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Effect of long-term cage fish-farming on the phytoplankton biodiversity in two large Bulgarian reservoirs

by

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Synopsis: The present paper provides data on recent (2010-2012) biodiversity of planktonic algae in two Bulgarian reservoirs, in which cage fish farming ran for more than 30 years (with different composition of fishes). Comparisons are made between the species composition of algae in both reservoirs, and between the recent phytoplankton structure and its structure from previous periods, for which literature data are available. In spite of different degree of impact of the cage fish farming on both reservoirs, a general trend of increase of number of species (double to triple) and shift in phytoplankton taxonomic structure and composition of dominant complexes was proved. However, it has to be noted that this trend ran in parallel with some losses in biodiversity and mainly with enhancement of cyanoprokaryotes and green algae.

Keywords: cyanoprokaryotes, green algae, diatoms, eutrophication, similarity

1. Introduction:

Bulgaria has long traditions in studies of algal biodiversity and recent estimates show that on its territory ca. 6000 algal taxa have been recognized (Stoyneva 2014). Attention to water reservoirs and their planktonic algae started to be paid in the end of 50s of 20^{th} century, generally simultaneously with the impoundment of new water bodies in the country. In total, data on 23 reservoirs with ca. 250 species had been published (Stoyneva & Temniskova-Topalova 2007; Stoyneva 2014). However, studies were focused mainly on phytoplankton quantitative structure, seasonal dynamics and dominants. Effects of fish rearing on the abiotic parameters and water biota in Bulgaria have been studied in fish farms and fish ponds, for which a total of ca. 600 algal taxa have been published (Stoyneva & Temniskova-Topalova 2007; Stoyneva 2014). The effects of fish cage farming in Bulgaria on physical and chemical water parameters and fish have been firstly documented and discussed by Naumova & Zhivkov (1988). Later, mainly chemical data for reservoirs with cage farming were provided (e.g. Iliev & Hadjinikolova 2011; Hadjinikolova & Iliev 2012). The subject of cage fish farming impact has attracted the attention of phyto-

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planktonologists worldwide, but the main studies have been aimed on its short-term effects and mainly on phytoplankton abundance, with the general assumption that the impact results and eventual danger are due to changed nutrient load and are generally similar to eutrophication (e.g. Arzul et al. 1996; Nogueira 2000; Demir et al. 2001; Diaz et al. 2001; Karakassis et al. 2005; Thanh Hung et al. 2005; Cao et al. 2007; Degefu et al. 2011; Bartozek et al. 2014). Generally, since water renewal time is shorter in reservoirs than in natural lakes, changes in ecosystems such as eutrophication resulting from fish cage culture may be less harmful and because of this reservoirs are accepted as very appropriate water bodies for cage culture (Demir et al. 2001). However, yet the evidence for long-term effects of different farm capacities is scarce. According to Crossetti et al. (2008) and Borges et al. (2010) the increased eutrophication decreases the phytoplankton diversity and enhances the growth of cyanoprokaryotes, and this is important for water reservoirs, which can be regarded as biodiversity hot-spots (e.g. Williams et al. 2004). On the other hand, the results of Bartozek et al. (2014) did not confirm the hypothesis of changes in the concentration of nutrients for the sites influenced by net cages and on the attributes of the phytoplankton community, including its composition and richness. The aim of the present paper is to compare the effect of long-tewrm cage fish farming (ca. 30 years) on the algal biodiversity in two reservoirs Dospat and Kurdzhali, which were the first reservoirs used for such purpose in Bulgaria.

