroskopske alge kraških jezera regiona Dumre (Centralna Albanija)

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Više od 90 kraških jezera, često površine manje od 1ha, I dubine manje od 10m nalazi se raštrkano na krečnjaku i gipsu širom Albanije. Najpoznatija su jezera oblasti Dumre, regije koja se prostire izmedju dolina Shkumbini i Devolli (Elbasan region). U ova jezera voda niti pritiče niti otiče, tako da njihov nivo drastično varira tokom godine. Sporadično uzorkovanje perifitona i fitoplanktona sakupljano je na jezerima oblasti Dumre (Belshi, Merhoja, Mulleza, Cepi). Takodje je uyorkovan i jedan sedimentni niz (oko 38cm) na Belshi jezeru, Juna 2005; na osnovu Pb210 i Cs137, sedimenti se lepo raslojavaju took poslednjih 20 godina (2005-1984). Izračunata vrednost sedimentacije je 1.76 cm/godišnje, i relativno je visoka pre svega zbog intenzovnog erozivnog spiranja.

Diverzitet dijatomeja jezera oblasti Dumre može se smatrati visokim i pored malog broja studiranih uzoraka. Oko 220 taksona mikroskopskih algi, dijatomeja (Bacillariophyta), registrovano je u sakupljenim uzorcima i najzastupljeniji rodovi su bili Navicula (28 vrsta), Nitzschia (23) i Cyclotella (17). Više od 170 vrsta je nadjeno na litoralnim delovima jezera, a više od 90 vrsta jezero Cepi ima najbogatiju litoralni zonu. Oko 140 vrsta je nadjeno u dubinskom uzorku Belshi jezera, gde su uglavnom dominirale Achnnathes minutissima, Cyclotella ocellata, C. stelligera, Gyrosigma acuminatum, Cymbella affinis, Gomphonema olivaceum ili Hantzschia amphioxys. Centrične dijatomeje Cyclotella ocellata i C. stelligera, i pentane Achnanthes minutissima se takodje ubrajaju u češće vrste zajednica sedimentnih slojeva. Pronadjeni trofički indeks dijatomeja (TIDIA) u svakom sedimentnom sloju oscilovao je od 1.2 (oligotrofni) do 3.4 (politrofni), ukazujući na umereno zagadjivanje nutrijentima (fosforom i azotom pre svih). Saprobni indeks bio je stabilniji, i oscilovaoi je od 1.5 (oligosaprobni) do 2 (beta-mezosaprobni), što odgovara slabo zagadjenim vodama (I-II klasa) do do umereno zagadjenim vodama (II klasa). Od retkih i interesantnih vrsta kraških jezera ističu se Caloneis cf. aerophila, Gomphonema augur, Neidium bisulcatum var. subampliatum, Nitzschia geitleri, N. lorenziana, Placoneis elginensis, P. clementioides, Sellaphora levissima, Surirella venusta, Surirella cf. tenera. Caloneis sp. i Surirella sp.

Brdski reljef, tipična mediteranska klima, kombinovana sa slabim korišćenjem zemljišta, su verovatno osnovni razlozi visoke stope sedimentacije na jezeru Belshi. Preporučuje se decentralizovano upravljanje otpadnim vodama da se spreče procesi eutrofikacije, I zaštiti kvalitet vode. Takodje, preporučuje se obnova vegetacije da bi se sprečila erozija.

Ključne reči: Krsška jezera Albanije, jezero Belshi, sedimenti, dijatomeje Albanije

APPENDIX
Checklist of diatoms found in Dumre lakes (Central Albania)

***Centrales* (18 species)**
Actinocyclus normanii (W. Gregory) Hustedt
Asterionella formosa Hassall
Aulacoseira granulata (Ehrenberg) Simonsen
Aulacoseira italica (Ehrenberg) Simonesn
Cyclotella antiqua W. Smith
Cyclotella commensis Hustedt
Cyclotella cyclopuncta Hakansson & Carter
Cyclotella krammeri Hakansson
Cyclotella meneghiniana Kützing
Cyclotella ocellata Pantocsek
Cyclotella praetermissa Lund
Cyclotella radiosa (Grunow) Lemmermann
Cyclotella stelligera (Cleve & Grunow) Van Heurck
Dimerogramma minor (Gregory) Ralfs
Melosira moniliformis (O.F. Müller) C. Agardh
Melosira varians C.A. Agardh
Stephanodiscus medius Hakansson
Stephanodiscus parvus Stoermer & Håkansson

