

Fishpond trophic status assessment based on nutrients and bioindication I. Phytoplankton

Hodnocení trofie rybníků podle nabídky živin a bioindikačních metod I. Fytoplankton

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Abstract

Two-year-study of selected environmental variables, phytoplankton abundance, structure and species composition at 12 fishponds was used for the evaluation of their trophic state.

Favourable conditions of Bouzov fishponds are probably influenced by their disposition in the landscape. On the contrary, fishponds near Hradec Králové are strongly endangered by rapid eutrophication. The negative development of fishponds can be mitigated only by rigorous management excluding intensive fish or duck production, recreation, and agriculture in the surrounding fields. Prevention of external and internal loading and forestation of wide surroundings can be recommended.

Introduction

Fishponds are man-made shallow water bodies in which water level, fish stock and, to some extent, nutrient and fish-food input are under human control (FOTT et al. 1980). Moreover, pond ecosystem is highly labile, and open to almost unpredictable random external disturbances (WEIMANN 1942). Czech fishponds were constructed in the Middle Ages, but they have often lost any artificial appearance and look like small lakes beautifully harmonizing with the landscape (KORÍNEK et al. 1987). The source of nutrients is partly from fertilization of ponds, through additional feeding of fish with corn and granulated food, and by run-off from agricultural land. Every pond has a rich nutrient pool in its bottom sediments. During the past few decades, the original

oligotrophic or mesotrophic character of the fishponds has changed to eutrophic, and even hypertrophic, state. This is a result of intensified management for fish-production, changes in agricultural practices in the catchment area, and the use of fishponds as wastewater recipients. Both external and internal loading caused the present situation. The projects of fishponds restoration can lead to improvements in near future. New fishponds have been constructed within the projects of landscape renewal. The development of these new fishponds depends on initial conditions and suitable management. The utilization of centenary experience and hindsight is an important presupposition for the success of these projects.

This study focuses on the comparison of phytoplankton and selected environmental variables at 12 fishponds and the assessment of their trophic status.

Material and methods

Investigations were carried out during the years 2001-2002.

Selected environmental variables (pH, oxygen, temperature, conductivity) were measured in situ using mobile instruments (WTW company). Samples for chemical analyses were taken to plastic bottles. Phosphates, nitrates, and ammonium ions were checked with a DR 2000 spectrophotometer by HACH (HEKERA 1999).

Phytoplankton samples were taken once a month from the surface layer (20 cm below the surface) at the windward side of the fishponds. The quantitative evaluation of the main groups of phytoplankton in the samples was carried out by centrifugation (1500 rpm, time 5 minutes) and counting in a Bürker chamber. The following algal groups were in the centre of our interest: diatoms, green algae, cyanophytes, euglenophytes, chrysophytes, and others. The abundance is expressed as a number of specimens (coccal algae) or filamentous units (1 filament unit = 100µm) per 1 ml of sample.

Samples were taken from three new fishponds near Bouzov (Central Moravia, Czech Republic), and three new fishponds near Hradec Králové (East Bohemia, Czech Republic). The same investigations were carried out at comparative sites near Prostějov (Central Moravia, Czech Republic) and Lednice (South Moravia, Czech Republic). Comparative sites are represented by three old eutrophic fishponds with stabilized management and intensive fish farming (Plumlov, Gala, Prostějov, Hlohovecký, Prostřední, Mlýnský). Table 1 presents the morphometric characteristics of the investigated fishponds.

Bouzov area

The investigated area forms a part of the Javoříčka Brook basin and is situated in Dražanská Highlands (500 m a. s. l.). Approximately 200 years ago, there were several fishponds in this region. New rebuilt fishponds were finished in 2000. They are mostly surrounded by forests; the shading of their water surface ranges from 10 (Bouzov 1) to 50%. Recently, the fishponds serve for fish farming (fish stock 500 kg. ha⁻¹).

Table 1. Morphometric characteristics of the investigated fishponds

Locality	MAX depth [m]	AVG depth [m]	Area[ha]	Volume[m ³]
Bouzov 1	3.8	1.6	1.2	16 500
Bouzov 2	2.2	0.9	1.3	10 305
Bouzov 3	1.8	1.1	0.9	11 136
Rohlíčky	*	2	2.3	17 852
Frešle	2.2	*	2.4	32 162
Kaltouz	2	*	2.3	30 000
Prostějov	1.8	1.3	1.4	18 388
Plumlov	3.5	1.8	14.3	330 729
Gaľa	1.6	0.9	0.9	10 000
Hlohovecký	3.5	*	104.6	1 841 720
Prostřední	3.5	*	46.7	768 830
Mlýnský	3.5	1.5	105.8	1 994 200

* missing information

Hradec Králové area

The investigated area is a part of the Librantický Brook (fishpond Rohlíčky) and Malostranský Brook (fishpond Kaltouz) basins near the village of Librantice (Hradec Králové, East Bohemia). Fishpond Frešle is a sky pond without any inflow. Fishponds are situated in a lowland (altitude 260 m a.s.l.), surrounded by fields. Shading is fractional, except for the fishpond Kaltouz (30%), which is partly surrounded by forest (western part). The ponds were constructed in an open, agricultural countryside and finished in the years 1996 (Frešle), 1998 (Rohlíčky) and 1999 (Kaltouz). Fishponds serve for fish and duck farming.

