

**FINAL REPORT
SWITCH-LODZ / RTD 2007
M: 13-24**

WG VII: Ecohydrology and Urban Aquatic Ecosystems

Date:	05/02/2008
Prepared by:	Aleksandra Skowron Department of Applied Ecology, University of Lodz European Regional Centre for Ecohydrology under the auspices of UNESCO, Polish Academy of Sciences
Content:	Monitoring of phytoplankton composition in five interlinked reservoirs on the Sokolowka River in 2007 year.

Content	
Summary	2 -
1. Introduction	3 -
2. Material and Methods	3 -
3. Results	5 -
Weather conditions	5 -
Physical and chemical conditions	6 -
Phytoplankton dynamic and diversity.	9 -
4. Discussion	12 -
The role of chemical conditions in controlling community structure.....	13 -
The role of physical conditions in controlling community structure.....	14 -
Conclusions and further steps:	16 -
References:	18

Monitoring of phytoplankton composition in five interlinked reservoirs on the Sokolowka River in 2007 year.

Summary

The investigations in 2007 were carried out on five cascade reservoirs located on the Sokolowka River - a typical urban storm water receiver. The main function of the reservoirs is retention and reduction of the storm water sewage flow peaks. Phytoplankton genera composition, chlorophyll-*a* concentration and physical (water temperature, oxygen concentration, pH, conductivity) and chemical (TP, TN, P-PO₄, N-NH₄, N-NO₃) variables were analysed to determine the control factors of this multi-stressed ecosystem, that can be used for it's restoration and prevention of algal blooms appearance.

The conditions resulting from the location of the particular reservoirs in the various sections of the cascade system along the river favour different biotic structures of their ecosystems. Therefore, they require different management and restoration measures. The first two reservoirs and the last one, which is additionally supplied with a tributary, receive high flood peaks, therefore their conditions are mostly modified and dependent on precipitation events. High turbidity induced by storm events favour turbulence tolerant species adapted to low light availability like *Oscillatoriales*. They are additionally more resistant to metals and water toxicity what makes them better competitors in urban water conditions. Third and fourth reservoirs located in the middle of the cascade are more physically stable. Domination of *Chroococcales* proves this calm conditions and better light availability. This makes the management based on ecohydrological control and shaping of biota potentially more successful.

1. Introduction

Urbanization processes lead to changes in stream hydrology and geomorphology with next consequences of accelerated fluxes of matter, nutrient and energy with degradation of their cycles. Thus most urban streams are small waters with a low self-purification capacity. Urban induced increase in riverine fluxes of nutrients and pollutants can also be diminished by anthropogenic retention due to reservoirs construction, which create an efficient cascade of sediments and nutrients traps (Meybeck and Trans 2003). However urban shallow interconnected reservoirs located along urban streams continuum are exposed to hydrological, physical and chemical instability due to storm water flush events. The passage of high total discharges volume from SWOs (Surface Water Outfall) and CSOs (Combined Sewage Overflow) through the drainage system in a comparatively short period of time may result in ecological degradation of receiving waterbodies during storm (Mullis *et al.*, 1996). Occurrence of such events in shallow reservoirs can change the phytoplankton community, favoring some organisms, and biomass decreasing it due to flushing and dilution of organisms and deterioration of light availability or increasing it due to resuspension of resting forms and stages, periodical lack of top-down control as an effect of zooplankton wash out, growth stimulation owing to nutrient supply (Barbiero, 1999). Such conditions may keep the system in the turbid state characterised by high algal biomass (Sheffer *et al.*, 1993) with possibility of toxic blooms occurrence what diminish the recreational function of reservoirs.

Phytoplankton taxonomic diversity increase from oligotrophic to mesotrophic and eutrophic lakes in which the role of cosmopolitan species with wide ecological amplitude rise. Hypertrophic conditions appear are characterized by reduction of taxonomic diversity due to pollution and it's toxic effect (Trifonova, 1998).

The aim of this study was to asses the phytoplankton composition and physical and chemical variables in the existing and newly constructed interlinked reservoirs on the Sokołówka River to infer possible control factors in this multi-stressed system what can be relevant for it's management and restoration.

2. Material and Methods

Sokołówka River, crossing the northern part of the city of Lodz stocked in combined sewer system, is a typical urban storm water receiver, supplied mostly by around 50 storm water outlets. The main channel was regulated by concrete slabs, to straighten the course and deepen the bed for purpose of runoff detention (Wagner *et al.*, 2006). The whole catchment of the river has 4593 ha from which the canalized part has an area of 2368 ha with 971 ha impervious and natural part, from which storm water flows into the river in an unorganized way, has 2225 ha. The average imperviousness factor of the catchment amount to 0,21 (Kujawa & Kujawa, 2003).

The investigations were carried out on five linked reservoirs on the Sokołówka river which were modified and/or constructed to reduce the storm water sewage flow peaks according to the concept of the restoration project of the Sokolowka river valley (Wagner *et al.*, 2006). The reservoirs are categorized as small one with riverine character (Straskraba and Tundisi; 1999) and differ from each other in age, size, theoretical water residence time, light intensity, input flow and nutrient supply (Tab. 1). Two first ponds are situated in an old park, two next are newly constructed ones located in estate area and the last one is placed on the outskirts of the city in the middle section of river valley which has maintained semi natural character. To asses the input of nutrients and suspended matter samples were taken also on stations above reservoirs.

Reservoir	S [ha]	V [km ³]	T [days]	Age	F [m ³ /s]		
1.Upper Pond	1.64	22,5	7.7	old	0.006	0.030	4.5
2.Lower Pond	1.10	11.1	7.07	old	0.007	0.033	1.7
3. Zgierska	0.50	4.1	1.16	new (2004)	0.007	0.033	1.5
4. Teresy	1.40	22	2.62	new (2006)	0.008	0.039	1.2
5. Pabianka	1.50	20	3.57	old	0.013	0.067	10.5

Tab 1. Characteristics of the Reservoirs (S – water area, V- volume, T- theoretical water residence time, F – input flow: min, average, max) (on the basis of Kujawa & Kujawa, 2003).

