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# Changes in the phytoplankton diversity of two oxbow lakes in a big city: a case study of Wrocław (Poland)

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**Abstract:** The subject of this study is to analyse changes in the taxonomic structure and development intensity of phytoplankton and, thus, to determine the diversity of cyanobacteria and algae along with the trophy state of two oxbow lakes in the Wrocław area (south-western Poland). The analysis of samples and data from previous years showed a total of 244 cyanobacteria and algae species within these two lakes. The species composition changed significantly in both of them – there were found 90 species new to the studied flora (37% of current flora) and 74 species which were previously recorded. The diversity of cyanobacteria and algae reflects the conditions in these water bodies and each change in ecological conditions (e.g., anthropological dangers) is reflected by a change in the phytoplankton assemblage structure. Consequently, knowledge of taxonomic diversity is useful in monitoring water bodies to preserve them in good conditions. Both studied oxbow lakes belong to eutrophic ecosystems as evidenced by their phycoflora, which is rich in species characteristic of high-trophy water, and recorded water blooms. The analysis of changes in cyanobacterial and algal assemblages in these lakes was also a basis for determining their trophy and finding it to be progressively eutrophic. Regular phycological studies of Wrocław numerous water bodies are essential and, in the future, will allow us to protect them and to react quickly in case of danger to these ecosystems. It will also allow us to study eutrophication processes in the water bodies that are crucial to the city.

**Key words:** phytoplankton composition, trophic status, environmental monitoring, oxbow lakes

## 1. Introduction

In cities located on big rivers, a vast network of surface water gives them a unique character. They have numerous water bodies left behind in the old river channels of regulated rivers. Wrocław is located within the hydrographic hub of the Odra and some of its tributaries and provide, therefore, a good location for phycological studies. The Odra branches out into several canals and river-arms which make the hydrographic network diverse. The regulation of the Odra river-bed, for shipping purposes and for flood protection, contributed to the formation of many oxbow lakes in the city area (Bieroński & Tarka 2010) and, consequently, different water bodies in Wrocław were subjects of many phycological studies (Hilse 1865, 1866; Kirchner 1878; Cohn 1884; Schröder 1897, 1899; Gołowin 1957; Panek 1976; Panek & Burzyński 1985; Panek *et al.* 1990, 1991; Dudek-Łacek 2007; Richter & Matuła 2003, 2004, 2012; Richter 2006, 2013; Bączek 2013). Knowledge about water ecosystems in this area, their biological diversity, functioning and the connection with the landscape is still insufficient. Such studies are crucial because there could be not only rare species to be discovered but also interesting biocoenotic structures. Therefore, the main goal of this study was to determine, both qualitatively and quantitatively, the current cyanobacteria and algae composition of the flora in two oxbow lakes in Szczytnicki Park in Wrocław. The additional data about phytoplankton were used to determine the ecological status of these water bodies as required by the Water Framework Directive (Lyche-Solheim *et al.* 2013; Napiórkowska-Krzebietke & Hutorowicz 2014), which allowed us to ascertain the trophy level in the studied lakes.

Water ecosystems in urban areas are susceptible to the city dynamics, which is reflected in the rate and intensity of anthropogenic factors. The development of

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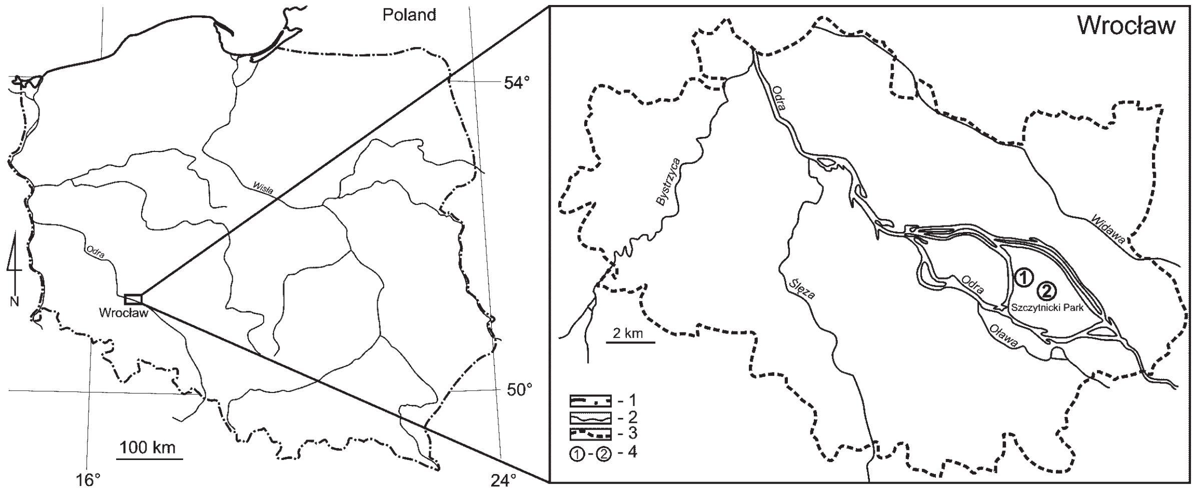