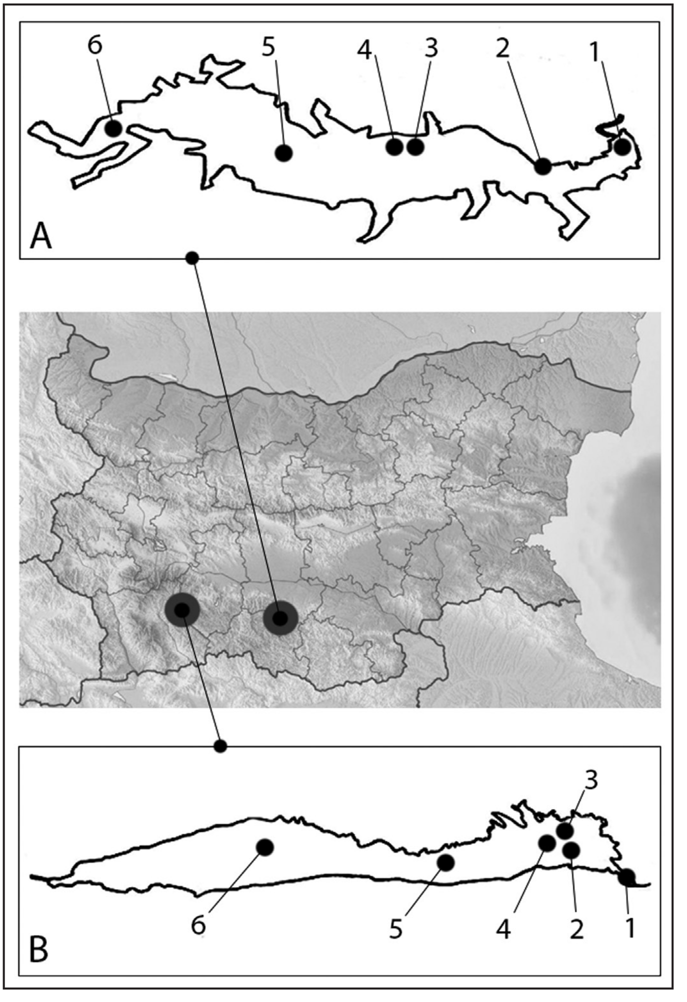

Figure 1: Maps of the reservoirs Kurdzhali (A) and Dospat with their position in Bulgaria and location of the studied sites (NN1-6, starting from the dam wall).

	Reservoir Kurdzhali	Reservoir Dospat
Geographic coordinates	41°37' 25°20'	41o41`54``24o05`10``
Average height (m a.s.l.)	280	1 200
Volume (m³)	497 235 698	449 248 693
Aquatory (m²)	15 991 735	22 099 371
Maximum length (m)	23 400	16 700
Average width (m)	1 323	683
Average depth (m)	31	20
Maximum depth (m)	85	50
Watershed basin (km²)	1882	432.30
Retention time (days)	205	180
Water temperature (range; °C)	3.8-26.4	3.9-23
Conductivity (range; µs/m)	294-346	103-118.6
Transparency (Secchi depth; m)	1.2-5.5	2.1-6.5
pH (range)	7.06-9.26	6.47-8.83
NH_4-N (range; mg l-1)	0.001-0.423	0.001-0.685
NO_3-N (range; mg l-1)	0.1-3.48	0.1-2.03
TN (range; mg l-1)	0.12-3.5	0.1-1.924
PO_4^{3}- (range; mg l-1)	0.001-0.38	0.001-0.92
TP (range; mg l-1)	0.03 - 0.215	0.01-0.418

Table 1: Morphometric characteristics and physical and chemical parameters (the last measured during the investigation period 2010-2012) of the reservoirs Kurdzhali and Dospat.

2. Material and methods:

Studied sites are two reservoirs situated in the low (Kurdzhali) and middle (Dospat) parts of Rhodopi Mts in Bulgaria. Their main morphometric characteristics and physical and chemical parameters (the last measured during the investigation period) are given in Table 1. More details on the abiotic features and biodiversity of both reservoirs are provided in Michev & Stoyneva (2007). Cage fish farming started in both reservoirs 30 years ago, but the reared fishes are different: sturgeons (Acipenseridae), common carp (*Cyprinus carpio*) and wels catfish (*Sylurus glanis*) in Kurdhzali and only rainbow trout (*Oncorhynchus mykiss*) in Dospat. According to our knowledge, there is no other significant impact on these reservoirs.

Phytoplankton samples have been taken by Danish bathometer (at each 5 m from the surface layer till the reservoir bottom) and processed by standard method of fixation with 4% formalin and further sedimentation. In both reservoirs sampling was conducted from April 2010 till March 2012 in 6 sites (Figs. 1a, b), with site numbers starting from the dam (1) and cage farms (2-3) down to the tail waters (4-6). Totally 547 samples have been analyzed (307 from deeper Kurdzhali reservoir and 240 from shallower Dospat reservoir).

Microscope work has been done on Bürker blood-counting chamber on microscope "Carl Zeiss Axioscope 2 plus" (magnification 400x) using standard taxonomic literature with critical use of AlgaeBase (Guiry & Guiry 2014). Comparisons have been done with the only available data on species composition, published on Dospat for the period 1972-1975 by Naidenow & Saiz (1977) and on Kurdzhali for the periods 2000-2002 and 2006 by Traykov (2005) and Belkinova et al. (2007), respectively. The similarity was calculated by the standard Sörensens' Similarity Index (SSI), according to the formula (2c/a+b), where: a - number of species in site (period) a, b – number of species of site (period) b, and c - number of common species for sites (periods) a and b.