Surface water samples were collected 2-4 times a month from April to September 2007. During the sampling, water temperature, oxygen concentration, pH and conductivity was measured. Total phosphorus (TP) and phosphate phosphorus (P-PO₄) were measured according to the ascorbic acid method (Golterman *et al.*, 1978). Total nitrogen (TN) was analyzed using the persulfate digestion method (method no. 10071; HACH, 1997). Nitrate nitrogen (N-NO₃) was determined using the cadmium reduction method (method no. 8039; HACH, 1997) and the ammonia nitrogen (N-NH₄) – the phenate method (Golterman *et al.*,

1978). Chlorophyll *a* concentration was estimated by method based on acetone extraction and determination by spectrophotometry (Lawton et al. 1999).

Total suspended matter content was determined in two replicates for each sample by filtering the water through 0,45 µm filters of known weight and drying at 105°C (12h). Mineral matter content was determined by next burning of the filters at a temperature of 500 °C (4 h). Organic suspended matter content was calculated as a difference between total and mineral matter content.

Meteorological data were obtained from the web site <http://www.tutienpo.net/en/Climate/LODZ/124650.htm>.

Phytoplankton species composition and biomass were measured in 20-litres surface water samples filtered through a plankton net with 45 µm mesh size and preserved with a Lugol's solution. Algae were identified to the generic level and counted using a Fusch-Rosenthal counting cell.

Species diversity was approximated by application of the Shannon-Weaver Index

$$H'' = -\sum n_i/N \log_2(n_i/N),$$

where n_i is the measure of the i th species (as number of counted cells) and N is total sum of n_i .

3. Results

Weather conditions

The year 2007 showed very short or lack of winter season (with average temperature 2,7 °C, minimum temperature minus 8,4 °C and only 19 days with temperature below 0 °C, a month-advanced Spring (the temperature above 0 °C stabilized after 25 of February) and high but stable rainfall conditions – low amplitude of rainfalls divided for long period (Tab.2). However at the end of season there was observed a typical for polish climate low-flow, which caused two weeks of no discharge in the spring part of the river.

Year	RAINFALL				TEMPERATURE			
	Sum [mm]	Average [mm]	Max [mm]	Number of days without rainfall	Average [°C]	Max [°C]	End of winter	Number of days with temperature below 0
2007	393.7	2.4	23.1	94	15.8	22.9	25.02	19

Tab 2. Characteristic of weather conditions in 2007 year.

Physical and chemical conditions

Water temperature at the beginning of investigation period in all reservoirs was below 20°C (Tab. 3). On 29 May this level was exceeded and was noted maximum with 24,4 °C average for all reservoirs. The temperature above 20 °C remained till 27 of September with three exceptions (05 June; 11, 31 July). After this period the temperature decreased again below 20°C. The highest average water temperature was noted in Zgierska and Teresa Reservoirs. This is due to the fact that Zgierska Reservoir is the smallest one with the highest surface/volume ratio, and Teresa is not directly flow with additional constructed barriers which slow down the discharge.

Oxygen average concentrations show decrease from the Upper Pond to the Lower Pond from which it increases reaching the highest mean amount in the Pabianka Reservoir – 9.1 mg/l. The minimum (0.9 mg/l) and maximum (20.1 mg/l) values were noted in Upper Pond due to high matter input and phytoplankton production. In all reservoirs over saturation of surface water was noted. The smallest amplitude was observed in Teresa Reservoir which was the only one where the oxygen depletion was not observed (Tab. 3).

The average values of pH in all Reservoirs were quite similar between 7.90 – 8.10 indicating low concentration of carbon dioxide in the water due to phytoplankton assimilation. There were observed occasional fluctuations in the range of 5.6 – 9.5 (Tab. 3).

Conductivity increases along cascade reaching the lowest amounts in the first two reservoirs and the highest in the last reservoir. Such a relation may result from the input of particulate forms of nutrients and their gradual mineralization (Tab. 3).

Total suspended matter concentration changed between 4.2 – 48.2 mg/l showing decrease from the first to third reservoir and then increase. The suspended matter in all reservoirs revealed mostly organic character. The Upper pond was exposed to the higher matter input with the highest amplitude of input. From the first Pond to the fourth the input was decreasing reaching higher value in the last Reservoir (Tab. 3).

The concentration of total phosphorus is falling from the Upper Pond to the last Pabianka Reservoir reaching in the latter one more than a half of the concentration of the first one. The dissolved form of phosphorus reached the highest average in the Lower Pond and the lowest in Pabianka Reservoir. There was seen no phosphorus limitation in the Upper Pond whereas in the others occasionally low level (<10 µg/l) was achieved. Total and dissolved

forms of nitrogen revealed similar relation along reservoirs. The amount decreased from the first one to fourth one with small increase in the last reservoir as a result of higher external input (Tab.3). The average amounts of ammonia ions revealed limitation in Zgierska and Teresa Reservoirs. The limitation level of 100 µg/l was also observed periodically in other reservoirs as a result of high assimilation by phytoplankton. The average nitrate value was kept above limitation level > 0.3 (Benion and Smith, 2000), reaching periodical falls also due to phytoplankton assimilation (Tab. 3).