Prostějov area

The fishponds were constructed in a lowland (altitude 225 - 282 m a.s.l.), probably in the 18th and 19th centuries. The area is a part of the Hloučela Brook

basin and fishponds Plumlov (Podhradský fishpond), Gala and Prostějov (Drozdovice fishpond) are situated below Plumlov reservoir. The fishponds serve for fish farming (fish production 1400 – 1900 kg.ha⁻¹). Shading is fractional (4% Plumlov, 14% Prostějov, 30% Gala).

Lednice area

Lowland fishponds (altitude 165 m a.s.l.) are used for intensive fish farming (fish production to the year 1996 was 911 - 1151 kg .ha⁻¹ ; HETEŠA & SUKOP 1997). The reduction of fish stock since the year 1996 has not brought any improvement yet. The fishponds were constructed in the Mikulovský Brook basin in 1418. They are lined by trees and bushes and surrounded by meadows and fields. The littoral vegetation, dominated by *Phragmites australis* and *Typha angustifolia*, occupies 5% of their total area. Due to their large area, there is almost no shading .

Results and discussion

Table 2 presents selected environmental variables of the investigated fishponds.

According to OECD scale, the evaluation of eutrophication is usually based on the annual averages of TP (total phosphorus). This scale was created for large lakes and, therefore, is not suitable in the case of our fishponds. They were assessed as hypertrophic or came out of the scale, although the algal species composition in some cases indicated better state (KITNER & POULÍČKOVÁ in press.). Hradec Králové area has the lowest TP values, but the NH₄ concentrations are higher than in Bouzov area. The highest nitrate concentrations and increased TP values are typical for Prostějov area. The highest TP values and NH₄ concentrations are characteristic for Lednice area.

A necessary consequence of pond eutrophication is a high biomass of phytoplankton (KOKÍNEK et al. 1987).

Thus, the evaluation of pond trophic state can be based on annual averages of chlorophyll-a concentrations. Although chlorophyll *a* is not an ideal measure of phytoplankton biomass (DESORTOVÁ 1981), it has a unique advantage in the ease of measurement. Other parameters reflecting the phytoplankton biomass can be also successfully used, for instance phytoplankton abundance or biovolume. While chlorophyll-a concentration is a more general parameter, we can evaluate the phytoplankton structure and species composition through algal counting.

Figure 1 presents the comparison of average annual algal abundances in the investigated fishponds. The algal abundances in new fishponds ranged from 700 to 18 000 specimens per 1ml. The forest fishponds near Bouzov had the lowest abundances. Abundances in old eutrophic fishponds near Prostějov

ranged from 14 000 to 38 000 specimens per 1 ml, but they can reach even higher in hypertrophic fishponds. Hypertrophic conditions are represented by three fishponds near Lednice with the highest phytoplankton abundances (HETEŠA & SUKOP, 1997; these data are not in specimens per 1 ml, but in cells per 1 ml).

Another compared parameter - the proportion of basic algal groups - is also in agreement with the previous findings. Figure 2 summarizes the annual average representation of 7 phytoplankton groups. A higher proportion of the group Chrysophyceae characterises the new fishponds. With the increasing eutrophication, the representation of this group decreases for the benefit of cyanophytes and green algae. The phytoplankton structure becomes more monotonous with only two groups at hypertrophic sites (Lednice, HETEŠA & SUKOP 1997). The occurrence of some cyanobacteria or algae is influenced not only by the nutrients concentration, but also by the presence of sufficient "inoculum". For this reason, such species can be absent at newly constructed fishponds in the initial years. Although Bouzov fishponds were free of cyanobacteria in 2001, the occurrence of *Microcystis aeruginosa* was observed in 2002. Similar situation was observed in Hradec Králové in 2002.

Figure 3 presents the results of hierarchical clustering analysis (Ward's method) on the basis of phytoplankton species composition. Localities are divided into two groups - Lednice area and the rest of fishponds. Significant dissimilarity of the fishponds near Lednice is caused by their highest trophic level and high conductivity. Many halotolerant species were observed there (Tab. 3). The remaining fishponds constitute also two groups - Prostějov area differs from the new fishponds near Hradec Králové and Bouzov.

Conclusion

Two-year-study of selected environmental variables, phytoplankton abundance, structure and species composition served for the evaluation of trophic status of several fishponds.

Fishponds near Bouzov are forest fishponds with relatively low nutrient concentrations, low phytoplankton abundances, diversiform phytoplankton structure, a high proportion of Chrysophyceae, and a low proportion of cyanophytes (especially in 2001). The favourable initial conditions are probably influenced by the ponds' disposition in the landscape. Their future development will depend on their management. According to the development in 2002, the danger of eutrophication is relevant.