**Fig. 1.** Location of the studied oxbow lakes in the Wrocław area
Explanations: 1 – state border, 2 – rivers, 3 – city border, 4 – studied oxbow lakes (see Table 1)

urban infrastructure, housing and industrial facilities, negatively influence the characteristics of water habitats. Qualitative changes are, however, directly influenced by eutrophication of water bodies, increases in fertility, air pollution, and climate warming. All these factors cause differences in the species diversity of cyanobacteria and algae (Messyasz & Jurgońska 2003; Wołowski 2003). By analyzing the species composition and quantitativeness of phytoplankton in a proper time-frame, we obtain information about water ecosystems and, in particular, about the changes in these water bodies (Burchardt 1994; Reynolds 1997; Carvalho *et al.* 2012). As data on cyanobacteria and algal flora of the studied oxbow lakes were available from previous investigations (Richter 2006; Dudek-Łacek 2007), the newer study provided valuable comparative material allowing us to determine changes in phycoflora over several years. Systematic biological studies provide quality control for these water bodies and allow us to conduct monitoring research aimed at maintaining their good condition. The moni-

**Table 1.** Study area – the characteristics of examined oxbow lakes

| Morphometric features | Oxbow lake | |
|---|---|---|
| | No. 1 | No. 2 |
| Situated in Wrocław | Szczytnicki Park, in the Centennial Hall area, near Mickiewicz street | Szczytnicki Park, near Heweliusz street |
| Latitude-Longitude | 51°06`31.1``N, 17°04`47.3``E, ADPOLBE-49 | 51°06`29.63``N, 17°05`19.15``E, ADPOLBE-49 |
| Total surface area | 6927 $m^2$ | 1200 $m^2$ |
| Depth | 70-100 cm (max. 150 cm) | 50-60 cm (max. 100 cm) |
| Shape | elongated, tape-like, extended at one end | kidney shaped |
| Shores | irregular, encased with stones | encased with stones |
| Parts of the water reservoirs | Vegetations | |
| Shore area | *Typha latifolia* L., *Schoenoplectus lacustris* (L.) Palla, the part in the Japanese Garden planned artificially (collections of exotic plants) | *Juncus articulatus* L. em. K. Richt., *Carex acuta* L. and single clumps of *Glyceria maxima* (Hartm.) Holmb. |
| Middle part | - | clumps of *Phragmites australis* (Cav.) Trin ex Stued. and *Schoenoplectus lacustris* (L.) Palla |
| Water surface | *Nuphar luteum* (L.) Smith, *Nymphaea alba* L. | *Nymphaea alba* L., *Nuphar luteum* (L.) Smith, *Lemna minor* L., *Potamogeton* sp. |
| Bottom | - | *Ceratophyllum demersum* L. |


**Fig. 2.** Study area – the view of studied oxbow lakes: a – near Mickiewicz street (No. 1), b – near Heweliusz street (No. 2)

toring of urban water bodies is always crucial because their attractiveness gives them aesthetic and touristic value. Their recreational values make it essential to keep them clean. Proper characteristics of phycoflora of water bodies that are representative for Wrocław will allow the constant monitoring of water environment in the city. Additionally, it will make possible to establish proper protection of numerous water bodies, canals and branches of the Odra river and a swift reaction in case of danger to these ecosystems.

## 2. Material and methods

### 2.1. Study sites and sampling

The phycological research was conducted between June and September 2013. The samples of cyanobacteria and algae were taken twice a month. Plankton net with 25 μm mesh diameter was used to collect the study material. The concentrated material was gathered into 200 ml plastic containers. The identification was performed live (fresh samples). Species observation was conducted with a Nikon Eclipse TE2000-S digital microscope equipped with a Nikon DS-Fi1 camera. Quantitative analyses were conducted following the Utermöhl method (Utermöhl 1958). In order to prepare the samples for quantitative analyses, 5l of water were poured through the net and, then, concentrated to 200ml. Such material was observed using a chamber (HYDRO-BIOS no. 435016). The quantitativeness of particular taxa was determined under the microscope using modified Starmach's 6-grade scale (1955), where 1 means the individual occurrence of a given species;

**Table 2.** Physical and chemical parameters of water from the examined oxbow lakes

| Parameter | Unit | Oxbow lake | | |
|---|---|---|---|---|
| | | No. 1 | No. 2 | |
| | | 2013 | 2006-2008** | 2013 |
| reaction | pH | 7.11 | 7.6* | 7.10 |
| conductivity | μS/cm³ | 2012 | 1180* | 762.3 |
| oxidation ($COD_{Mn}$) | $mgO_2l^{-1}$ | 5.20 | 5.09* | 4.80 |

Explanations: * – mean values of four replicates, ** – from Richter 2012

2 – from 1 to 6 units on standard viewing surface; 3 – from 7 to 20 units on standard surface; 4 – from 1 to 10 visible units; 5 – from 11 to 30 visible units; 6 – water blooms (over 30 units in every field).

The taxonomic classification was conducted in accordance with Hoek *et al.* (1995). Species names were updated according to the detailed literature on the species (Wacklin *et al.* 2009; Komárek 2016).

Two natural water bodies located within the city of Wrocław (south-western Poland) were chosen for the study (Figs. 1-2, Table 1).

### 2.2. Physical, chemical and statistical analyses

Physicochemical property analyses of the studied oxbow lakes were also conducted (Table 2). The samples for physicochemical analyses in 2013 were collected at about 12.00, individually in case of both oxbow lakes, on 15.04.2013. In 2006-2008, the samples were collected four times, in the afternoon, on 5.04.2006, 10.04.2006, 10.10.2008 and 15.10.2008. In the studied lakes, the samples were collected 1m from the bank, at the depth of 20-30cm, in water free from aquatic plants. pH and conductivity were measured using PN-90/C-0440.01 and oxygen concentration with PN-ES-ISO 8467.

Statistical analyses were performed using STATISTICA v. 12 packages (StatSoft Inc., 2014). Shannon's diversity index (Shannon & Weaver 1949) was used to describe species diversity and evenness.