Reservoir	1.Upper Pond	2. Lower Pond	3. Zgierska Reservoir	4. Teresa Reservoir	5. Pabianka Reservoir
Chl a [mg/m ³]	86.5	47.8	28.3	28.4	64.1
min-max	2.6 – 258.2	1.0 – 202.2	4.2 – 95.8	2.5 – 85.4	6.4 – 154.4
O ₂ [mg/l]	7.4	5.4	6.7	7.8	9.1
min-max	0.9 – 20.1	1.0 – 14.1	1.4 – 12.1	4.8 – 14.9	2.1 – 16.8
Temp °C	16.6	16.7	17.6	17.3	16.6
min-max	6.5 – 23.7	6.1 – 23.8	6.6 – 24.4	6.0 – 25.9	5.9 – 24.2
Cond. US/	462	491	476	579	595
min-max	356 - 1036	380 - 1068	365 - 1098	432 - 1016	398 - 952
pH	8.10	7.90	8.00	7.90	7.90
min-max	5.8 – 9.5	5.6 – 9.3	5.6 – 8.9	5.6 – 8.8	5.6 – 8.7
TP [mg/l]	0.43	0.35	0.31	0.30	0.21
min-max	0.12 – 0.58	0.06 – 0.67	0.15 - 0.66	0.10 – 0.84	0.11 – 0.37
P-PO ₄ [mg/l]	0.10	0.14	0.12	0.07	0.03
min-max	0.10 – 0.27	0.00 – 0.25	0.0 – 0.41	0.0 – 0.17	0.0 – 0.10
TN [mg/l]	2.19	1.87	1.24	1.21	1.53
min-max	0.40 – 4.50	0.30 – 4.50	0.10 – 3.25	0.40 – 3.10	0.40 – 3.80
N-NH ₄ [mg/l]	0.23	0.21	0.08	0.04	0.12
min-max	0.03 – 0.76	0.01 – 0.52	0.01 – 0.29	0.00 – 0.14	0.00 – 0.26
N-NO ₃ [mg/l]	0.75	0.52	0.47	0.53	0.60
min-max	0.10 – 1.40	0.10 – 1.30	0.10 – 1.40	0.10 – 1.20	0.20 – 1.20
TSS [mg/l]	23.39	13.53	10.28	12.29	19.71
min-max	8.05 – 48.17	4.20 – 24.40	4.40 – 21.93	5.20 – 18.90	9.15 – 32.38
OSS:TSS	0.81	0.79	0.77	0.78	0.78
min-max	0.62 – 1.00	0.63 – 1.00	0.44 – 1.00	0.61 – 1.00	0.54 – 1.00
input					
TP [mg/l]	0.73	0.40	0.38	0.39	0.31
min-max	0.00 – 1.53	0.22 – 0.78	0.07 – 1.06	0.11 – 0.83	0.20 – 0.60
TN [mg/l]	4.33	2.39	1.87	1.58	1.71
min-max	0.00 – 5.90	0.50 – 4.20	0.30 – 1.50	0.70 – 4.30	0.60 – 4.80
TSS [mg/l]	45.62	23.95	13.53	11.91	27.85
min-max	0.00 – 307.60	7.50 – 38.40	4.20 – 24.40	3.65 – 27.80	7.98 – 206.40
OSS:TSS	0.67	0.82	0.7	0.76	0.78
min-max	0.00 – 0.89	0.65 – 0.99	0.63 – 1.00	0.55 – 1.00	0.52 – 1.00

Tab 3. Comparison of mean amounts of measured parameters for five linked reservoirs in 2007 year

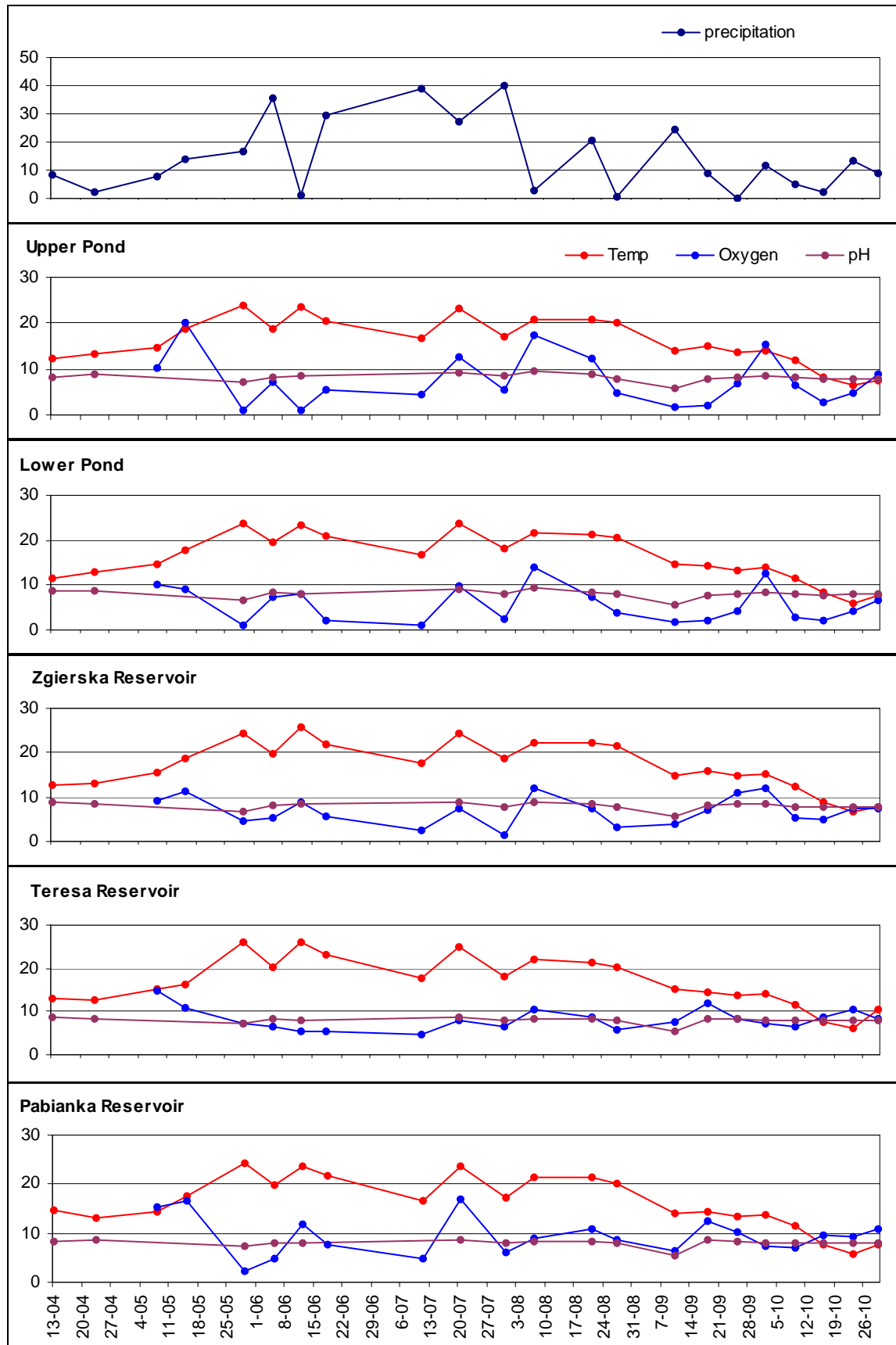


Figure 1. Dynamic of physical conditions in five reservoirs on the Sokolowka River in relation to precipitation conditions.

Phytoplankton dynamic and diversity.