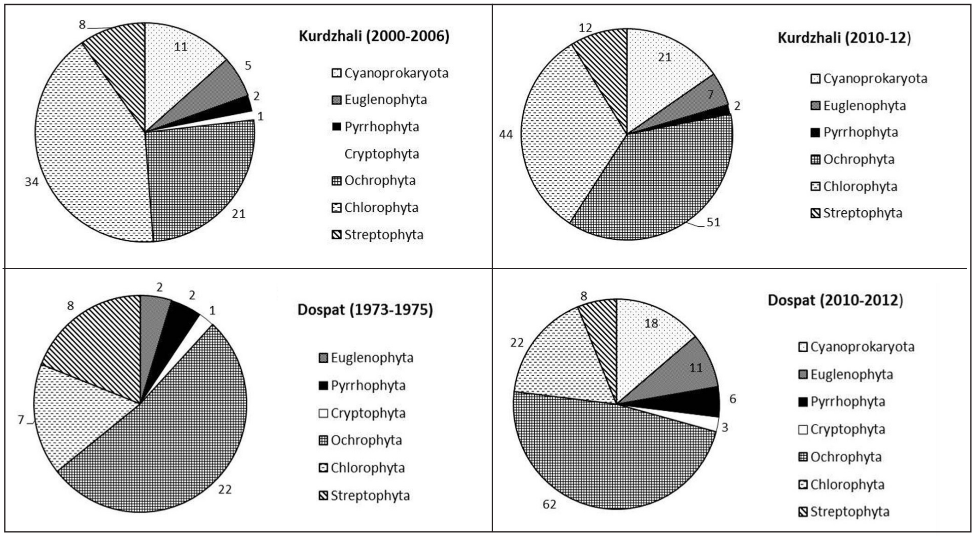

Figure 2: Taxonomic structures of the phytoplankton from the reservoirs Kurdzhali and Dospat during different periods of investigations (1973-1975 – acc. to NAIDENOW & SAIZ (1977); 2006-2012 – acc. to combined data of TRAYKOV (2005) and BELKINOVA et al. (2007); 2010-2012 – data from present study).

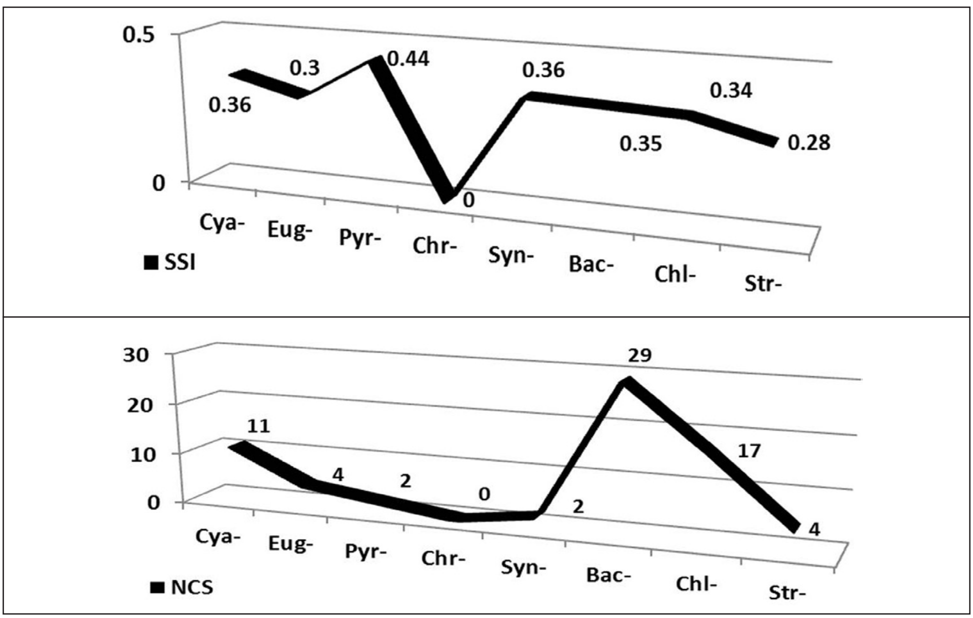

Figure 3: Sörensens' Similarity Index (SSI) between different taxonomic groups of algae, recorded in the reservoirs Kurdzhali and Dospat in the period 2010-2012.
Abbreviations: Cya – Cyanoprokaryota; Eug – Euglenophyta, Pyr – Pyrrhophyta, Cry – Cryptophyta, Chr – Chrysophyceae, Syn – Synurophyceae, Bac – Bacillariophyceae, Chl – Chlorophyta and Str – Streptophyta.

3. Results and discussion:

During our studies in Kurdzhali 137 taxa from 6 divisions have been identified: Cyanoprokaryota (21), Euglenophyta (7), Pyrrhophyta (2), Ochrophyta (51: Bacillariophyceae - 48; Synurophyceae - 3), Chlorophyta (44) and Streptophyta (12) – Table 2, Fig. 2. In Dospat 131 taxa from 7 divisions have been identified: Cyanoprokaryota (18), Euglenophyta (11), Pyrrhophyta (6), Cryptophyta (3), Ochrophyta (62: Bacillariophyceae 58; Chrysophyceae – 1, Synurophyceae - 3), Chlorophyta (22), Streptophyta (8) – Table 2, Fig. 2. Common for both reservoirs are 70 taxa and the Sörensens' similarity index (SSI) between them is 0.52. Similarity by different taxonomic groups ranged between 0.28 and 0.44 and together with common taxa in each group is shown on Fig. 3.