## 3. Results

### 3.1. Phytoplankton composition of the studied oxbow lakes

The studied ecosystems are characterized by qualitatively rich phytoplankton composition. Particular cyanobacterial and algal assemblages have diverse taxonomic composition. They differ in species number, quantitative arrangement, the share of particular taxonomic groups and taxonomic diversity. The Diversity Index of cyanobacteria and algae in the studied oxbow lakes was high with a slightly higher species diversity in the lake no. 2. Evenness Index in both examined water bodies showed a diverse species share in cyanobacterial and algal assemblages (Table 3). The phycoflora of the studied; lakes showed a clear dominance of Bacillariophyceae (82 taxa, 33% of all recorded species) and Chlorophyceae (57 taxa, 23% of all recorded species). Within this group, the highest number of species and species diversity along with species with higher quantitative scale was found to occur, which distinguished the lakes as diatoms-green algae structure (Appendix 1). The shares of these groups differed between both water bodies. In the oxbow lake no. 1, the number of diatoms was twice higher than Chlorophyceae, whereas it was very similar in the oxbow lake no. 2. In the case of other groups, the study revealed 47 taxa of Euglenophyta (19.3% of all recorded species) and 35 taxa of Cyanophyta (14.4% of phycoflora). Dinophyta (2 taxa, 0.82%) and Cryptophyta (1 taxon, 0.4%) were the least numerous (Table 3). The studied lakes also had an increased number of Cyanophyceae and Euglenophyceae species and some of these species contributed to water blooms.

### 3.2. Changes in time in cyanobacteria and algal flora of the studied oxbow lakes

Current results, as compared to data from previous years (Richter 2006; Dudek-Łacek 2007), suggest that the total number of cyanobacteria and algae taxa found in the studied oxbow lakes grew insignificantly or remained the same. However, there was a change in species composition. Ninety new species were found to occur in the studied flora and only 74 previously recorded species were confirmed (Table 3).

In the oxbow lake no. 1 significant changes occurred in the combination of species of particular types. Many hitherto occurring species disappeared and new species emerged in their place (50 new taxa, over 60% of current flora). The biggest change was noticed in the emergence of 15 new Euglenophyta class taxa. This is particularly important as species belonging to this class were not recorded earlier in this water body. Both previously and now, within blue-greens, there were blooms of *Microcystis aeruginosa*. In the group of diatoms, most

**Table 3.** The number of species found in the studied oxbow lakes showing temporal changes and the values of biodiversity and evenness indices of phycoflora

| Taxonomical groups | Oxbow lake | | | | Sum of all |
|---|---|---|---|---|---|
| | No. 1 | | No. 2 | | |
| | 2006-2007* | 2013 | 2006-2008** | 2013 | |
| Phyla Cyanophyta | 9 | 9 | 15 | 15 | 35 |
| Class Cyanophyceae | 9 | 9 | 15 | 15 | 35 |
| number of species not previously reported | | 5 | | 8 | |
| number of species not confirmed | | 5 | | 8 | |
| number of species confirmed | | 4 | | 7 | |
| Phyla Heterokontophyta | 44 | 42 | 35 | 32 | 96 |
| Class Bacillariophyceae | 42 | 39 | 28 | 27 | 82 |
| number of species not previously reported | | 18 | | 9 | |
| number of species not confirmed | | 21 | | 10 | |
| number of species confirmed | | 21 | | 18 | |
| Class Chrysophyceae | 2 | 1 | 0 | 0 | 3 |
| number of species not previously reported | | 1 | | 0 | |
| number of species not confirmed | | 2 | | 0 | |
| number of species confirmed | | 0 | | 0 | |
| Class Xanthophyceae | 0 | 2 | 7 | 5 | 9 |
| number of species not previously reported | | 2 | | 1 | |
| number of species not confirmed | | 0 | | 3 | |
| number of species confirmed | | 0 | | 4 | |
| Phyla Euglenophyta | 0 | 15 | 21 | 26 | 47 |
| Class Euglenophyceae | 0 | 15 | 21 | 26 | 47 |
| number of species not previously reported | | 15 | | 16 | |
| number of species not confirmed | | 0 | | 11 | |
| number of species confirmed | | 0 | | 10 | |
| Phyla Chlorophyta | 21 | 16 | 36 | 31 | 65 |
| Class Chlorophyceae | 18 | 14 | 30 | 27 | 57 |
| number of species not previously reported | | 6 | | 15 | |
| number of species not confirmed | | 10 | | 18 | |
| number of species confirmed | | 8 | | 12 | |
| Class Cladophorophyceae | 0 | 1 | 1 | 1 | 1 |
| number of species not previously reported | | 1 | | 0 | |
| number of species not confirmed | | 0 | | 0 | |
| number of species confirmed | | 0 | | 1 | |
| Class Zygnematophyceae | 3 | 1 | 5 | 3 | 7 |
| number of species not previously reported | | 1 | | 1 | |
| number of species not confirmed | | 3 | | 3 | |
| number of species confirmed | | 0 | | 2 | |
| Phyla Dinophyta | 0 | 1 | 0 | 1 | 2 |
| Class Dinophyceae | 0 | 1 | 0 | 1 | 2 |
| number of species not previously reported | | 1 | | 1 | |
| number of species not confirmed | | 0 | | 0 | |
| number of species confirmed | | 0 | | 0 | |
| Phyla Cryptophyta | 0 | 0 | 0 | 1 | 1 |
| Class Cryptophyceae | 0 | 0 | 0 | 1 | 1 |
| number of species not previously reported | | 0 | | 1 | |
| number of species not confirmed | | 0 | | 0 | |
| number of species confirmed | | 0 | | 0 | |
| Total number of species | 74 | 83 | 107 | 106 | 244 |
| Total number of species previously reported | | 50 | | 52 | 90 |
| Total number of species not confirmed | | 41 | | 53 | 80 |
| Total number of species confirmed | | 33 | | 54 | 74 |
| Diversity index | 4.20 | 4.30 | 4.56 | 4.53 | |
| Evenness | 0.977 | 0.972 | 0.975 | 0.972 | |