In all reservoirs chlorophyll *a* concentration revealed highly hypertrophic conditions with very high amplitude of changes in the range between 1 – 258 mg/m³ (Fig. 2). In the three first reservoirs which are directly connected the highest concentration was observed in the Upper Pond 86.5 mg/m³ reaching almost a half of this amount in the Lower Pond and one third in the Zgierska Reservoir (Tab. 3). The chlorophyll *a* concentration in Teresa Reservoir remained almost on the same level as in Zgierska increasing highly in Pabianka Reservoir.

The phytoplankton composition revealed appearance of 6 taxonomic groups: Bacillariophyceae, Cyanobacteria, Euglenophyta, Chlorophyta, Xantophyceae and Chrysophyceae (Fig. 3, Tab. 4). Two first reservoirs showed absence of last two groups, and in the third reservoir weren't found Chrysophyceae. In two last reservoirs all groups were noted. Four reservoirs revealed presence of Bacillariophyceae at the beginning and ending of investigations period with shift to Cyanobacteria dominance in early spring and summer. Teresa Reservoir differed and revealed Chrophycaea/Cyanobacterial dominance at the beginning however at the end of investigation period Bacillariophyceae were noted (Fig. 3). Phytoplankton number oscillate between 500 cell/dm³ and 705 thousands cell/dm³, reaching the maximum in the Upper Pond and minimum in Pabianka Reservoir (Tab. 4).

Cyanobacteria were the dominant group in four reservoirs reaching there the highest average percentage participation - above 40 %. Only in Zgierska Reservoir the Cyanophyta percentage participation was below 40 % and there was observed Chlorophyta domination (Tab. 4).

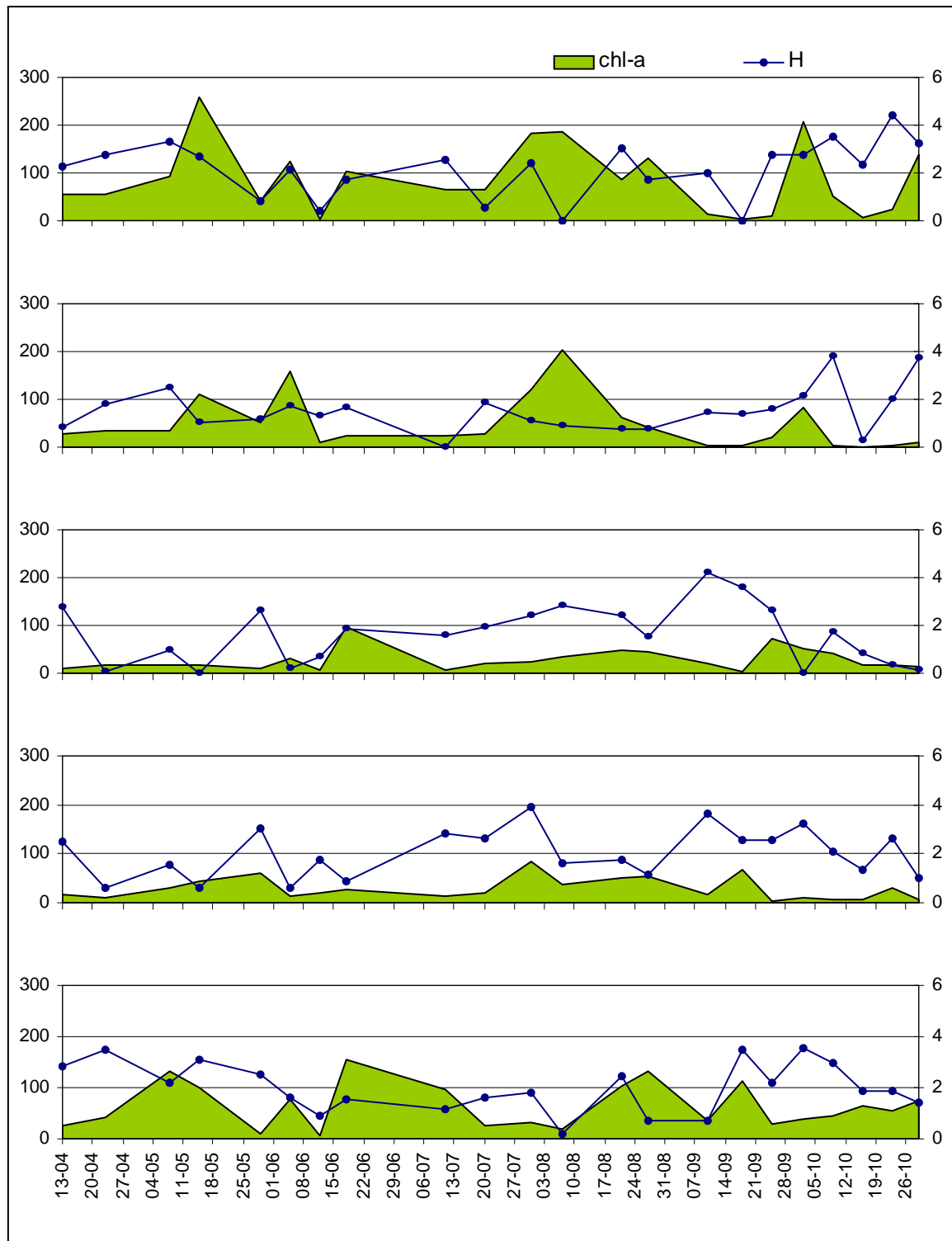


Figure 2. Dynamic of chlorophyll a concentration and Shannon Index (H) in five interlinked Reservoirs on the Sokolowka River in the 2007 year.