Fishponds near Hradec Králové are halfway loaded field fishponds with higher phytoplankton abundances than previous sites, and with an increased representation of cyanophytes. Due to their location in the landscape, these fishponds are strongly endangered by rapid eutrophication. This negative development can be mitigated only by rigorous management excluding intensive

fish or duck production, recreation, and agriculture in the surrounding fields. Prevention of external and internal loading and forestation of wide surroundings can be recommended.

Fishponds near Prostějov were not loaded as much as we expected. In any case, they represent the worse part of the trophic spectrum - eutrophic sites. For the improvement of this situation, the changes in management are necessary. With the intensive fish farming and recreation they would catch up with the hypertrophic sites very quickly.

Fishponds near Lednice represent the result of a long term intensive fish production and a totally unsuitable management. The improvement of this situation will be very expensive and will require a complex approach including the decrease in the internal and external loading. A pure decrease in fish stock cannot be sufficient under the present conditions.

Acknowledgement

The presented study was accomplished with the support of the research grant from the Ministry of Education of the Czech Republic (FRVŠ 1248/2002). The authors express their special thanks to RNDr. J. Heteša, CSc. for his information about Lednice area.

References

- FOTT, J., PECHAR, L. & PRAŽÁKOVÁ, M. (1980): Fish as a factor controlling water quality in ponds. – In: Barica, J. & Mur, L.R. (eds.): *Hypertrophic Ecosystems. Developments in Hydrobiology*, 2: 255-261.
- DESORTOVÁ, B. (1981): Relationship between chlorophyll-a concentrations and phytoplankton biomass in several reservoirs in Czechoslovakia. *Int. Rev. Ges. Hydrobiol.* 66: 153-169.
- HEKERA, P. (1999): Vliv antropogenní činnosti na chemismus řeky Moravy. – PhD Thesis, Masaryk University, Brno, 82 pp.
- HETEŠA, J. & SUKOP, I. (1997): Lednické rybníky po třiceti letech. – In: *Sborník referátů XI. limnologické konference, Doubrava u Třeboně*, 38-41.
- KITNER, M. & POULÍČKOVÁ, A. (in press.): Littoral algae and eutrophication of shallow lakes. – *Hydrobiologia*, in press.
- KOŘÍNEK, F., FOTT, J., FUKSA, J., LELLÁK, J. & PRAŽÁKOVÁ, M. (1987): Carp ponds of Central Europe. – In: Michel, R.G. (ed.): *Managed aquatic ecosystems*, Elsevier Science Publishers B.V., Amsterdam, 29-62.
- OECD (1982): *Eutrophication of waters. Monitoring, assessment and control*, OECD, Paris, 155pp.
- WEIMANN, R. (1942): Zur Gliederung und Dynamik der Flachgewässer. – *Arch. Hydrobiol.* 38: 481-524.
- ZELINKA, M., MARVAN, P. (1961): Zur Präzisierung der biologischen Klassifikation der Reinheit fließender Gewässer. – *Arch. Hydrobiol.* 57: 389-407.

Table 2. Annual averages of selected parameters

Fishpond/Variable	Conductivity	pH	NO ₃ ⁻ mg.l ⁻¹	NH ₄ ⁺ mg.l ⁻¹	Total phosphorus mg.l ⁻¹	OECD classification**
Bouzov 1	160*	8.3±0.1	0.898±0.761	0.0777±0.043	0.178 ± 0.084	hypertrophic
Bouzov 2	210*	8.2±0.3	0.639±0.358	0.947±0.052	0.165±0.041	hypertrophic
Bouzov 3	120*	8.2±0.1	0.428±0.198	0.813±0.098	0.192±0.084	hypertrophic
Rohličky	102*	8.5*	0.850±0.280	2.898±1.478	0.149±0.072	hypertrophic
Prešle	862*	8.9*	0.523±0.097	2.318±2.017	0.147±0.044	hypertrophic
Kaltouz	277*	9.8*	0.438±0.182	2.641±2.333	0.150±0.052	hypertrophic
Prostějov	277.4±57.2	8.5±0.6	1.398±2.748	0.852±0.415	0.284±0.155	hypertrophic
Plumlov	281.3±62.1	8.3±0.7	1.946±2.654	1.837±1.832	0.355±0.107	hypertrophic
Gala	278.0±63.5	7.8±0.5	0.245±0.238	1.087±1.287	0.394±0.140	hypertrophic
Hlohovecký	1553*	8.5*	0.437±0.129	3.620±1.120	0.519±0.041	hypertrophic
Prostřední	1431*	8.6*	0.484*	2.802*	0.883*	hypertrophic
Mlýnský	1375*	8.6*	0.471±0.031	2.601±0.560	0.697±0.160	hypertrophic

** OECD classification according to annual average total phosphorus: oligotrophic ≤ 0.01 mg.l⁻¹; mesotrophic 0.01–0.035 mg.l⁻¹; eutrophic 0.035 – 0.1 mg.l⁻¹; hypertrophic ≥ 0.1 mg.l⁻¹