***Pennales* (193 species)**
Achnanthes catenata Bily & Marvan
Achnanthes clevei Grunow var. *clevei*
Achnanthes delicatula (Kuetzing) Grunow
Achnanthes exilis Kuetzing
Achnanthes lanceolata (Brebisson) Grunow agg.
Achnanthes ploenensis Hustedt
Achnathes minutissima Kuetzing
Amphipleura pellucida (Kuetzing) Kuetzing
Amphora cf. *aequalis* Krammer
Amphora copulata (Kuetzing) Schoeman & Archibald
Amphora fogediana Krammer
Amphora inariensis Krammer
Amphora lybica Ehrenberg
Amphora montana Krasske
Amphora ovalis Kuetzing
Amphora pediculus (Kuetzing) Grunow
Amphora veneta Kuetzing
Aneumastus minor (Hustedt) Lange-Bertalot
Aneumastus tuscula (Ehrenberg) Mann & Stickle
Anomoneis sphaerophora (Ehrenberg) Pfitzer
Bacillaria paradoxa J.F. Gmelin
Brachysira vitrea (Grunow) Ross
Caloneis cf. *aerophila* Bock
Caloneis alpestris (Grunow) Cleve
Caloneis cf. *hendey* Lange-Bertalot
Caloneis macedonica Hustedt
Caloneis silicula (Ehreneberg) Cleve
Caloneis thermalis (Grunow) Krammer
Caloneis sp.
Cocconeis neodiminuta Krammer
Cocconeis placentula Ehrenberg agg.
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck
Craticula accomoda (Hustedt) D. G. Mann
Craticula ambigua (Ehrenberg) D. G. Mann
Craticula cuspidata (Kuetzing) D.G.Mann
Cymatopleura elliptica Geissler & Gerloff
Cymatopleura solea (Brebisson) W. Smith
Cymbella affinis Kuetzing agg.
Cymbella amphicephala Naegeli
Cymbella caespitosa (Kuetzing) Brun
Cymbella cistula (Ehrenberg) Kirchner
Cymbella cymbiformis C.A. Agardh
Cymbella ehrenbergii Kuetzing
Cymbella helvetica Kuetzing
Cymbella lanceolata Ehrenberg
Cymbella lange-bertalotii Krammer
Cymbella microcephala Grunow gr.
Cymbella minuta Hilse
Cymbella norvegica Grunow
Cymbella prostrata (Berkeley) Cleve
Cymbella silesiaca Bleisch
Cymbella sinuata Gregory
Cymbella tumida (Brébisson) Van Heurck
Cymbella tumidula Grunow
Cymbella ventricosa Agardh
Diatoma ehrenbergii Kuetzing
Diatoma mesodon (Ehrenberg) Kuetzing
Diatoma moniliformis Kuetzing
Diatoma tenuis Kuetzing
Diatoma vulgaris Bory
Diploneis cf. *modica* Hustedt
Diploneis maulerii (Brun) Cleve
Diploneis oblongella (Nägeli) Cleve-Euler
Epithemia adnata (Kuetzing) Brebisson)
Epithemia smithii Carruthers
Epithemia sorex Kuetzing
Epithemia turgida (Ehrenberg) Kuetzing
Eunotia bidens Ehrenberg
Fallacia pygmaea Kuetzing
Fragilaria acus (Kuetzing) Lange-Bertalot
Fragilaria biceps (Kuetzing) Lange-Bertalot
Fragilaria bidens Heiberg
Fragilaria brevistriata Grunow
Fragilaria capitellata (Grunow) J. B. Petersen
Fragilaria capucina Desmazières var. *capucina*
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot
Fragilaria capucina var. *vaucheriae* (Kuetzing) Lange-Bertalot
Fragilaria construens (Ehrenberg) Grunow agg. (fo. *construens*)
Fragilaria construens fo. *binodis* (Ehrenberg) Hustedt
Fragilaria crotonensis Kitton
Fragilaria dilatata (Brébisson) Lange-Bertalot
Fragilaria fasciculata (Agardh) Lange-Bertalot
Fragilaria tenera (W. Smith) Lange-Bertalot
Fragilaria ulna (Nitzsch) Lange-Bertalot agg.
Fragilaria virescens Ralfs