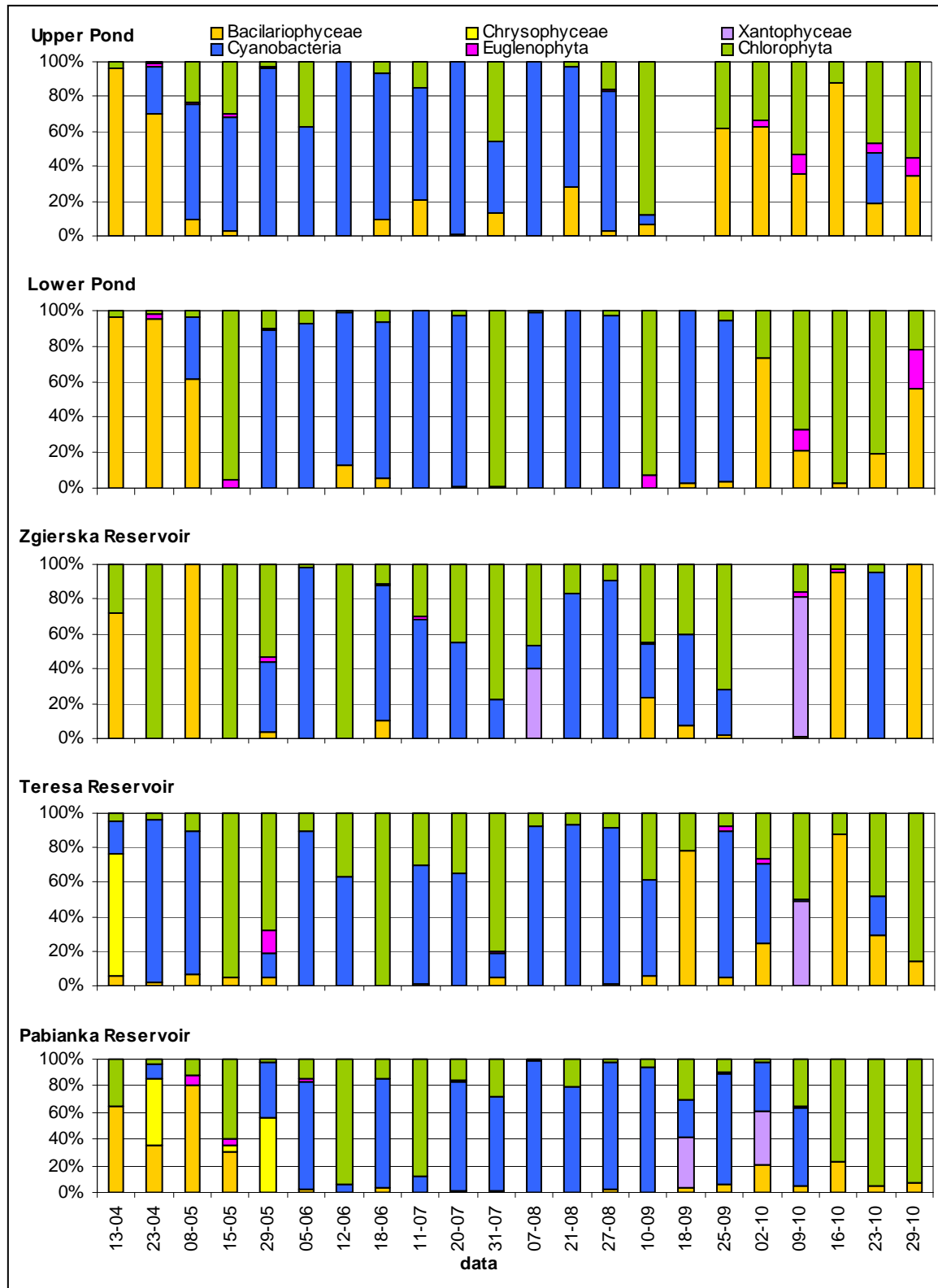


Figure 3. Dynamic of phytoplankton community structure in five reservoirs of the Sokolowka River.

The name of taxonomic group	1.Upper Pond	2. Lower Pond	3. Zgierska Reservoir	4. Teresa Reservoir	5. Pabianka Reservoir
Bacillariophyceae	26.8 (9)	20.6 (9)	19.8 (8)	12.4 (10)	13.4 (9)
Chrysophyceae	0 (0)	0 (0)	0 (0)	3.2 (1)	5.1 (1)
Xantophyceae	0 (0)	0 (0)	5.9 (1)	2.2 (1)	3.5 (1)
Cyanobacteria	47 (5)	48.7 (4)	35.9 (7)	45.3 (8)	43.5 (8)
Euglenophyta	1.8 (3)	2.2 (3)	0.6 (3)	1.0 (3)	0.8 (3)
Chlorophyta	24.3 (20)	28.5 (13)	38.1 (21)	35.8 (23)	33.7 (21)
Cells density Average / SD	5308503 14459829	1902485 4292474	858507 1453196	1067240 1706639	728915 875979
Average H	2.2 0.0 - 3.3	1.5 0.0 - 2.5	1.6 0.0 - 2.7	2.0 0.6 - 3.0	2.0 0.2 - 3.5

Tab 4. The average percentage participaton of particular phytoplankton groups in five reservoirs on the Sokołówka River; SD – standard deviation, H- Shannon-Weaver Index, 1-D – Simpson Index of diversity. In the brackets is given the number of found genera.

In the Cyanobacteria group there were found genera from three orders: Osscillatoriales, Nostocales and Chroococcales (Tab. 5), from which Oscillatoriales were the most abundant in two first reservoirs and in the last one whereas the remaining two reservoirs were rich mainly in Chroococcales.

The order	1.Upper Pond [%]	2. Lower Pond [%]	3. Zgierska Reservoir [%]	4. Teresa Reservoir [%]	5. Pabianka Reservoir [%]
Nostocales	5.2	16.4	3.2	16.1	0.4
Chroococcales	0.0	18.4	65.8	50.9	27.6
Osscillatoriales	66.2	65.2	31.1	33.1	66.7

Tab 5. The average participation of found orders of Cyanobacteria in the Reservoirs on the Sokolowka River.

4. Discussion

Small and shallow reservoirs are more productive than large and deep lakes due to the higher ratio of the area of catchment and area of reservoir what contribute to higher nutrients and matter input. Additionally in shallow reservoirs the internal nutrient input is higher due to the increased contact with sediments. Urban catchments are more exposed as a result to imperviousness of the catchment. Sokolowka River characterized as high/medium impervious has decreased water storage capacity, what by increased runoff, sustain transport of suspended sediments (Ellison and Brett, 2006; Marsalek *at al.*, 2005). This also lead to more frequent appearance of flood waves caring high amounts of suspended matter and nutrients (Ristic *at al.*, 2006) and flushing earlier deposited sediments. The great amount of matter and nutrients is intercepted by reservoirs what increases their trophy, turbulence and changes the light

conditions due to higher turbidity. The classification of reservoirs located on the Sokolowka river as riverine with short retention time (Tab. 1) could be pointed to the less possibility of harmful cyanobacterial blooms occurrence which diminish the recreational and ecological status of waterbodies. Moreover hypertrophic lakes and ponds are often associated with small green-algae with blue-green algae scarce or absent. (Reynolds, 1989; Jensen *et al.*, 1994; Trifonova, 1998). Investigated reservoirs revealed the presence of Chlorophyta, however the problem of green water containing cyanobacteria bloom also appeared.