Explanations: * – from Duda-Łack 2007, ** – from Richter 2012 of them occurred in higher quantitativeness and many of them increased their quantitativeness. Current flora, as compared to earlier years, exhibited changes in the dominants within Chlorophyceae. In 2007, *Desmodesmus protuberans* and *Pandorina* sp. 2 were dominant, whereas in 2013 – *Chloromonas* sp. formed water blooms along with numerous accompanying *Scenedesmus* sp. 3.

In the case of the oxbow lake no. 2, changes were also visible in the species combinations of particular classes and in the quantitativeness. Within Cyanophyceae, there was an increase in the species characteristic of eutrophic species, such as *Microcystis aeruginosa*, *M. novacekii*, which increased their share in cyanobacteria assemblages. *Aphanocapsa incerta* was also recorded in a higher quantity. Their increased share, along with new species characteristic of eutrophic water bodies, may suggest increased trophy of this lake. The biggest species similarity between current phycoflora and earlier phycoflora was observed in the diatom assemblage because 18 out of 27 taxa were confirmed, which constitutes almost 70% of unchanged group composition. The highest number of previously unrecorded species was within Euglenophyceae (16 taxa). Both previously recorded species and new species were recorded in high quantities. In euglenoid assemblages, the study recorded water blooms of *Trachelomonas volvocina* with numerous accompanying *T. hispida*, *Phacus longicauda*, *P. longicauda* var. *tortus*. Within Chlorophyta, the study recorded 15 previously absent taxa, particularly coccoid green algae. Additionally, the rocks around the lake had well developed *Cladophora glomerata* periphyton communities.

## 4. Discussion

### 4.1. Phytoplankton composition – a response to change in time

Species richness, changes in the taxonomic composition and structure, the dynamics of phytoplankton development may indicate, along with other ecosystem elements, the direction of trophy changes in water bodies (Burchardt 1993; Burchardt *et al.* 1994; Burchardt & Łastowski 1999; Reynolds 2000; Reynolds *et al.* 2002).

In both studied oxbow lakes, diatoms and green algae were dominant groups in phytoplankton assemblages. The dominance of Bacillariophyceae and Chlorophyta in flora is typical of eutrophic species (Burchardt *et al.* 2003, 2014), which allows us to classify these lakes as high-trophy water bodies. Their eutrophic character is also confirmed by the presence of a large number of typically eutrophic species of *Coelastrum*, *Scenedesmus*, *Oocystis* and *Pediastrum* genera (Berlinger & Sigee 2010; Jachniak & Kozak 2011; Jachniak *et al.* 2015). Among coccoid green algae found in the lakes, there were numerous representations of taxa characteristic of high trophy waters, such as: *Coelastrum microporum*, *C. pseudomicroporum*, *Desmodesmus opoliensis*, *Pediastrum duplex*, *Scenedesmus obliquus* var. *dimorphus* (Comas *et al.* 2007). The intensive development of coccoid green algae confirms the eutrophic character of the studied oxbow lakes, because, as a function of their rapid response to environmental conditions, they are a good indicator for identifying and typifying limits and directions of environmental changes in aquatic ecosystems (Burchardt *et al.* 2003; Comas *et al.* 2007). On stones in the oxbow lake no. 2, numerous species of *Cladophora glomerata* were also reported, which is characteristic of eutrophic water bodies (Dodds 1991; Rybak *et al.* 2012).

The high trophy of the studied oxbow lakes was also suggested by higher quantitativeness of species typical of eutrophic water bodies, such as: *Microcystis aeruginosa*, *M. novacekii*, and *Aphanocapsa incerta* (Komárek & Anagnostidis 1999). High biomass of cyanobacteria is often found in eutrophic water bodies (Grabowska & Mazur-Marzec 2011; Grabowska 2012). Both, the oxbow lake no. 1 and no. 2 revealed a significant increase of Euglenophyta species. The occurrence of Euglenophyceae means that the studied lakes are polluted because these taxa occur usually in small and polluted water bodies and in sewage, where high nutrient content is favorable for species of this group (Wołowski 1998, 2003). Additionally, some species of this group formed water blooms. These species indicate a higher concentration of organic matter, which may also suggest increased trophy of the studied water body (Matuła 1995; Owsianny & Gąbka 2004; Bucka & Wilk-Woźniak 2007).

Diatoms have long been used in various diatom indices to assess water quality throughout Europe (e. g. Kolkwitz & Marson 1908; Prygiel 2002; Kelly *et al.* 2008; Szulc & Szulc 2013), since they are a good indicator of environment properties. In the oxbow lake no. 1, many species emerged within Bacillariophyceae (18 taxa), including species typical of fertile waters, among others *Amphora ovalis*, *Asterionella formosa*, *Aulocoseira granulata*, *A. ambigum*, *Melosira varians*, *Fragilaria capucina*, *Rhoicosphenia abbreviata* (Rakowska 2001; Bąk *et al.* 2012). On the other hand, in the oxbow lake no. 2, within this group, earlier and current studies recorded the following species: *Cyclotella meneghiniana*, *Gomphonema parvulum* var. *parvulum*, *Nitzschia palea* and *Ulnaria ulna* – which are characteristic of eutrophic waters (Rakowska & Szczepocka 2011).