* single sampling

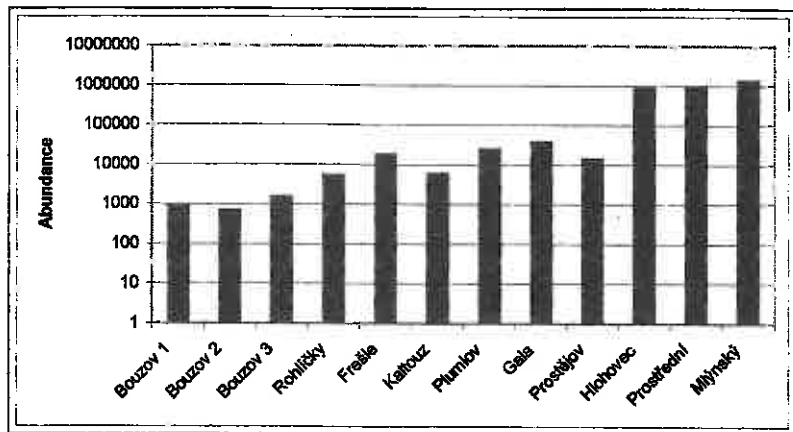


Fig. 1: Annual averages of phytoplankton abundance at investigated fishponds (abundance in individuals per 1 ml – logarithmic scale)

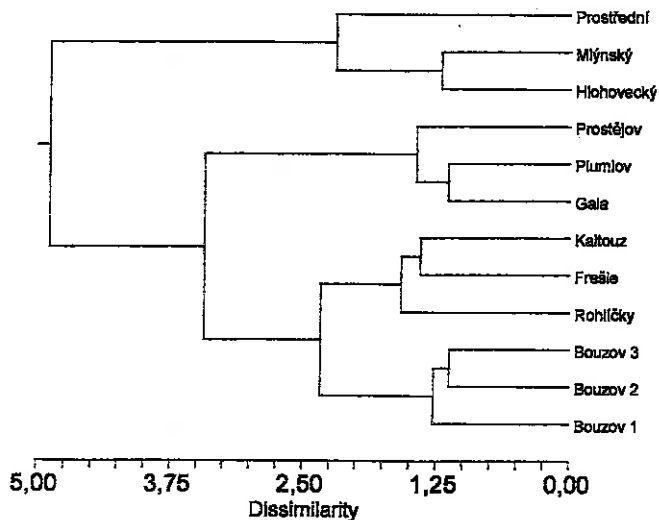


Fig. 3: Results of cluster analysis (Ward's minimum variance) of the investigated ponds based on phytoplankton species

Taxon/Locality	Bouzov	Hradec	Prostějov	Lednice
<i>Acanthosphaera zachariasii</i> LEMM.		1	1	
<i>Actinactrum hantzschii</i> LAGERH.		1	1	1
<i>Achnanthes lanceolata</i> (BRÉB.) GRUN.	1			
<i>Amphora ovalis</i> (KÜTZ.) KÜTZ.		1	1	1
<i>Anabaena circinalis</i> RABENH			1	
<i>Anabaena flos-aquae</i> BR. ex BORN, FLAH				1
<i>Anabaena lemmermannii</i> RICH.				1
<i>Anabaena solitaria</i> KLEB.				1
<i>Anabaena sigmoides</i> NYGAARD				1
<i>Anabaenopsis</i> cf. <i>arnoldii</i> APTEK.		1		
<i>Anabaenopsis elenkinii</i> MILL.				1
<i>Ankistrodesmus bibrarianus</i> (REINSCH) KORŠ.	1			
<i>Ankistrodesmus gracilis</i> (REINSCH) KORŠ.	1	1		1
<i>Ankyra ancora</i> (G. M. SMITH) FOTT				1
<i>Ankyra juday</i> (G. M. SMITH) FOTT				1
<i>Ankyra lanceolata</i> (KORŠ.) FOTT				1
<i>Anomoeconeis sphaerophora</i> (EHRENB.) PFITZER			1	
<i>Aphanizomenon flos-aquae</i> (L.) RALFS et BORNET et FLAHAULT				1
<i>Aphanizomenon gracile</i> (LEMM.) LEMM.				1
<i>Aphanizomenon issatschenkoii</i> (USAČ.) PROŠK.-LAVR.				1
<i>Aphanocapsa holsatica</i> (LEMM.) CRONBERG et KOM.			1	
<i>Aphanocapsa incerta</i> (LEMM.) CRONG. et KOM.				1
<i>Aphanothece nidulans</i> RICHT.			1	
<i>Aphanothece stagnina</i> (SPRENG.) A. BR.			1	
<i>Asterionella formosa</i> HASS.	1		1	
<i>Aulacoseira ambigua</i> (GRUN.) SIMON.			1	
<i>Aulacoseira granulata</i> (EHRENB.) SIMON.			1	1
<i>Botryococcus protuberans</i> W. et G. S. WEST				
<i>Caloneis amphisbaena</i> (BORY) CL.				1
<i>Centritractus belenophorus</i> LEMM.				1
<i>Centronella reicheltii</i> VOIGT			1	
<i>Ceratium hirundinella</i> (O. F. MÜLLER) SCHRANK		1		1
<i>Chlamydomonas bichlora</i> PASCH. et JAHODA	1			
<i>Chlamydomonas reinhardtii</i> DANG.				1
<i>Chlorella emersonii</i> SHIH. et KRAUSS		1		
<i>Chlorella homosphaera</i> SKUJA		1	1	
<i>Chlorella minutissima</i> FOTT et NOVÁKOVÁ	1		1	
<i>Chlorella vulgaris</i> BEIJERINCK	1		1	
<i>Chlorogonium elongatum</i> DANG.				1
<i>Chlorosarcina superba</i> SKUJA	1			
<i>Chroococcus</i> cf. <i>minutus</i> (KÜTZ.) NÄG.		1	1	
<i>Chroomonas caudata</i> GEITLER				1
<i>Chrysococcus cordiformis</i> NEUMANN	1			
<i>Chrysococcus rufescens</i> KLEBS		1		
<i>Chrysococcus triporus</i> MACK	1	1		
<i>Closteriopsis acicularis</i> (G. M. SMITH) BELCH. et SWALE	1			
<i>Closterium acerosum</i> (SCHRANK) EHRENB.		1		1
<i>Closterium limneticum</i> LEMM.			1	1
<i>Cocconeis pediculus</i> EHRENB.	1			
<i>Cocconeis placentula</i> EHRENB.	1			
<i>Codomonas pascheri</i> VAN - GOOR		1		1
<i>Coelastrum asteroideum</i> DE-NOTARIS			1	1
<i>Coelastrum cambricum</i> ARCHER			1	
<i>Coelastrum microporum</i> NÄG.	1	1	1	1