Data on phytoplankton of both reservoirs under investigation, published before this study, are quite scarce. According to Traykov (2005), the phytoplankton of Kurdzhali Reservoir in the three studied by him sites during the period 2000-2002 contained 55 taxa from 6 divisions (Table 2) and the number of species during different months of his investigation ranged between 28 and 55. The author did not provide detailed data on seasonal differences in the species composition and dominant species, but mentioned the summer mass development of *Fragilaria crotonensis* and "intensive" autumn bloom of *Microcystis aeruginosa, Anabaena* sp. and *Aphanizomenon flos-aquae*. In 2006, based on two summer samplings in July and September in four sites of the same reservoir, Belkinova et al. (2007) also published 55 algal taxa from 6 divisions (Table 2). The authors noted that the number of species in July and September 2006 was equal (40) but common for both months were only 24, with a big difference in the species composition of cyanoprokaryotes. According to the two cited above works, the highest number of taxa belonged to green algae and the highest number of species was detected in the tail waters. Belkinova et al. (2007) marked 17 algae as abundant in their taxonomic tables and outlined in the text the following dominants: *Synechoccoccus elongatus, Fragilaria crotonensis, Synedra ulna, Stephanodiscus hantzschii, Ankyra judayi, Monactinus simplex* and *Eudorina elegans* (Table 2). Obviously, the comparison of data for the periods 2000-2002 and 2006 with our results is difficult due to the big differences in the number of investigated samples and their horizontal and temporal distribution. However, some similarities and dissimilarities could be outlined. Similarity coefficient of Sörensen (SSI) between the periods 2000-2002 and 2009-2012 is only 0.25, 2006 and 2009-2012 – only 0.38, and when data from both previous studies are combined (2000-2006) the similarity between them and 2009-2012 is only 0.38.This low similarity is easily explainable with differences in the sampling design, but since the studies from two different previous independently came to the same general number of 55 algae for each of them, and our investigation proved presence of 137 species (with notable increase of number of cyanoprokaryotes, green algae and diatoms – Fig. 2), it is possible tentatively to suggest a trend of general increase of biodiversity due to augmented nutrient loading as effect of long-term cage fish farming. However, the effect on phytoplankton biomass and quantitative distribution is not so obvious – the average biomass detected by us is on conformity with data, provided by Belkinova et al. (2007) and the quantitative phytoplankton distribution and trophic gradient follow the normal spatial and temporal patterns, known for temperate reservoirs with general increase from dam to tail waters (Dochin, in prep.).

According to Naidenow & Saiz (1977), the phytoplankton in Dospat Reservoir comprised of 45 algal taxa, found in a three-year period (1972-1975). The authors explained this low number with the low insolation of this reservoir, peculiar by its narrow shape and deep situation in a mountain gorge. Another feature of the qualitative composition was the similar number of species of diatoms and green algae (19 and 18, respectively). The authors provided a generalized table of species composition by seasons, where 19 taxa were pointed for spring, 35 – for summer and 31 – for autumn period. In the text, the number of algae (without flagellates), detected annually during different seasons was much lower – 12 species in spring (11 diatoms and 1 green), 11 species in summer (1 diatom and 5 greens) and 14 in autumn (9 diatoms and 5 greens). The comparison of these data with our results shows significant (triple) increase of the species number (from 45 to 131 – Table 2), and also a change in the taxonomic structure and enrichment of the phytoplankton with the group of cyanoprokaryotes (Fig. 2). The increase in the number of species belonging to euglenophytes and pyrrhophytes during the 2010-2012 period is also notable (Fig. 2). In contrast with the situation in the 70s, when diatoms and green algae have been almost equally represented in the phytoplankton, during our study, diatoms have clear leading role in the species composition – they comprise 45% of all species found, while green algae occupied second place. Detailed analysis of the species composition also shows significant shifts with "appearance" and "disappearance" of given species (Table 2) during the last 30 years. For some of them, like *Uroglena volvox* and *Synura uvella*, 'disappearance" was predicted by former authors since they accepted these species as a part of the "primary biopool" (NNaidenow & Saiz 1977). Other, algae from the same "primary" group, also known as worldwide broadly distributed, like *Trachelomonas volvocina* and *Eudorina elegans*, continue to grow in the reservoir in recent times. In general, most of the "new" taxa found, are algae, pointed in standard manuals and floras as common members of eutrophic waters (e.g. *Dolichospermum spiroides, Planktothrix agardhii, P. rubescens*) but some are with not well-known ecology (e.g. L*imnococcus limneticus* – Komárek & Anagnostidis 1999). Common for both periods of investigations are 22 taxa, which means that their similarity (acc. to Sörensens' coefficient) is only 0.25.