In conclusion, the studies suggest that trophy levels of the oxbow lakes changed in a short period of time. They are still eutrophic, but due to numerous water blooms, the increase in quantitativeness of particular species may indicate increasing trophy of these waters. Additionally, the emergence of new species and an increased number of Euglenophyta species as well as their higher quantitativeness may suggest that there is more organic matter in the lakes. Consequently, the analysis of changes in cyanobacterial and algal assemblages of the oxbow lakes provided a basis for conclusions about the trophy of these water bodies and its determination as increasingly eutrophic.

To sum up, it needs to be mentioned that in large urban agglomerations, due to failed anthropic activity, water ecosystems show changes in pH, electrolytic conductivity and nutrient availability. These unfavorable processes lead to distortions in water ecosystems, including phycoflora. Cyanobacteria may react to these factors by changing quantity and quantitativeness of species, taxonomic composition and diversity index. Algae and cyanobacteria respond to environment change very quickly and, thus, may be treated as indicative species. This role is clearly understandable as they are a complex group of organisms having many features useful in evaluating environment stability.

They are relatively simply built and, due to their physiological properties, they quickly react to changes in their habitat and, thus, have an advantage over vascular plants. Individual taxa may respond differently to the same environmental factors. They may be used to characterize various environments, including still water habitats mentioned in this paper. They may also indicate seasonal changes and water productivity. Cyanobacteria and algae studied together as all groups help in complex environment evaluation. On the other hand, individual species inform us about particular factors disturbing a habitat. Consequently, we may use both individual species and whole cyanobacteria and algae communities as universal bio-indicators in monitoring the environment and determining fertility, contamination and purity.

Carr *et al.* (2005) showed that the abundance of periphyton depends on nutrient concentration. Additionally, a shift in dominants in cyanobacterial and algal communities shows the contamination of water basins. Peinador (1999) noticed a larger share of Cyanophyta in more contaminated areas. Higher phosphate and nitrate availability favors the development of green algae. In a study by Akpan & Akpan (1994), phytoplankton was dominated by Chlorophyceae, which showed the biggest species richness, density and diversity. Such phytoplankton state was caused by the eutrophic character of the pond (sewage entered the water reservoir). The above-mentioned remarks confirm the validity of using cyanobacteria and algae in determining the state and stability of ecosystems.

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**Appendix 1.** The list of cyanobacteria and algae in two oxbow lakes in the Wrocław area: near Mickiewicz street in 2006-2007 (A) and 2013 (B), and near Heweliusz street in 2006-2008 (C) and 2013 (D), 1-6 quantitative scale

| | A | B | C | D |
|---|---|---|---|---|
| Phyla Cyanophyta (Cyanobacteria) | | | | |
| Class Cyanophyceae | | | | |
| *Anabaena oscillarioides* Bory de Saint-Vincent ex Bornet & Flahault | | | | 2 |
| *Anabaena* sp. | | 1 | | |
| *Aphanocapsa holsatica* (Lemmermann) G.Cronberg & Komáre | 1 | | | 3 |
| *Aphanocapsa incetera* (Lemmermann) Clonberg et Komárek | | 1 | | 3 |
| *Calothrix* sp. 1 | | | 2 | |
| *Calothrix* sp. 2 | 1 | | | |
| *Geitlerneima* sp. | | 1 | | |
| *Geitlerinema splendidum* (Greville ex Gomont) Anagnostidis | | | 1 | |
| *Jaaginema pseudogeminatum* (Schmid) Anagnostidis & Komárek | | | 1 | 1 |
| *Kamptonema formosum* (Bory de Saint-Vincent ex Gom.) Strun. Kom. & Smarda | | | 1 | 2 |
| *Leptolyngbya angustissima* (West & West) Anagnostidis & Komárek | 1 | 1 | | |
| *Leptolyngbya* sp. 1 | 1 | | | |
| *Leptolyngbya* sp. 2 | | | | 1 |
| *Limnothrix planctonica* (Woloszynska) Meffert | | | 1 | 1 |
| *Limnoraphis cryptovaginata* (Shkorbatov) Komárek, Zapomelová, Smarda, Kopecky, Rejmámková, Woodhouse, Neilan & Komárková | | | 1 | |
| *Lyngbya* sp. 1 | | | 1 | |
| *Lyngbya* sp. 2 | | | | 1 |
| *Merismopedia glauca* (Ehrenberg) Kützing | | | 3 | 2 |
| *Merismopedia punctata* Meyen | | | | 1 |
| *Microcystis aeruginosa* (Kützing) Kützing | 5 | 4 | 2 | 3 |
| *Microcystis natans* Lemmermann ex Skuja | | | | 2 |
| *Microcystis novacekii* (Komárek) Compére | | | 1 | 3 |
| *Microcystis wesenbergii* (Komárek) Komárek ex Komárek | 1 | 1 | | |
| *Oscillatoria* sp. 1 | | | 1 | |
| *Oscillatoria* sp. 2 | | 1 | | |
| *Oscillatoria subbrevis* Schmidle | | | 1 | 1 |
| *Planktolyngbya lacustris* (Lemmermann) Anagnostidis & Komárek | | | 1 | |
| *Phormidium aerugineocaeruleum* (Gomont) Anagnostidis & Komárek | | | 1 | |
| *Phormidium granulatum* (Gardner) Anagnostidis | 3 | 1 | | |
| *Phormidium irriguum* (Kützing ex Gomont) Anagnostidis & Komárek | 1 | | | |
| *Pseudoanabaena* sp. | | 1 | | |
| *Spirulina* sp. | | | | 1 |
| *Synechocystis salina* Wislouch | | | 1 | |
| *Tetrarcus ilsteri* Skuja | | | | 1 |
| *Woronichinia* sp. | | | | 1 |
| Phyla Heterokontophyta | | | | |
| Class Bacillariophyceae | | | | |
| *Achnanthes exigua* Grunow | | | 1 | 1 |
| *Amphora ovalis* (Kützing) Kützing | 1 | 3 | | |
| *Asterionella formosa* Hassall | | 2 | | |
| *Aulacoseira ambigua* (Grunow) Simonsen | 1 | | | |
| *Aulacoseira granulata* (Ehrenberg) Simonsen | 1 | 2 | | |
| *Aulacoseira* sp. | 1 | | | |
| *Caloneis* sp. | | 1 | | |
| *Chamaepinnularia obsoleta* (Hustedt) Wetzel & Ector | | | 1 | |
| *Cocconeis neodiminuta* Krammer | 1 | 1 | 3 | 1 |
| *Cocconeis placentula* Ehrenberg | | 2 | | |
| *Cyclotella glomerata* Bachmann | 2 | 1 | 4 | |
| *Cyclotella meneghiniana* Kützing | | | 2 | 2 |
| *Cyclotella ocellata* Pantocsek | 1 | | 3 | 1 |
| *Cyctotella* sp. 1 | | | | 1 |
| *Cyclotella* sp. 2 | | | | 3 |
| *Cyclotella* sp. 3 | 2 | | | |
| *Cymatopleura solea* (Brébisson) Smith | | 1 | | |
| *Cymbella affinis* Kützing | 1 | 1 | | |
| *Cymbella cistula* (Ehrenberg) Kirchner | 1 | 1 | 1 | 1 |