<i>Coelastrum pseudomicroporum</i> KORŠ.	1	1	
<i>Cosmarium pygmaeum</i> ARCH.			1
<i>Crucigenia fenestrata</i> (SCHMIDLE)	1		
<i>Crucigenia quadrata</i> MORREN		1	
<i>Crucigenia tetrapedia</i> (KIRCHN.) W. et G. S. WEST	1	1	1
<i>Crucigenia triangularis</i> CHOD.		1	
<i>Crucigeniella apiculata</i> (LEMM.) KOM.		1	1
<i>Crucigeniella rectangularis</i> (NÄG.) KOM.	1	1	
<i>Crucigeniella neglecta</i> (FOTT et ETTL) KOM.			1
<i>Crucigeniella pulchra</i> (W. et G. S. WEST) KOM.			1
<i>Cryptomonas</i> cf. <i>marsonii</i> SKUJA	1	1	1
<i>Cryptomonas</i> cf. <i>reflexa</i> SKUJA	1	1	
<i>Cryptomonas curvata</i> EHRENB.	1	1	1
<i>Cryptomonas cylindrica</i> EHRENB.	1		
<i>Cyclotella atomus</i> HUST.		1	
<i>Cyclotella</i> cf. <i>comta</i> (EHRENB.) KÜTZ.		1	
<i>Cymatopleura libralis</i> (EHRENB.) PANT.		1	
<i>Cymatopleura elliptica</i> (BRÉB.) W. SMITH			1
<i>Diatoma elongata</i> (LYNGBYE) AG.			1
<i>Diatoma vulgare</i> BORY	1		
<i>Dichotomococcus curvatus</i> KORŠ.			1
<i>Dictyosphaerium</i> cf. <i>pulchellum</i> WOOD	1		1
<i>Dictyosphaerium</i> cf. <i>tetrachotomum</i> PRINTZ	1	1	
<i>Dictyosphaerium ehrenbergianum</i> NÄG.	1		
<i>Dictyosphaerium primum</i> SKUJA	1		
<i>Dictyosphaerium subolitarium</i> VAN GOOR			1
<i>Didymocystis planctonica</i> KORŠ.			1
<i>Didymocystis inconspicua</i> KORŠ.			1
<i>Dinobryon divergens</i> IMH.	1	1	1
<i>Dinobryon sociale</i> EHRENB.		1	
<i>Elakatothrix genevensis</i> (REVERD.) HIND.			1
<i>Eudorina elegans</i> EHRENB.	1		1
<i>Eudorina illinoisensis</i> (KOFOID) PASCH.	1		
<i>Euglena acus</i> EHRENB.		1	1
<i>Euglena</i> cf. <i>caudata</i> HUBN.	1		1
<i>Euglena</i> cf. <i>intermedia</i> (KLEBS) SCHMITZ		1	
<i>Euglena</i> cf. <i>veleta</i> KLEBS.		1	
<i>Euglena ehrenbergii</i> KLEBS		1	
<i>Euglena geniculata</i> DUJARDIN			1
<i>Euglena gracilis</i> KLEBS	1		1
<i>Euglena oxyuris</i> SCHMARDT		1	1
<i>Euglena proxima</i> DANG.	1	1	
<i>Euglena polymorpha</i> DANG.			1
<i>Euglena spirogyra</i> DANG.			1
<i>Eutetramorus foetili</i> (HIND.) KOM.			1
<i>Eunotia incisa</i> GREGORY	1		
<i>Fragilaria crotonensis</i> KITZ.		1	
<i>Fragilaria delicatissima</i> (W. SMITH) LANGE-BERT.		1	
<i>Fragilaria ulna</i> (NITZSCH) EHRENB.		1	1
<i>Francelia ovalis</i> (FRANCE) LEMM.			1
<i>Gloeotila spiralis</i>			1
<i>Golenkinia radiata</i> CHOD.		1	1
<i>Golenkinopsis solitaria</i> (KORŠ.) KORŠ.		1	
<i>Gomphonema ventricosum</i> GREGORY			1
<i>Gomphosphaeria pusilla</i> (VAN GOOR) KOM.			1