Differences concern also the composition of dominants and subdominants. In 70s, they were represented mainly by diatoms, one dinoflagellate and two green streptophyte algae, whereas during our studies, in addition to them, chlorophyte green algae and cyanoprokaryotes appeared in dominant complexes (Table 2). The "new" complexes include some species typical for oligotrophic waters (e.g. *Gymnodinium uberrimum* – Starmach 1974; Popovský & Pfiester 1990), but also some well-known harmful algae, producers of cyanotoxins, related with eu- and even hypertrophic waters (e.g. *Aphanizomenon flos-aquae, Planktothrix rubescens*). It is difficult to make strong conclusions, based on dominant composition only, since for some of the species different ecological characteristics are provided from different authors. For example, Staurastrum gracile according to Coesel

(1997) is mesotrophic, according to LENZENWEGER (1997) – oligotrophic, while in the opinion of PALAMAR-MORDVINTZEVA (1982) it is broadly distributed and strongly variable in different water bodies. According to the previous studies of one of the authors, this species was found by us in strongly eutrophicated Bulgarian lakes Srebarna and Durankulak (STOYNEVA 1998, 2000 ab). In Dospat, this species was pointed once among July 1973 dominants (NAIDENOW & SAIZ 1977), while in our studies it was relatively equally distributed in the reservoir aquatory, but was not recorded in the dominant complexes. However, the detected recent shift in the taxonomic structure of dominant complexes (with appearance of cyanoprokaryotes, chlorophytes and small centric diatoms) combined with their diversification with twice increased number of species (from 8 in 70s to 17 nowadays – Table 2), indicates, in our opinion, the trend of water eutrophication caused by the long-term cage-fish farming and increased organic matter in the reservoir due to non-utilized (uneaten) food from the cages. The increased trophic state of Dospat waters was proved also by quantitative phytoplankton spatial distribution and double increase of average annual algal biomass (from 0.7 in 70s to 1.35 mg l^{-1} – DOCHIN & STOYNEVA, in press). In addition, in Dospat, much more abundant phytoplankton was detected near the dam and cage farms than in tail waters (DOCHIN & STOYNEVA, in press).

In conclusion, the results obtained during this study allow us to suggest gradual general increase in algal biodiversity of the phytoplankton communities in two Bulgarian reservoirs, combined with shifts in dominant complexes and in total composition with some species losses and enhancement of harmful species, caused by long-term fish cage farming (ca 30 years). It is possible to suggest also that due to accumulation effect, this process is gradually speeded-up. For example, during the last 30 years in Dospat the number of species showed triple increase, while the recorded increase in Kurdzhali in the period of the last 6-12 years there was double increase in the species number. The comparison between the effects of cage fish farms in both reservoirs shows that in Dospat the impact is strongly expressed than in Kurdzhali. Most probably, the larger volume of Kurdzhali, its deeper character and longer insolation are among the reasons for these differences. There are almost no data concerning the influence of species composition of reared fishes on water quality and therefore for the moment this factor is not discussed here in detail. The cage impact concerns the general more notable change in the biodiversity, in the phytoplankton abundance and distribution, and in the general trophic status in Dospat reservoir. The lower trophic state of Kurdzhali and the "normal" pattern of spatial distribution of phytoplankton abundance indicates lower impact from fish cages, and the main data, which suggest such influence could be found in the recorded double increase of algal biodiversity and dominant shifts during the last 12 years.

Table 2: Species composition of the phytoplankton from the reservoirs Kurdzhali (K) and Dospat (D) during different periods of investigations (1973-1975 – acc. to NAIDENOW & SAIZ 1977; 2000-2002 – acc. to TRAYKOV 2005; 2006- acc. to BELKINOVA et al. 2007; 2010-2012 – data from present study): xxx – dominant, xx – subdominant; x - occurrence.

Taxa	K-2000-2002	K-2006	K-2010-2012	D-1972 1975	D-2010-2012
Cyanoprokaryota					
Anabaena sphaerica Bornet et Flahault			x		
Anabaena sp.	xxx				
Anabaenopsis sp.					x
Anathece clathrata (West et G.S.West) Komárek, Kastovsky et Jezberová			x		
Aphanizomenon flos-aquae Ralfs ex Bornet & Flahault	xxx	xxx/x	x		xxx/x
Aphanocapsa spp.			x		x
Calothrix sp.					x
Chroococcus dispersus (Keissler) Lemmermann			x		
Chroococcus minutus (Kützing) Nägeli			x		
Chroococcus turgidus (Kützing) Nägeli			x		x
Coelosphaerium kutzingianum Nägeli			x		x
Dolichospermum affine (Lemmermann) Wacklin, Hoffmann et Komárek		xxx/x			
Dolichospermum flos-aquae (Brébisson ex Bornt et Flahault) Wacklin, Hoffmann et Komárek			x		x
Dolichospermum solitarium (Klebahn) Wacklin, Hoffmann et Komárek		xxx	x		
Dolichospermum spiroides (Klebahn) Wacklin, Hoffmann et Komárek			x		x
Eucapsis alpina		x			
Limnococcus limneticus (Lemmermann) Komárková, Jezberová, O. Komárek et Zapomélová			x		xx/x
Merismopedia glauca (Ehrenberg) Kützing	x				
Microcystis aeruginosa (Kützing) Kützing	xxx	xxx/x	x		x
Microcystis pulverea (H.C. Wood) Forti emend. Elenkin		x	x		
Noctoc sp.					x
Oscillatoria limosa C.Agardh ex Gomont			x		xx/x