| | A | B | C | D |
|---|---|---|---|---|
| *Cymbella helvetica* Kützing | | 1 | | |
| *Cymbella* sp. 1 | 1 | | | |
| *Cymbella* sp. 2 | | 1 | | |
| *Cymbella tumida* (Brébisson) van Heurck | | | 1 | 1 |
| *Denticula* sp. | | 1 | | |
| *Diatoma anceps* (Ehrenberg) Kirchner | 1 | 3 | | |
| *Diatoma vulgaris* Bory de Saint-Vincent | | | | 2 |
| *Encyonema prostratum* (Berkeley) Kützing | | 1 | | |
| *Epithemia adnata* (Kützing) Brébisson | | | 4 | 1 |
| *Epithemia sorex* Kützing | 1 | 1 | 1 | 1 |
| *Epithemia turgida* (Ehrenberg) Kützing | | | 1 | 1 |
| *Eunotia* sp. | | | | 1 |
| *Fragilaria capucina* Desmazières | | 3 | 1 | 1 |
| *Fragilaria construens* f. *venter* (Ehrenberg) Hustedt | | | 1 | |
| *Fragilaria crotonensis* Kitton | | | 3 | 3 |
| *Fragilaria parasitica* var. *subconstricta* Grunow | 1 | | | |
| *Fragillaria* sp. 1 | | | 2 | |
| *Fragillaria* sp. 2 | | | | 1 |
| *Fragillaria* sp. 3 | 2 | | | |
| *Fragillaria* sp. 4 | | 1 | | |
| *Gomphonema acuminatum* Ehrenberg | | 2 | 3 | 1 |
| *Gomphonema augur* Ehrenberg | 1 | 1 | 1 | |
| *Gomphonema parvulum* var. *parvulum* (Kützing) Kützing | | | 3 | 3 |
| *Gomphonema* sp. | | 2 | | |
| *Gomphonema truncatum* Ehrenberg | 1 | 2 | | 2 |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | 2 | 2 | | |
| *Gyrosigma* sp. | 2 | | | |
| *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski | 1 | 1 | | |
| *Lemnicola hungarica* (Grunow) Round & Basson | | 3 | | |
| *Melosira undulata* (Ehrenberg) Kützin | | 2 | | |
| *Melosira varians* Agardh | 2 | 4 | 1 | 1 |
| *Melosira* sp. 1 | 2 | | | |
| *Melosira* sp. 2 | | 3 | | |
| *Navicula capitatoradiata* Germain | 1 | | | |
| *Navicula cincta* (Ehrenberg) Ralfs | | | 1 | |
| *Navicula radiosa* Kützing | | | | 1 |
| *Navicula rhynchocephala* Kützing | 1 | 2 | 1 | 1 |
| *Navicula* sp. 1 | | | | 1 |
| *Navicula* sp. 2 | 1 | | | |
| *Navicula* sp. 3 | | 3 | | |
| *Navicula viridula* (Kützing) Ehrenberg | 1 | 1 | | |
| *Nitzschia acicularis* (Kützing) W. Shmith | | | | 2 |
| *Nitzschia amphibia* Grunow | 1 | 1 | | |
| *Nitzschia* cf. *nana* Grunow | 1 | | | |
| *Nitzschia* cf. *sigmoidea* (Nitsch) W. Shmith | 1 | | | |
| *Nitzschia* cf. *supralitorea* Lange - Bertalot | | | 1 | |
| *Nitzschia draveillensis* Coste & Ricard | 2 | | | |
| *Nitzschia amabilis* Suzuki | 2 | 1 | | |
| *Nitzschia palea* (Kutzing) Smith | 1 | | 1 | 1 |
| *Nitzschia* sp. | 1 | 2 | | |
| *Nupela impexiformis* (Lange-Bertalot) Lange-Bertalot | 1 | | 1 | |
| *Pinnularia* cf. *maior* (Kützing) Cleve | 1 | | | |
| *Pinnularia viridis* (Nitzsch) Ehrenberg | 1 | 1 | | |
| *Pleurosigma salinarum* (Grunow) Grunow | 1 | | | |
| *Pleurosigma* sp. | | | 3 | |
| *Pleurosigma* sp. | 1 | | | |
| *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot | | 2 | | |
| *Surirella* sp. | | 1 | | |
| *Tabellaria* sp. | | 1 | | |
| *Tabularia fasciculata* (Agardh) Williams & Round | 1 | | | |
| *Tryblionella angustata* W.Smith | 1 | | 1 | 1 |
| *Tryblionella kuetzingii* Ãlvarez-Blanco & Blanco | 1 | 1 | | |