<i>Goniochloris fallax</i> FOTT				1
<i>Goniochloris laevis</i> PASCHER				1
<i>Goniochloris mutica</i> (A. BR.) FOTT				1
<i>Goniochloris sculpta</i> GEITLER				1
<i>Goniochloris spinosa</i> PASCH.				1
<i>Goniochloris smithii</i> (BOURR.) FOTT				1
<i>Granulocystis helenae</i> HIND.				1
<i>Gyrosigma acuminatum</i> (KÜTZ.) RABENH.			1	
<i>Heterothrix debilis</i> VISCH.	1			
<i>Hyaloraphidium contortum</i> PASCH. et KORŠ.		1	1	
<i>Kephyrion mastigophorum</i> G. SCHMID	1			
<i>Kephyriopsis cincta</i> SCHILLER	1	1		
<i>Kephyriopsis conica</i> SCHILLER	1			
<i>Kephyriopsis cylindrica</i> (LACKEY) FOTT	1			
<i>Kephyriopsis entzii</i> (CONRAD) FOTT	1	1		
<i>Stanokalyx monilifera</i> G. SCHMID	1			
<i>Kirchneriella contorta</i> (SCHMIDLE) BOHL.		1	1	1
<i>Kirchneriella irregularis</i> (G. M. SMITH) KORŠ.	1			
<i>Kirchneriella lunaris</i> (KIRCHN.) MOEB.	1			
<i>Kirchneriella obesa</i> (W. WEST) SCHMIDLE	1			
<i>Kirchneriella rotunda</i>				1
<i>Koliella longiseta</i> (WISLOUCH) HIND.	1			1
<i>Koliella spiculiformis</i> (WISLOUCH) HIND.	1		1	1
<i>Lagerheimia ciliata</i> (LAGERH.) CHOD.				1
<i>Lagerheimia genevensis</i> CHOD.		1	1	1
<i>Lagerheimia longiseta</i> (LEMM.) WILLE		1	1	
<i>Lagerheimia marssonii</i> LEMM.				1
<i>Lagerheimia subsalsa</i> LEMM.			1	
<i>Lagerheimia wratislaviensis</i> SCHROD.	1			
<i>Lepocinclis ovum</i> (EHRENB.) LEMM.				1
<i>Lepocinclis texta</i> (DUJARD.) LEMM.	1			1
<i>Limnothrix cf. redekei</i> (VAN GOOR) MEFERT.		1	1	1
<i>Limnothrix planctonica</i> WOLOSZYŃSKA			1	
<i>Lobomonas aple</i> PASCH.			1	
<i>Mallomonas acaroides</i> PERTY			1	
<i>Mallomonas cf. fastigata</i> ZACHARIAS	1			
<i>Melosira varians</i> AG.				1
<i>Merismopedia elegans</i> A. BRAUN in KÜTZ.			1	
<i>Merismopedia glauca</i> (EHRENB.) KÜTZ.			1	
<i>Merismopedia punctata</i> MEYEN		1		1
<i>Merismopedia tenuissima</i> LEMM.		1	1	1
<i>Merismopedia warmingiana</i> LAGER.			1	
<i>Mesostigma viride</i> LAUTERB.				1
<i>Micractinium bornhemliense</i> (CONR.) KORŠ.	1			
<i>Micractinium pusillum</i> FRES.	1	1		
<i>Microcystis aeruginosa</i> (KÜTZ.) KÜTZ.	1	1		1
<i>Microcystis ichthyoblabe</i> KÜTZ.				1
<i>Microcystis novacekii</i> (KOM.) COMPÈRE			1	
<i>Microcystis viridis</i> (A. BRAUN in RABENH.) LEMM.			1	
<i>Monomorphina pyrum</i> (EHRENB.) MERESK				1
<i>Monoraphidium arcuatum</i> (KORŠ.) HIND.	1	1	1	1
<i>Monoraphidium circinale</i> (NYG.) NYG.				1
<i>Monoraphidium contortum</i> (THUR.) KOM. - LEGN.	1	1	1	1
<i>Monoraphidium convolutum</i> (CORDA) KOM. - LEGN.	1		1	
<i>Monoraphidium griffithii</i> (BERKELEY) KOM. - LEGN.	1		1	1