Generally in almost all investigated reservoirs the typical shifts in phytoplankton succession was observed with Bacillariophyceae dominance in spring and beginning of autumn and summer Cyanobacteria domination (Fig. 3). The phytoplankton composition discovered presence of typically occurring groups of phytoplankton. The concentration of chlorophyll *a* revealed highly hypertrophic conditions what could suggest low biodiversity (Trifonova, 1998). In all Sokolowka reservoirs were found 52 genera what makes them quite rich. However the Indexes fell periodically to 0 meaning no diversity, what means high pollution. The highest diversity was observed in the first reservoir, the richest in phytoplankton density, with Shannon Index - 2.2 (Tab. 4). The highest diversity of this reservoir may result from its dual character and occurrence of genera characteristic both for lotic and lenitic environments. Additionally there were periodically observed genera with benthic type of life (most pennant Bacillariophyceae) what could result from mixing regime and resuspension of organisms. The highest diversity was observed I Teresa Reservoir and the last Pabianka Reservoir where was not seen such a decrease in diversity. According to Cyanobacterial orders occurrence the reservoirs can be divided in two groups: first with Oscillatoriales domination – Upper Pond, Lower Pond, Pabianka Reservoir and second with Chroococales domination – Zgierska and Teresa Reservoir.

The role of chemical conditions in controlling community structure.

The high concentration of nutrients in all reservoirs revealed favorable conditions for phytoplankton development. The maximum amounts of nutrients and matter were noted in first reservoir (Tab. 3) what stems from the fact that it opens the cascade and thus receive the highest loads (Tab. 3). The loaded nutrients are mostly in particulate forms as the conductivity is there the lowest (Tab.3), however the biologically available pool reaches high amounts. (Tab. 3). The Upper Pond retain almost 55% of TP and 51% of TN (Tab. 3). Due to the retention of nutrients and matter in reservoirs their concentration falls down along the

cascade, however average amounts exceed the critical value for eutrophication (0.1 mg P/l and 1.5 mg N/l OECD 1983). The Upper Pond is also characterized as the only reservoir in the cascade which never suffers available phosphorus limitation (Tab.3). Due to the age of pond (Tab. 1) this can be a result of higher internal input from deposited riverine sediments and large amounts of leaf litters which adds to the sediment and additionally enhance phosphorus release by creation of periods of high oxygen demand and depletion (Tab.3) (Birch and McCaskie; 1999). Similar conditions appeared in the Lower Pond as a result of close connection and in the Pabianka Reservoir supplied additionally by waters from the Sokolowka tributary- the Brzoza River which is a highly polluted storm water recipient. Therefore the nitrogen concentration in this reservoir is higher despite the fact that it is the last one in the cascade. High nitrate content showed intensive sewage contamination. When high nutrient loading is achieved by high rates of inflow, retention time may be correspondingly reduced; the dominant algae would necessarily be those whose growth rate exceed the rate of dilution. The lake which received large quantity of industrial and domestic effluent was dominated by Chlamydomonas, Scenedesmus, Chlorella and centric diatoms (Reynolds, 1989). In all reservoirs Cyanobacteria achieved domination instead of expected Chlorophyta. In all reservoirs their occurrence correlated with TP input (0.28), and pH (0.30), what confirm their requirements and reveal positive chemical conditions for their development. The periodically observed nitrogen limitation which occurred due to high assimilation in all ponds could suggest occurrence of Nostocales in all reservoirs, but this order was not so highly present (Tab. 5). The other factors had to interact in controlling community structure.

The role of physical conditions in controlling community structure.

Low water temperature and mixing in the beginning and in the end of investigated period was responsible for Bacillariophyceae domination. The increase of temperature above 20 °C led to Cyanobacteria occurrence (Fig. 4), what confirm their temperature requirements (Smith and Bennet, 1999; after Tillman, 1984). Very short and mild winter season and a month-advanced Spring could create good conditions for summer phytoplankton development due to weakened top-down control (Zalewski and Wagner, 2004). Quite high but stable rainfall conditions led to changes in nutrient and matter input, altered mixing regime and therefore modified light conditions. Cyanobacteria are known to dominate in calm weather conditions which provide stabilisation of water column (Webster and Hutchinson,

1994; Köhler, 1992; Rappala, 1998). According to Reynolds (1998) blue-green algae also occur widely in polymictic bodies of water where light penetrates to a small fraction of the mixed depth. With such conditions small or solitary blue-green algae are often associated. The conceptual model proposed by Havens et al, (1998) of cyanobacterial assemblage of a shallow eutrophic lake based on this suggestion explicate the dominance of Cyanobacteria in Sokolowka Reservoirs. Two first ponds and the last one are characterized by highest turbidity due to intensive matter input (Tab.3) and nutrient promoted phytoplankton development. Such conditions lead to self-shading and promote low-light adapted species like *Oscillatoria* (Reynolds and Bellinger, 1992; Mur and Schreus, 1995; Havens et al, 1998; Köhler and Hoeg, 2000; Mishke, 2003). This explain also the low development of Nostocales and Chroococales in this ponds, which have high light demand (Dokulil and Teubner, 2000; Mishke, 2003). Zgierska and Teresa Reservoirs were mostly characterised by Chroococales occurrence with *Microcystis* domination what according to the conceptual model is connected with calm conditions. *Microcystis* was also noted in other reservoirs during most stable weather conditions (mostly when sum of precipitation was lower or equal 20 mm) which due to diminished mixing led to the maximum surface water temperature. As *Microcystis* is conspicuous during the warmer, high insolation periods it developed mostly in two warmest reservoirs (Tab. 3).