| | A | B | C | D |
|---|---|---|---|---|
| *Ulnaria ulna* (Nitzsch) Compère | 1 | 3 | 3 | 3 |
| Class Chrysophyceae | | | | |
| cysty Chrysophyceae | 1 | | | |
| *Dinobryon divergens* Imhof | | 3 | | |
| *Epipyxis* sp. | 1 | | | |
| Class Xanthophyceae | | | | |
| *Centritractus capillifer* Pascher | | | | 1 |
| *Characiopsis elegans* Ettl | | | 1 | |
| *Characiopsis gibba* (Braun) Borzi | | | 1 | 1 |
| *Characiopsis* sp. | | | 1 | |
| *Goniochloris smithii* (Bourrelly) Fott | | 1 | 1 | 1 |
| *Ophiocytium cochleare* (Eichwald) Braun | | | 1 | |
| *Ophiocytium parvulum* (Perty) Braun | | | 1 | 1 |
| *Tribonema aequale* Pascher | | 1 | | |
| *Tribonema pyrenigerum* Pascher | | | 1 | 1 |
| Phyla Euglenophyta | | | | |
| Class Euglenophyceae | | | | |
| *Colacium* sp. 1 | | | 2 | |
| *Colacium* sp. 2 | | | | 2 |
| *Colacium* sp. 3 | | 2 | | |
| *Colacium vesiculosum* Ehrenberg | | 2 | | |
| *Euglena pisciformis* Klebs | | | 1 | |
| *Euglena ehrenbergii* Klebs | | | 1 | 3 |
| *Euglena hemichromata* Skuja | | 1 | 1 | 2 |
| *Euglena* sp. 1 | | | 1 | |
| *Euglena* sp. 2 | | | | 3 |
| *Euglena* sp. 3 | | | | 4 |
| *Euglena* sp. 4 | | 2 | | |
| *Euglenaria anabaena* (Mainx) Karnkowska & Linto | | | 1 | |
| *Euglenaria clara* Skuja | | 2 | | |
| *Euglenaformis proxima* (Dangeard) Bennett & Triemer | | | 1 | 1 |
| *Lepocinclis acus* (Müller) Marin et Malkonian | | | 2 | 1 |
| *Lepocinclis fusiformis* (Carter) Lemmermann | | | 1 | |
| *Lepocinclis ovum* var. *alata* Swirenko | | | | 1 |
| *Lepocinclis oxyuris* (Schmarda) Marin & Melkonian | | | 2 | 3 |
| *Lepocinclis texta* (Dujardin) Hübner | | 2 | 2 | 3 |
| *Lepocinclis tripteris* (Dujardin) Marin & Melkonian | | 2 | 1 | |
| *Monomorphina pyrum* (Ehrenberg) Mereschkowsky | | | 1 | 1 |
| *Peranema* sp. | | | | 1 |
| *Petalomonas* sp. | | | | 1 |
| *Phacus acuminatus* Stokes | | 1 | | |
| *Phacus granum* Drežepolski | | | 1 | |
| *Phacus helikoides* Pochmann | | 2 | | 2 |
| *Phacus limnophilus* (Lemmermann) Linton & Karnkowska-Ishikawa | | | 3 | |
| *Phacus longicauda* (Ehrenberg) Dujardin | | 2 | 1 | 4 |
| *Phacus longicauda* var. *tortus* (Lemmermann) Popova | | | 1 | 2 |
| *Phacus orbicularis* Hübner | | | 1 | 2 |
| *Phacus parvulus* Klebs | | | | 2 |
| *Phacus pleuronectes* (Müller) Nitzsch ex Dujardin | | | | 3 |
| *Phacus pusillus* Lemmermann | | | 1 | |
| *Phacus* sp. 1 | | | | 4 |
| *Phacus* sp. 2 | | 2 | | |
| *Phacus strongylus* Pochmann | | | 1 | |
| *Strombomonas* sp. 1 | | | | 4 |
| *Strombomonas* sp. 2 | | 1 | | |
| *Trachelomonas hispida* (Perty) Stein | | | | 4 |
| *Trachelomonas intermedia* Dangeard | | | | 1 |
| *Trachelomonas lacustris* Drežepolski | | 1 | | |
| *Trachelomonas lefevrei* Deflandre | | | | 2 |
| *Trachelomonas planctonica* Swirenko | | 1 | | |