Taxa	**K-2000-2002**	**K-2006**	**K-2010-2012**	**D-1972 1975**	**D-2010-2012**
Oscillatoria spp.	x				
Phormidium willei (Gardner) Anagnostidis et Komárek			x		
Phormidium sp.	x		x		x
Planktothrix agadhii (Gomont) Anagnostidis et Komárek					x
Planktothrix rubescens (De Candolle ex Gomont) Anagnostidis et Komárek					xxx/xx
Scopulonema sp.			x		
Scytonema sp.	x				
Snowella lacustris (Chodat) Komárek et Hindák			xxx/xx/x		
Spirulina major Kützing ex Gomont					x
*Synechococcus elongatus (*Nägeli) Nägeli		xxx	x		
Woronichinia naegeliana (Unger) Elenkin			x		
Chlorophyta			x		
Actinastrum hantzschii Lagerheim					x
Actinastrum hantzschii var. *gracile* V. K. Tschernov			x		
Ankyra judai (G.M. Smith) Fott		xxx/x	x		
Ankyra occellata (Korshikov) Fott			x		
Ankyra sp.					
Carteria sp.			x		
Chlamydomonas reinhardtii P.A.Dangeard			x		
Chlamydomonas spp.	x		x		
Coelastrum microporum Nägeli in A. Braun		x	x		
Coelastrum sphaericum Nägeli			x		x
Coelastrum sp.		x			
Coenochloris hindakii Komárek		x			
Coenochloris sp.		x			
Coenococcus planctonicus Korshikov		x			
Coenococcus sp.			x		
Comassiella arcuata var. *platydiscus* (G. M. Smith) Hegewald et M. Wolf				x	
Crucigenia quadrata Morren			xxx		
Crucigenia tetrapedia W. et G. S. West				x	
Desmodesmus bicaudatus (Dedusenko) P. M. Tsarenko		x			

Taxa	K-2000-2002	K-2006	K-2010-2012	D-1972 1975	D-2010-2012
Dictyosphaerium simplex Korshikov			x		
Dictyosphaerium sp.	x				
Elakatothrix gelatinosa Wille			x		x
Elakatothrix genevensis (Reverdin) Hindak					x
Elakatothrix spirochroma (Reverd.) Hind					x
Ennalax acutiformis (Schöder) Hindák					xx
Eudorina elegans Ehrenberg	x	xxx	x	x	xxx/x
Golenkinia radiata Chodat			x		x
Hariotina reticulata P. A. Dangeard			x		
Koliella sp.					x
Lagerheimia ciliata (Lagerheim) Chodat			xxx		
Lagerheimia longiseta Lemmermann) Printz			x		
Micractinium pussilum Fresenius			x		x
Monactinus simplex (Meyen) Corda	x	xxx/x	x		x
Monoraphidium pusillum		x			
Monoraphidium sp.	x				
Mucidosphaerium pulchellum (H.C. Wood) C. Bock, Proschold et Krienitz		xxx/x	x	x	x
Mychonastes elegans (Bachmann) Krienitz, C. Bock, Dadlech et Proschold		x			
Oocystidium ovale Korshikov			xx		xxx/x
Oocystis borgei J.Snow		x	x		x
Oocystis lacustris Chodat		xxx/x	xx		
Oocystis socialis Ostenfeldt		x			
Oocystis sp.				x	
Oedogonium sp.					x
Pandorina morum (O.F.Müller) Bory de Saint-Vincent		x	xx/x		xxx/x
Pediastrum duplex Meyen	x	xxx/x	x		x
Pseudopediastrum boryanum (Turpin) Hegewald in Buchheim et al.	x		x		
Pseudoschroederia robusta (Korshikov) Hegewald et E.Schnepf		x	x		
Pseudostaurastrum limneticum (Borge) Couté et G. Rousselin			x		
Quadricoccus ellipticus Hortobágyi		x			