Abiotic factors like weather conditions seemed to be the most important for community structure development in this interlinked system, as factors controlling nutrient supply, light conditions, water column stability and wash out what confirms earlier investigations (Mishke, 2003). The interconnection of reservoirs create differences between them which might be important for their management and restoration. Two first reservoirs intercept the high flood peaks therefore their conditions are mostly modified and dependant on precipitation events. Similar situation is in the last reservoir which receive additional pool of substances from the Sokolowka tributary. High turbidity induced by storm events favour turbulence tolerant species adapted to low light availability like *Oscillatoriales* (R-strategic according to Huszar and Caraco, 1998 after Reynolds) which are additionally more resistant to metals and water toxicity (Shehata et al, 1999) what makes them better competitors in urban water conditions. Moreover rainfall events could weaken the top-down effect as a result of favoring Rotifera what with dominance of filamentous phytoplankton forms limit development of big crustacean (Rennella and Quirús, 2006). Zgierska and Teresa reservoirs which are in the middle of cascade are more physically stable. Domination of Chroococales prove this calm

conditions and better light availability. Therefore the manipulation and shaping of biota can be there possible and relevant.

Conclusions and further steps:

1. The first step for blue-green algae prevention in the reservoirs opening the cascade is reduction of bottom-up effect. This can be achieved by complex activities in the upper part of the river, including limitation of supply from point sources, construction of biofilters on stormwater outlets, improvement of functioning of the settlement pond.
2. The more stable conditions of reservoirs in the middle of the cascade enable direct activities in reservoirs like macrophytes planting for nutrients allocation into unavailable pool and trophic manipulations.
3. To achieve and verify the suggested activities the further analysis of plankton dynamic and trophic interactions in reservoirs is needed in addition the metal transfer in trophic pyramid will be assessed.
4. Furthermore the cyanobacteria cell-bound toxins (microcystins and anatoxins) appearance and eventual concentration will be analysed.

UPPER POND	LOWER POND	ZGIERSKA RES.	TERESA RES.	PABIANKA RES.
Bacillariophyceae				
Cymbella sp.	Cymbella sp.	Cymbella sp.	Cymbella sp.	Cymbella sp.
Fragilaria sp.	Fragilaria sp.	Fragilaria sp.	Fragilaria sp.	Fragilaria sp.
Navicula sp.	Navicula sp.	Navicula sp.	Navicula sp.	Navicula sp.
Nitschia sp.	Other Pennante	Nitschia sp.	Nitschia sp.	Nitschia sp.
Asterionella sp.	Aulacoseira sp.	Other Pennante	Pinnularia sp.	
Other Pennante	Melosira sp.	Aulacoseira sp.	Cymatopleura sp.	Cymatopleura sp.
Aulacoseira sp.	Other Centric	Melosira sp.	Other Pennante	Other Pennante
Melosira sp.		Other Centric	Aulacoseira sp.	Aulacoseira sp.
Other Centric			Melosira sp.	Melosira sp.
			Other Centric	Other Centric
Chrysophyceae				
			Dinobryon sp.	Dinobryon sp.
Xantophyceae				
		Rhizochloris sp.	Rhizochloris sp.	Rhizochloris sp.
Cyanobacteria				
Anabaena sp	Aphanisomenon sp	Aphanisomenon sp	Anabaena sp	
Aphanisomenon sp	Gomphosphaeria sp.	Gomphosphaeria sp.	Aphanisomenon sp	Aphanisomenon sp
Oscillatoria sp	Microcystis sp.	Microcystis sp.	Gomphosphaeria sp.	Gomphosphaeria sp.
Phormidium sp.	Merismopedia sp	Merismopedia sp	Microcystis sp.	Microcystis sp.
Spirulina sp.	Oscillatoria sp	Oscillatoria sp	Merismopedia sp	Merismopedia sp
NN	Spirulina sp.	Phormidium sp.	Oscillatoria sp	Oscillatoria sp
	NN	NN	Phormidium sp.	Phormidium sp.
			NN	Spirulina sp.
				NN
Euglenophyta				
Euglena sp	Euglena sp	Euglena sp	Euglena sp	Euglena sp
Phacus sp	Phacus sp	Phacus sp	Phacus sp	
Trachelomonas sp.	Trachelomonas sp.	Trachelomonas sp.	Trachelomonas sp.	Trachelomonas sp.
Chlorophyta				
Dictosphaerium sp.	Micractinium sp.	Kirchneriella sp.	Dictosphaerium	Dictosphaerium
Micractinium sp.	Lagerheimia sp.	Monoraphidium sp.	Golenkinia sp.	Kirchneriella sp.
Kirchneriella sp.	Monoraphidium sp.	Oocystis SP.	Kirchneriella sp.	Monoraphidium sp.
Monoraphidium sp.	Oocystis SP.	Tetraedron sp.	Lagerheimia sp.	Oocystis SP.
Oocystis sp.	Coelastrum sp.	Actinastrum sp.	Monoraphidium sp.	Tetraedron sp.
Tetraedron sp.	Scenedesmus sp.	Coelastrum sp.	Oocystis SP.	Actinastrum sp.
Actinastrum sp.	Pediastrum duplex	Scenedesmus sp.	Coelastrum sp.	Coelastrum sp.
Coelastrum sp.	Sphaerocystis sp.	Staurodesmus sp.	Scenedesmus sp.	Scenedesmus sp.
Scenedesmus sp.	Chlamydomonas sp.	Tetrastrum sp.	Staurodesmus sp.	Tetrastrum sp.
Tetrastrum sp.	Chloromonas sp.	Pediastrum boryanum	Tetrastrum sp.	Pediastrum boryanum
Pediastrum duplex	Pandorina sp.	Pediastrum duplex	Pediastrum boryanum	Sphaerocystis sp.
Sphaerocystis sp.	Closterium sp.	Sphaerocystis sp.	Pediastrum duplex	Chlamydomonas sp.
Chlamydomonas sp.	NN	Chlamydomonas sp.	Sphaerocystis sp.	Chloromonas sp.
Chloromonas sp.		Chloromonas sp.	Chlamydomonas sp.	Pandorina sp.
Pandorina sp.		Pandorina sp.	Chloromonas sp.	Closterium sp.
Volvox sp.		Closterium sp.	Eudorina sp.	Cosmarium sp.
Closterium sp.		Cosmarium sp.	Pandorina sp.	Staurastrum sp.
Cosmarium sp.		Staurastrum sp.	Closterium sp.	Mougeotia sp.
Chlorella sp.		Mougeotia sp.	Cosmarium sp.	Chlorella sp.
Peridinium sp.		Chlorella sp.	Staurastrum sp.	Peridinium sp.
NN		Koliella sp.	Spirogyra sp.	Koliella sp.
		NN	Chlorella sp.	Crucigena
			Peridinium sp.	NN

			Koliella sp.	
			NN	

Tab 6. List of found phytoplankton genera in five interlinked, urban reservoirs.