| | A | B | C | D |
|---|---|---|---|---|
| *Trachelomonas* sp. 1 | | | | 2 |
| *Trachelomonas* sp. 2 | | 2 | | |
| *Trachelomonas verrucosa* Stokes | | | 1 | |
| *Trachelomonas volvocina* (Ehrenberg) Ehrenberg | | | | 6 |
| Phyla Chlorophyta | | | | |
| Class Chlorophyceae | | | | |
| *Acutodesmus acuminatus* (Lagerheim) Tsarenko | | | 1 | 2 |
| *Ankistrodesmus falcatus* var. *acicularis* (A. Br.) West | | | 1 | |
| *Ankistrodesmus fusiformis* Corda | 1 | 1 | 1 | |
| *Ankistrodesmus gracilis* (Reinsch) Korshikov | | | | 2 |
| *Aphanochaete repens* A. Braun | | | 1 | 1 |
| *Chaetophora lobata* Schrank | | | 1 | |
| *Characium acuminatum* A. Braun | | | 1 | 1 |
| *Characiopsis subulata* var. *ensiformis* (Hermann) Lemmermann | 1 | | | |
| *Chlamydomonas* sp. | 1 | | | |
| *Chlorella* sp. | 1 | | | |
| *Chlorobotris* sp. | | | 1 | |
| *Chloromonas* sp. | | 6 | | |
| *Coelastrum astroideum* De Notaris | | | 2 | |
| *Coelastrum microporum* Nägeli | | | 1 | 2 |
| *Coelastrum pseudomicroporum* Korshikov | | | | 2 |
| *Coelastrum reticulatum* (Dang.) Senn sensu Teil. | | 2 | | |
| *Crucigenia tetrapedia* (Kirchner) Kuntze | | | | 2 |
| *Desmodesmus dispar* (Brébisson) Hegewald | 1 | | 1 | |
| *Desmodesmus flavescens* (Chodat) Hegewald | | | 1 | |
| *Desmodesmus magnus* (Meyen) Tsarenko | 1 | 2 | 1 | |
| *Desmodesmus opoliensis* (Richter) Hegewald | 1 | 2 | 1 | 3 |
| *Desmodesmus protuberans* (Fritsch & Rich) Hegewald | 3 | 2 | 1 | 3 |
| *Desmodesmus spinosus* (Chodat) Hegewald | | | 1 | |
| *Desmodesmus subspicatus* (Chodat) Hegewald & Schmidt | | 1 | 1 | |
| *Golenkinia radiata* Chodat | | | | 3 |
| *Gonium formosum* Pascher | | | | 2 |
| *Hydrodictyon reticulatum* (Linnaeus) Bory de Saint-Vincent | | | 1 | |
| *Kirchneriella dianae* (Bohlin) Comas Gonzalez | | | | 2 |
| *Lagerheimia marssonii* Lemmermann | | | 1 | |
| *Lagerheimia wratislaviensis* Schröder | 1 | 1 | 1 | 2 |
| *Micractinium pusillum* Fresenius | | | | 2 |
| *Mucidosphaerium pulchellum* (Wood) Bock, Proschold & Krienitz | | 2 | | 2 |
| *Oedogonium* sp. | | | 1 | 1 |
| *Oocystis lacustris* Chodat | | | 1 | |
| *Oocystis* sp. 1 | | | | 1 |
| *Oocystis* sp. 2 | 1 | | | |
| *Pandorina morum* (Müller) Bory de Saint-Vincent | 1 | 1 | | |
| *Pandorina* sp. 1 | | | 1 | |
| *Pandorina* sp. 2 | 3 | | | |
| *Pseudodidymocystis planctonica* (Korshikov) Hegewald & Deason | 1 | 2 | | |
| *Pseudopediastrum boryanum* (Turpin) Hegewald | | 2 | 1 | 3 |
| *Pediastrum duplex* Meyen | | | 1 | 2 |
| *Scenedesmus aldavei* Hegewald | 1 | | | |
| *Scenedesmus armatus* (Chodat) Chodat | | | 1 | |
| *Scenedesmus gutwinskii* var. *heterospina* Bodrogk | 1 | | 1 | |
| *Scenedesmus longispina* Chodat | 2 | 2 | 1 | 1 |
| *Scenedesmus quadricauda* (Turpin) Brébisson | 1 | | 1 | 3 |
| *Scenedesmus obliquus* var. *dimorphus* (Turpin) Hansgirg | | | | 3 |
| *Scenedesmus* sp. 1 | | | 1 | |
| *Scenedesmus* sp. 2 | 1 | | | |
| *Scenedesmus* sp. 3 | | 3 | | |
| *Selenastrum bibraianum* Reinsch | | | | 4 |
| *Staurastrum* sp. | | | | 1 |
| *Tetrastrum triacanthum* Korshikov | | | 1 | |
| *Tetrastrum triangulare* (Chodat) Komárek | | | | 1 |

| | A | B | C | D |
|---|---|---|---|---|
| *Treubaria planctonica* (Smith) Korshikov | | | | 1 |
| *Ulothrix* sp. | | | | 1 |
| Class Cladophorophyceae | | | | |
| *Cladophora glomerata* (Linnaeus) Kützing | | 1 | 1 | 3 |
| Class Zygnematophyceae | | | | |
| *Cosmarium* sp. | 1 | | | |
| *Cosmarium wembaerense* Schmidle | 1 | | 1 | 1 |
| *Mougeotia* sp. 1 | | 1 | 1 | |
| *Mougeotia* sp. 2 | | | | 2 |
| *Spirogyra* sp. 1 | 1 | | 1 | 3 |
| *Spirogyra* sp. 2 | | | 1 | |
| *Zygnema* sp. | | | 1 | |
| Phyla Dinophyta | | | | |
| Class Dinophyceae | | | | |
| *Gymnodinium* sp. | | 1 | | |
| *Katodinium* sp. | | | | 1 |
| PhylaCryptophyta | | | | |
| Class Cryptophyceae | | | | |
| *Cryptomonas* sp. | | | | 1 |