<i>Monoraphidium komarkovae</i> NYGAARD				1
<i>Monoraphidium minutum</i> (NÄG.) KOM. - LEGN.	1	1		1
<i>Monoraphidium nanum</i>				1
<i>Monoraphidium pusillum</i> (PRINTZ) KOM. - LEGN.	1			1
<i>Monoraphidium tortile</i> (W. et G. S. WEST) KOM. - LEGN.				1
<i>Navicula cryptocephala</i> KÜTZ.	1			
<i>Navicula lanceolata</i> (AG.) KÜTZ.	1			
<i>Navicula radiosa</i> KÜTZ.	1			
<i>Neodesmus danubialis</i> HIND.				1
<i>Nephrocliamys subsolitaria</i> (G. S. WEST) KORŠ.	1			
<i>Nephrocliamys willeana</i> (PRINTZ) KORŠ.				1
<i>Nitzschia cf. dissipata</i> (KÜTZ.) GRUN.	1			
<i>Nitzschia acicularis</i> W. SMITH	1	1	1	1
<i>Nitzschia sigmoidea</i> (EHRENB.) W. SMITH				1
<i>Oocystis lacustris</i> CHOD.	1	1		1
<i>Oocystis marssonii</i> LEMM.	1	1		1
<i>Oocystis parva</i> W. et G. S. WEST			1	1
<i>Oocystis solitaria</i> WITTR.	1			
<i>Oocystis verrucosa</i> ROLL.			1	
<i>Ophlocytium capitatum</i> WOLLE			1	
<i>Ophlocytium lagerheimii</i> LEMM.				1
<i>Pandorina morum</i> (O. F. MÜLLER) BORY				1
<i>Pediastrum angulosum</i> (EHRENB.) MENECH.			1	
<i>Pediastrum boryanum</i> (TURP.) MENECH.	1	1	1	1
<i>Pediastrum cf. subgranulatum</i> (RACIBORSKI) KOM.			1	
<i>Pediastrum duplex</i> MEYEN	1	1	1	1
<i>Pediastrum integrum</i> LEFÈVRE				
<i>Pediastrum simplex</i> MEYEN		1	1	
<i>Pediastrum tetras</i> (EHRENB.) RALFS	1	1	1	1
<i>Phacotus lenticularis</i> EHRENB.		1	1	1
<i>Phacus longicauda</i> (EHRENB.) DUJARDIN	1			1
<i>Phacus manguinii</i> LEFÈVRE				
<i>Phacus orbicularis</i> HUBN.	1	1	1	
<i>Phacus pleuronectes</i> (O. F. MÜLLER) DUJARDIN	1		1	
<i>Phacus pyrum</i> EHRENB.	1		1	
<i>Phacus tortus</i> (LEMM.) SKVORC.	1	1		1
<i>Phacus triquetus</i> (EHRENB.) DUJARDIN				1
<i>Pinnularia biceps</i> GREGORY			1	
<i>Planctothrix agardhii</i> (GOMONT) ANAGN. et KOM.		1	1	1
<i>Planctosphaeria gelatinosa</i> G. M. SMITH			1	
<i>Planctonema lauterbornii</i> SCHMIDLE				1
<i>Pseudosphaerocystis lacustris</i> (LEMM.) NOVÁKOVÁ			1	
<i>Pseudanabaena catenata</i> LAUTERB.				1
<i>Pseudanabaena limnetica</i> (LEMM.) KOM.				1
<i>Rhodomonas rubra</i> GEITLER			1	
<i>Rhodomonas lacustris</i> PASCH. et. RUTTNER				1
<i>Rhoicosphenia curvata</i> (KÜTZ.) RABENH.				1
<i>Scenedesmus abundans</i> (KIRCHN.) CHOD.	1	1	1	
<i>Scenedesmus acuminatus</i> (LAGERH.) CHOD.	1	1	1	1
<i>Scenedesmus acutus</i> MEYEN	1	1	1	1
<i>Scenedesmus alternans</i> REINSCH	1	1	1	
<i>Scenedesmus bicaudatus</i> (HANSG.) CHOD.				1
<i>Scenedesmus brasiliensis</i> BOHLIN	1		1	
<i>Scenedesmus denticulatus</i> LAGERH.	1			
<i>Scenedesmus dimorphus</i> (TURP.) KÜTZ.	1	1	1	1