References:

- Barbiero R.P., 1999. The effect of disturbance events on phytoplankton community structure in a small temperate reservoir. *Freshwater Biology* 42.
- Birch S., McCaskie J., 1999. Shallow urban lakes: a challenge for lake management. *Hydrobiologia* 395/396: 365 – 377.
- Ellison M.E., Brett M.T., 2006. Particulate phosphorus bioavailability as a function of stream water flow and land cover. *Water Research* 40: 1258 – 1268.
- Dokulil M. T., Teubner K., 2000. Cyanobacterial dominance in lakes. *Hydrobiologia* 438: 1 – 12.
- Golterman H.L., Clymo R.S., Ohstand M.A.M. 1978. Methods for physical and chemical analysis of freshwater. Blackwell Scientific Publication, Londres, 214 pp.
- HACH (1997) Water analysis handbook. Hach Company, 1309 pp.
- Havens K.E., Philips E.J., Cichra M.F., Li B.-L.; 1998. Light availability as a possible regulator of cyanobacteria species composition in a shallow subtropical lake. *Freshwater Biology*. 39, 547 – 556.
- Huszar V.L. De M., Caraco N., 1998. The relationship between phytoplankton composition and physical-chemical variables: a comparison of taxonomic and morphological-functional descriptors in six temperate lakes. *Freshwater Biology* 40, 679 – 696.
- Jensen J.P., Jeppesen E., Olrik K., Kristensen P.; 1994. Impact of nutrients and physical factors on the shift from Cyanobacterial to Chlorophyte dominance in shallow Danish lakes. *Can.J.Fish.Aquat. Sci.* 51: 1692 – 1699.
- Köhler J., Hoeg S., 2000. Phytoplankton selection in a river-lake system during two decades of changing nutrient supply. *Hydrobiologia* 424: 13 – 24.
- Köhler J, 1992. Influence of turbulent mixing on growth and primary production of *Microcystis aeruginosa* in the hypertrophic Bautzen Reservoir. *Hydrobiologia* 123: 413 – 429
- Kujawa I., Kujawa M., 2003. The general Project of the Sokolowka River.
- Lawton, L., Marsalek, B., Padisak, J. and Chorus, I. 1999. Determination of cyanobacteria in the laboratory In.: Chorus, I. and Bartram, J., editors, Toxic cyanobacteria in water. A guide to their public health consequences, monitoring and management. E&FN Spon, pp. 347-367.
- Marsalek J., Rochfort Quintin, Grapentine L., 2005. Aquatic habitat issues in urban stormwater management: challenges and potential solutions. *Ecology & Hydrobiology* Vol. 5 , No. 4 269 – 279.
- Meybeck M., *Phil.Trans*; 2003. Global analysis of river systems: from Earth system controls to Anthropocene syndromes. *R. Soc. Lond.* 2003 358: 1935 – 1955.
- Mischke U., 2003. Cyanobacterial associations in shallow polytrophic lakes: influence of environmental factors. *Acta Oecologica* 24: S11 – S23.
- Mullis Robert M., D. Michael Revitt, R. Brian Shutes, 1996. The impacts of urban discharges on the hydrology and water quality of an urban watercourse. *The science of the Total Environment* 189/190 385 – 390.
- Mur L.R, Schreus H; 1995. Light as a selective factor in the distribution of phytoplankton species. *Wat Sci. Tech.* Vol 32, No. 4, pp 25 –34.
- Sheffer, M., Hosper S.H., Meijer M-L., Moss B., Jeppesen E.; 1993. Alternative equilibria in shallow lakes. *Trends in Ecology and Evolution* 8: 275-279.
- Rappala J., 1998. Toxin production by freshwater Cyanobacteria: effect of environmental factors.
- Rennella A.M., Quirús R., 2006. The effects of hydrology on plankton biomass in shallow lakes of the Pampa Plain. *Hydrobiologia* 556: 181 – 191.

- Reynolds C.S. 1989. Relationships among the biological properties distribution and regulation of production by planktonic cyanobacteria.. *Toxicity assessment: an international Journal* Vol. 4, 229 – 255.
- Reynolds C.S., Bellinger E.G., 1992. Patterns of abundance and dominance of phytoplankton of Rostherne Mare. *Aquatic Sciences* 54/1, 1992, 10 – 36.
- Ristic R., Gavrilovic Z., Stefanovic M., Malusevic I., Milovanovic I., 2006. Effects of urbanization on appearance of torrential floods. Conference materials. <http://www.balwois.org/papers.htm>
- Smith V.H., Bennet S.J., 1999. Nitrogen:phosphorus supply ratios and phytoplankton community structure in lakes Arch. *Hydrobiol.* 146: 37 – 53.
- Staskraba M., Tundisi J.G., 1999. Reservoir ecosystem functioning: theory and application. *Theoretical Reservoir Ecology and its Applications* 565 – 597.
- Shehata S., A.; Lasheen M.R.; Kobbia I.; Gamila H. A.; 1999. Toxic effect of certain metal mixture on some physiological and morphological characteristics of all freshwater algae. *Water , Air and Soil Pollution* 110: 119 – 135.
- Trifonova I.S. 1998. *Hydrobiologia*. Phytoplankton composition and biomass structure in relation to trophic gradient in some temperate and subarctic lakes of north-western Russia and the Prebaltic.
- Wagner I., Izydorczyk K., Drobniwska A., Fraczkak W., Zalewski M, 2006. Inclusion of ecohydrology concept as integral component of systemic in urban water resources management. The city of Lodz case study, Poland. Conference materials.
- Webster T. Hutchinson P.A., 1994. Effect of wind on the distribution of phytoplankton cells in lakes revisited. *Limnol. Oceanogr.* 39: 365 – 373.
- Zalewski and Wagner editors, 2004. *Integrated Watershed Management _ Ecohydrology & Phytotechnology – Manual- UNEP.*