Taxa	**K-2000-2002**	**K-2006**	**K-2010-2012**	**D-1972 1975**	**D-2010-2012**
Scenedesmus acuminatus (Lagerheim) Chodat incl. var. *biseriatus Reinsch sensu* Kors.	x			x	x
Scenedesmus acuminatus var. *elongatus* G. M. Smith			x		x
Scenedesmus communis (Breb.) Hegewald	x		x	x	x
Scenedesmus intermedius var. *bicaudata* Hortobágyi			x		
Scenedesmus obliquus (Turpin) Kützing			xxx		x
Scenedesmus obtusus Meyen			x		
Scenedesmus sp.	x				
Schroederia setigera (Schröder) Lemmermann		xxx/x	x		
Schroederia spiralis (Printz.) Korshikov		x	x		
Schroederia sp.	x				
Selenastrum bibraianum Reinsch			x		
Tetrachlorella sp.			x		
Tetradesmus cumbricus G. S. West		x			
Tetrastrum glabrum (Y. V. Roll) Ahlstrom et Tiffany			x		x
Tetrastrum sp.			x		
Treubaria planctonica (G.M.Smith) Korshikov			x		
Trochiscia planctonica E. M. Lind et Pearsall		x			
Volvox aureus Ehrenberg		x	x		
Willea irregularis (Wille) Schmidle			x		x
Streptophyta					
Arthrodesmus sp.	x				
Closterium aciculare T. West	x	x	xxx/x		
Closterium acutum Brébisson		x	x		
Closterium baillyanum (Brébisson ex Ralfs) Brébisson				x	x
Closterium moniliferum Ehrenberg ex Ralfs			x		
Closterium pronum Brébisson			x		
Closterium venus Kützing ex Ralfs		x	x		
Closterium spp.	x	x			

Taxa	**K-2000-2002**	**K-2006**	**K-2010-2012**	**D-1972 1975**	**D-2010-2012**
Cosmarium depressum Bailey					x
Cosmarium margaritiferum Meneghini ex Ralfs			x		
Cosmarium pseudoholmii Borge					x
Cosmarium spp.	x		x	xxx/x	x
Gonatozigon pilosum Wolle				x	x
Gonatozygon monotaenium De Bary	x	x	x		
Mougeotia sp.				x	
Spirogyra sp.				x	
Staurastrum apiculatum Brébisson				x	
Staurastrum depresum (Nägeli)			x		
Stauratsrum dickiei Ralfs				x	
Staurastrum gracile Ralfs.	x	xxx/x	x	xxx/x	x
Staurastrum pinque Teiling			xxx/x		x
Staurastrum planctonicum Teiling			x		x
Staurastrum sp.	x		x		
Euglenophyta					
Euglena clara Skuja		x	x		
Euglena granulata (Klebs) F. Schmitz			x		x
Euglena polymorpha f. *minor* T. Hortobágyi					x
Euglena spp.	x	x	x		
Lepocynclis oxyuris (Schmarda) Marin et Melkonian in Marin et al.					x
Lepocynclis acus (O. F. Müller) Marin et Melkonian in Marin et al.			x		x
Phacus longicauda (Ehrenberg) Dujardin					x
Phacus orbicularis K. Hübner			x		x
Phacus sp.	x				
Strombomonas sp.					x
Trachelomonas hispida (Perty) F. Stein emend. Deflandre				x	x
Trachelomonas planctonica Svirenko			x		
Trachelomonas rotunda Svirenko		xxx/x	x		
Trachelomona volvocina Ehrenberg				x	
Trachelomonas sp.	x	x			
Pyrrhophyta			x		
Ceratium cornutum (Ehrenberg) Claparède et J. Lachmann					x

Taxa	K-2000-2002	K-2006	K-2010-2012	D-1972 1975	D-2010-2012
Ceratium hirundinella (O.F. Muller) Dujardin	x	x	x	x	
Glenodinium sp.					x
Gymnodinium uberrimum (G.J.Allman) Kofoid et Swezy					xxx/xx/x
Gyrodinium helveticum (Penard) Y. Takano et T. Horiguchi					x
Peridinium spp.	x	x	x	xxx/x	
Cryptophyta					
Cryptomonas caudata J.Schiller					x
Cryptomonas erosa Ehrenberg					x
Cryptomonas ovata Ehrenberg					x
Cryptomonas spp.	x			x	
Ochrophyta			x		
Chrysophyceae					
Dinobryon divergens O.E.Imhof				x	x
Dinobryon sp.	x				
Uroglena volvox Ehrenb.	x				
Synurophyceae			x		
Mallomonas akrokomos Ruttner in Pascher					x
Mallomonas caudata Iwanoff			x		x
Mallomonas elongata Reverdin			x		x
Mallomonas spp.			x	x	
Synura uvella Ehrenberg				x	
Bacillariophyceae					
Achnanthes sp.			x		x
Amphora ovalis (Kützing) Kützing			x		x
Asterionella formosa Hassal		x	xxx/xx/x	xxx/x	xxx/xx/x
Asterionella gracillima (Hantzsch) Heib.				xxx/x	
Asterionella ralfsii W. Smith			x		x
Asterionella sp.	x				
Aulacoseira ambiqua (Grunow) Simonsen					x
Aulacoseira granulata (Ehrenberg) Simonsen	x	x	xxx/xx/x	x	xx/x
Aulacoseira granulata var. *angustissima* (O. F. Müller) Simonsen				xxx	