<i>Scenedesmus disciformis</i> (CHOD.) FOTT et KOM.			1	1
<i>Scenedesmus dispar</i> BRÉB.			1	
<i>Scenedesmus eornis</i> (RALFS) CHOD.			1	1
<i>Scenedesmus gutwinski</i> CHOD.			1	
<i>Scenedesmus intermedius</i> CHOD.	1		1	
<i>Scenedesmus linearis</i> KOM.	1	1	1	1
<i>Scenedesmus obliquus</i> (TURP.) KÜTZ.	1		1	
<i>Scenedesmus opollensis</i> RICHTER	1			1
<i>Scenedesmus pannonicus</i> HORTOB.			1	1
<i>Scenedesmus peccensis</i>				1
<i>Scenedesmus quadricauda</i> (TURP.) BRÉB.	1	1	1	1
<i>Scenedesmus sempervirens</i> CHOD.			1	1
<i>Scenedesmus serratus</i> (CORDA) BOHL.			1	
<i>Scenedesmus subspicatus</i> CHOD.				1
<i>Scenedesmus velitaris</i> KOM.		1		
<i>Scenedesmus verrucosus</i> ROLL.			1	
<i>Schizochlamys gelatinosa</i> A. BRAUN	1			
<i>Schroederia nitzschioides</i>				1
<i>Schroederia robusta</i> KORŠ.				1
<i>Schroederia setigera</i> (SCHRÖD.) LEMM.			1	1
<i>Schroederia spiralis</i> (PRINTZ) KORŠ.	1		1	1
<i>Skeletonema potamos</i> (WEBER) HASLE			1	1
<i>Snowella arachnoidea</i> KOM. et HIND.			1	
<i>Snowella atomus</i> KOM. et HIND.			1	
<i>Spirulina maior</i> KÜTZ. ex GOM.		1		1
<i>Staurostrum cf. chaetoceros</i> (SCHRODER) G. M. SMITH		1		
<i>Staurostrum gracile</i> RALFS	1	1		
<i>Staurostrum paradoxum</i> MEYEN	1	1	1	
<i>Staurostrum planctonicum</i> TEIL.	1		1	
<i>Stenocalyx incostans</i> SCHMID	1		1	
<i>Stenocalyx monilifera</i> SCHMID	1			
<i>Stenocalyx spiralis</i> (LACKEY) FOTT		1		
<i>Stephanodiscus hantzschii</i> GRUN.	1			1
<i>Stephanodiscus minutulus</i> (KÜTZ.) CLEVE et. MOLLER	1			
<i>Stichococcus cf. bacillaris</i> NÄG.			1	
<i>Stichococcus contortus</i> (CHOD.) HIND.				1
<i>Stichococcus minor</i> NÄG.				1
<i>Strombomonas gibberosa</i> (PLAYF.) DEFL.		1		
<i>Surirella ovata</i> KÜTZ.		1		1
<i>Synedra tabulata</i> (AG.) KÜTZ.				1
<i>Synedra acus</i> KÜTZ.		1		1
<i>Synura uvella</i> EHRENB. em. KORŠ.		1		
<i>Tetraëdron caudatum</i> (CORDA) HANSG.	1	1	1	1
<i>Tetraëdron incus</i> (TEIL.) G. M. SMITH	1			
<i>Tetraëdron minimum</i> (A. BR.) HANSG.	1	1	1	1
<i>Tetraëdron platyisthmum</i> (ARCH.) G. S. WEST		1	1	
<i>Tetraëdron quadratum</i> (REINSCH) HANSG.		1		1
<i>Tetraëdron triangulare</i> (KORŠ.)		1		1
<i>Tetrastrum cf. punctatum</i> (SCHMIDLE.) AHLSTR.	1		1	
<i>Tetrastrum elegans</i> PLAYF.		1	1	
<i>Tetrastrum glebrum</i> (ROLL) AHLSTR.		1		1
<i>Tetrastrum staurogeniaeforme</i> (SCHROD.) LEMM.	1	1	1	1
<i>Tetrastrum triangulare</i> (CHOD.) KOM.		1		1
<i>Trachelomonas armata</i> (EHRENB.) STEIN		1		
<i>Trachelomonas hispida</i> (PERTY) STEIN em. DEFL.	1	1	1	

<i>Trachelomonas irregularis</i> SVIR.	1			
<i>Trachelomonas planctonica</i> SVIR.		1	1	
<i>Trachelomonas stokesiana</i> PALMER	1			
<i>Trachelomonas verrucosa</i> STOKES			1	
<i>Trachelomonas volvocina</i> EHRENB.			1	1
<i>Trachelomonas volvocinopsis</i> SVIR.	1	1	1	1
<i>Treubaria schmidlei</i> SCHRÖD.				1
<i>Treubaria cf. varia</i> TIFF. et AHLSTR.			1	
<i>Treubaria planctonica</i> (G. M. SMITH) KORŠ.			1	
<i>Treubaria triappendiculata</i> BERN.			1	
<i>Uroglena americana</i> CALKINS		1		
<i>Volvox aureus</i> EHRENB.		1		
	81	109	120	145

Fig. 2: Annual average representation of the main phytoplankton groups (Cy – Cyanophyta, Chry – Chrysophyceae, Bac – Bacillariophyceae, Cry – Cryptophyta, Eu – Euglenophyta, Gre – green algae, Ot – others)