Frustulia spicula Amosse
Frustulia vulgaris (Thwaites) DeToni
Gomphonema angustatum (Kuetzing) Rabenhorst
Gomphonema augur Ehrenberg
Gomphonema clavatum Ehrenberg
Gomphonema micropus Kuetzing var. micropus
Gomphonema minutum (Agardh) Agardh agg.
Gomphonema olivaceum (Hornemann) Brebisson gr.
Gomphonema parvulum (Kuetzing) Kuetzing var. parvulum
Gomphonema parvulum var. *exilissimium* Grunow
Gomphonema pumilum (Grunov) Reichardt & Lange-Bertalot
Gomphonema sarcophagus W. Gregory
Gomphonema truncatum Ehrenberg
Gyrosigma acuminatum (Kuetzing) Rabenhorst
Gyrosigma scalproides (Rabenhorst) Cleve
Hantzschia amphioxys (Ehrenberg) Grunow
Luticola kotschyi (Grunow) D. G. Mann
Luticola mutica (Kützing) D.G. Mann
Luticola muticopsis (Van Heurck) D. G. Mann
Luticola nivalis (Ehrenberg) D.G. Mann
Luticula sp.
Meridion circulare (Greville) C. Agardh
Navicula antonii Lange-Bertalot (=Navicula menisculus var. grunowii Lange-Bertalot)
Navicula atomus (Kützing) Grunow
Navicula capitatoradiata Germain
Navicula caterva M.H.Hohn & Hellerman
Navicula cf. concentrica J.R. Carter
Navicula cryptocephala Kuetzing
Navicula cryptofallax Lange-Bertalot & Hofmann
Navicula cryptotenella Lange-Bertalot
Navicula cryptotenelloides Lange-Bertalot
Navicula dealpina Lange-Bertalot
Navicula duerrenbergiana Hustedt
Navicula leistikowii Lange-Bertalot
Navicula libonensis Schoeman
Navicula menisculus Schumann
Navicula minuscula Grunow var. *minuscula*
Navicula oligotraphenta Lange-Bertalot & G. Hofmann
Navicula peregrina (Ehrenberg) Kuetzing
Navicula radiosa Kuetzing
Navicula radiosafallax Lange-Bertalot
Navicula reichardtiana Lange-Bertalot
Navicula reinhardtii Grunow
Navicula seibigii Lange-Bertalot
Navicula subminuscula Manguin
Navicula tenelloides Hustedt
Navicula trivialis Lange-Bertalot
Navicula veneta Kuetzing
Navicula viridula (Kuetzing) Kuetzing,
Navicula viridula var. *germainii* (J. H. Wallace) Lange-Bertalot
Navicula viridula var. linearis Hustedt
Naviculadicta subrotundata (Hustedt) Lange-Bertalot
Neidium affine (Ehrenberg) Pfitzer
Neidium ampliatum (Ehrenberg) Krammer
Neidium bisulcatum var. subampliatum Krammer
Neidium dubium (Ehrenberg) Cleve
Nitzschia alpina Hustedt
Nitzschia amphibia Grunow
Nitzschia angustata Grunow
Nitzschia bacilliformis Hustedt
Nitzschia brunoii Lange-Bertalot
Nitzschia calida Grunow
Nitzschia constricta (Gregory) Grunow
Nitzschia denticula Grunow
Nitzschia dissipata (Kuetzing) Grunow
Nitzschia fonticola Grunow
Nitzschia geitleri Hustedt
Nitzschia graciliformis Lange-Bertalot & Simonsen
Nitzschia hungarica Grunow
Nitzschia incospicua Grunow
Nitzschia lacuum Lange-Bertalot
Nitzschia linearis (Agarth) W. Smith var. *linearis*
Nitzschia lorenziana Grunow
Nitzschia palea (Kuetzing) W. Smith var. *palea*
Nitzschia recta Hantzsch
Nitzschia scalpelliformis (Grunow) Grunow
Nitzschia sigma (Kützing) Smith
Nitzschia sigmoidea (Ehrenberg) W. Smith
Nitzschia solita Hustedt
Nitzschia vermicularis (Kuetzing) Hantzsch
Opephora olsenii M. Møller
Pinnularia microstauron (Ehrenberg) Cleve
Pinnularia microstauron var. *brebissonii* (Kuetzing) A. Mayer
Pinnularia nobilis (Ehrenberg) Ehrenberg
Pinnularia rupestris Hantzsch
Pinnularia viridiformis Krammer
Pinnularia viridis (Nitzsch) Ehrenberg
Placoneis clementioides (Hustedt) E.J. Cox
Placoneis elginensis (Gregory) Ralfs
Placoneis paraelginensis Lange-Bertalot
Placoneis pseudoanglica Lange-Bertalot var. *pseudoanglica*
Pleurosigma elongatum W. Smith
Rhoicosphaenia abbreviata (Agardh) Lange-Bertalot
Rhopalodia gibba (Ehrenberg) O. Mueller
Rhopalodia musculus (Kuetzing) O.Mueller
Sellaphora bacillum (Ehrenberg) D.G. Mann
Sellaphora levissima (Kuetzing) D.G. Mann
Sellaphora pupula (Kuetzing) Mereschkovsky
Stauroneis anceps Ehrenberg
Stauroneis phoenicenteron (Nitzsch) Ehrenberg
Stauroneis smitthii Grunow
Surirella angusta Kuetzing
Surirella bifrons Ehrenberg
Surirella brebissonii Krammer & Lange-Bertalot
Surirella cf. splendida Kuetzing
Surirella gracilis Grunow
Surirella linearis W. Smith
Surirella minuta Brébisson
Surirella cf. tenera W. Gregory
Surirella terricola Lange-Bertalot et Alles
Surirella venusta Østrup
Tabellaria flocculosa (Roth) Kuetzing
Tetracyclus rupestris (Braun) Grunow