Taxa	**K-2000-2002**	**K-2006**	**K-2010-2012**	**D-1972 1975**	**D-2010-2012**
Aulacoseira islandica O. Müll			x		x
Aulacoseira italica (Ehrenberg) Simonsen			x		x
Aulacoseira italica var. *tennuissima* (Grunow) Simonsen			x		
Bacillaria sp.					x
Caloneis amphisbaena (Bory de Saint Vincent) Cleve			x		x
Caloneis silicula (Ehrenberg) Cleve					x
Ceratoneis arcus (Ehrenberg) Kützing				x	
Cocconeis pediculus Ehrenberg			x		
Cocconeis placentula Ehrenberg			x		x
Cocconeis spp.			x	x	x
Cyclotella meneghiniana Kutzing			xxx/xx/x		xxx/x
Cyclotella spp.	x			x	
Cymatopleura solea (Brébisson) W. Smith			x	x	x
Cymbella cistula (Hemprich & Ehrenberg) O. Kirchner					x
Cymbella cymbiformis C.Agardh			xx/x		x
Cymbella helvetica Kützing			x		
Cymbella lanceolata (C.Agardh) van Heurck			x		
Cymbella tumida (Brébisson) van Heurck			x		
Cymbella ventricosa C. Agardh					x
Cymbella spp.	x	x		x	
Diatoma ehrenbergii Kützing					x
Diatoma elongatum (Lyngb.) Ag.			x		
Diatoma hyemalis (Roth) Heiberg			x		x
Diatoma vulgaris Bory			x	x	x
Diploneis ovalis (Hilse) Cleve					x
Diploneis sp.			x		
Epithemia sp.			x		x
Eunotia bilunaris (Ehrenberg) Schaarschmidt					x
Eunotia minor (Kützing) Grunow					x
Eunotia soleirolii (Kützing) Rabenhorst					x
Eunotia sp.	x				

Taxa	K-2000-2002	K-2006	K-2010-2012	D-1972 1975	D-2010-2012
Fragilaria capucina Desmazières		x		x	x
Fragilaria crotonensis Kitton	xxx	xxx	xx/x	xxx/x	xxx/xx/x
Fragilaria sp.	x				
Frustulia rhomboides (Ehrenberg) De Toni					x
Gomphonema acuminatum Ehrenberg					x
Gophonema acuminatum var. *coronatum* (Ehrenberg) Ehrenberg					x
Gomphonema constricum Ehrenberg			x	x	x
Gomphonema gracile Ehrenberg			x		
Gomphonema lagerheimii A.Cleve					x
Gomphonema truncatum Ehrenberg					x
Gomphonema spp.	x		x		
Gyrosigma acuminatum (Kützing)					x
Gyrosigma sp.	x				
Hannaea arcus (Ehrbg.) Patrick	x		xx/x		x
Melosira varians C. A. Agardh		xxx	xxx/xx/x	x	x
Melosira sp.		x			
Meridion circulare (Greville) C.Agardh			x		x
Navicula gracilis Ehrenberg			x		
Navicula lanceolata Ehrenberg			x		x
Navicula radiosa Kützing			x		x
Navicula reinhardtii (Grunow) Grunow					x
Navicula rhynchocephala Kützing			x		x
Navicula vulpina Kützing					x
Navicula spp.	x		x	x	
Nitzschia closterium (Ehrenberg) W. Smith			x		
Nitzschia graciliformis Lange-Bertalot & Simonsen			x		
Nitzschia sp.			x		x
Pinnularia borealis Ehrenberg					x
Pinnularia spp.	x		x	x	
Pleurosigma elongatum W. Smith			x		
Rhopalodia gibba (Ehrenberg) O. Müller					x
Stephanodiscus astraea (Ehrenberg) Grunow			x		xx/x
Stephanodiscus hantzschii Grunow		x	x		x
Stephanodiscus sp.	x				

Taxa	K-2000-2002	K-2006	K-2010-2012	D-1972 1975	D-2010-2012
Surirella sp.					x
Synedra acus Kützing	x		x	xxx/x	x
Synedra acus var. *radians* Kützing				xxx/x	
Synedra famelica Kützing			x		
Synedra pulchela (Ralfs) Kützing					x
Synedra rumpens Kützing					x
Synedra tabulata (C. Agardh) Kützing			x		
Synedra ulna (Nitzsch.) Ehrenberg	x	x	xxx/xx/x	x	x
Synedra ulna var. *biceps* (Kützing) Schönfeldt					x
Synedra vaucheriae (Kützing) Kützing			x		
Tabellaria fenestrata (Lyngbye) Kützing					xxx/xx/x
Tabellaria fenestrata var.*asterionelloides* Grunow in Van Heurck				x	x
Tabellaria fenestrata var. *intermedia* Grunow				x	
Tabellaria flocculosa (Roth.) Kützing				x	xxx/x

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