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ALGAE AS BIOINDICATORS OF WATER QUALITY IN THE CHAŃCZA WATER RESERVOIR

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ABSTRACT. This paper presents the results of preliminary studies on algae and cyanobacteria of the "Chańcza" reservoir situated in the Czarna Staszowska River (south-east part of Świętokrzyskie Province). Phycological samples were collected in a period from 2007 to 2008. In total, 82 taxa (including algae – 64 species and cyanobacteria – 18) have been recorded in the study area. The most interesting of them are: *Anomoeoneis sphaerophora*, *Navicula rhynchocephala*, *Tribonema vulgare*, *Microcystis aeruginosa*, *M. wesenbergii*, *Woronichinia compacta*, *Cosmarium botrytis*, *C. granatum*. All taxa are briefly described and ecological indicator values for some of them are also analysed.

KEY WORDS: algae, cyanobacteria, bioindicators, Chańcza reservoir

INTRODUCTION

Bioindication is the process, which is using indicative characteristics of taxa (their populations, communities, or even whole biocenosis) to evaluate other biotic and abiotic properties of natural environment (Roo-Zielińska 2004). According to Fałtynowicz (1994) the bioindicators can be the whole ecosystems, plant and animal communities, populations, and also single organisms belonging to various taxonomic groups, for example algae. However, bioindicators can be only those plant species, which react to a specific natural or anthropogenic factor (e.g. content of specific chemical substances, humidity, etc. in the environment or habitat). It has been known for a long time that the water organisms act as the biological indicators sensitive to the water quality changes. Their presence or absence reflects the prevailing conditions in a given environment. According to many investigators these organisms are the best synthetic indicator of water quality (Chełmicki 2001). Their advantage over other indicators is because they not only define the conditions in the water environment in a given moment, but they contain informations concerning the prevalent conditions in a longer period of time (this due to their ability to accumulate some substances). According to Matuła (1995) each algal community has defined properties, formed under the influence of habitat conditions. Taking advantage of such communities parameters as: species number, quantity and taxonomic composition of algae, one can propose conclusions concerning the properties of various environments. Algae can determine such environmental features as: temperature, velocity of water current, light, salinity, water pH, trophy, pollution, oxygen level, calcium content and others. To evaluate the environment features, algae belonging to various taxonomic groups are used, in particular the preference is given to: diatoms, filamentous green algae, desmids, stoneworts, and chrysophytes. According to Kawecka and Eloranta (1994) only the stenotypic organisms, which live and are well proliferated in a narrow range of changing environmental conditions, can be good indicators.

Diatoms (Bacillariophyceae) belong to the most widespread and most abundant taxonomic algal group in the water biotops (Rakowska 2003). In the process of defining the composition and the qualitative changes of diatom species, it is possible to define the essential features of occupied environment. Whitton et al. (1991), Whitton and Rott (1996), Kawecka et al. (1999), Wojtal (2004) and others use diatoms as bioindicators to monitor the quality of waters.

The object of this study was composition of algae and cyanobacteria occurring in the "Chańcza" water reservoir situated in the neighbourhood of Raków, in the Świętokrzyskie Province. Whereas the aim of this study was to demonstrate that the diatoms can play the role of potential indicators of the actual conditions of water environment in the investigated reservoir. At the same time this report is the first with regards to the occurrence and the role of algal species in this water reservoir. In the area of the Świętokrzyskie Province small dam reservoirs are distributed, of which most have the capacity below 1 mln m^3. They are indispensable for the proper retention and regulation of water flow in the rivers, as well as elimination of the flood-wave culmination. The reservoirs, considering their distribution in the areas of high natural and landscape amenities, usual also play recreational and tourist function. Among the taxa occurring in the reservoir, both in algae and vascular plants, the species which can be indicators of now existing ecological condition, were isolated. According to Kawecka and Eloranta (1994) the algae and cyanobacteria, even in case of their partial destruction, do not lose their indicative properties, therefore the algae are invaluable to evaluate the scale and the range of human influence on the natural environment.

STUDY AREA

The "Chańcza" water reservoir was built in the years 1974-84 on the 34.5 km of the Czarna Staszowska River (left-bank tributary of the Vistula River), for the needs of the mine and the chemical plants "Siarkopol" in Grzybów. It was made by flooding the Czarna Staszowska River valley. In 2006 the water of this river along its entire length represented the quality of III class (Informacja o stanie środowiska... 2007). The forest growing in the valley was cut down, only tree trunks were left on the bottom of the reservoir (almost on its entire area) and even today they are still there. The drainage of reservoir is afforested in 35% (pine forests). In the agricultural land dominate the arable fields (68.6%), whereas the green crops constitute 31.4% of their surface. Presently, considering the limited production, the use of reservoir for the industrial purposes is small, and its function is mainly recreational and flood controlling.

The reservoir is located in the south-east part of the Świętokrzyskie Province (Fig. 1). The southern part of the reservoir is located in the county Staszów, the borough of Staszów, the northern part within the area of the county Kielce, the borough of Raków. The northern outskirts of the reservoir are overgrown by emergent plants, namely reed (*Phragmites australis*), and cattail (*Typha angustifolia*), the aquatic plants, the plants of habitat periodically flooded (*Bidentetea tripartite* and *Isoëto-Nanojuncetea*), and sporadically the water plants of the *Potametea* class. The southern edges of the reservoir are mainly overgrown by the rushes and swamp species of the *Phragmitetea* class (e.g. *Glyceria maxima*, *G. fluitans*). In the majority of shallow waters of which the depth does not exceed 2 m, the following species were encountered e.g. *Callitriche polymorpha*, *Elodea canadensis*, *Hydrocharis morsus-ranae*, *Myriophyllum verticillatum*, *Polygonum amphibium*. The hydrological characteristic of the reservoir is presented in Table 1.

Table 1. The morphometric features of the "Chańcza" water reservoir

Total surface area	340 hectares
Gross capacity	24.22 mln m^3
Flood-control capacity	10 mln m^3
Total length (from dam to the bridge of Łagowica)	5.3 km
Depth	Average 2.0-3.0 m in the middle, maximal near the dam about 11 m
Watershed area	km^2
Normal water level	217.80 m a. s. l.
Location	34.5 km of the Czarna Staszowska River

MATERIAL AND METHODS

The field investigations were carried out in the years 2007-2008 and included: phytoplankton, microbenthic and periphytic algae. The samples for phycological studies were collected every two weeks from May till November 2007, and in May, June and July 2008 from three sites (Fig. 1). The sampling methods and the frequency of sampling were depending on the research objective. Material for the qualitative and quantitative investigations were collected directly in the field, taking into consideration the algal groups occurring in the water column, benthos and on the vascular plants. For the qualitative investigations net samples were collected from the water using the 0.5 l container and the no. 25 planktonic net in order to obtain the entire spectrum of the investigated community. The benthic algae were sampled from the surface of bottom, measuring about 5 cm^2. Deposits were scraped with a penknife to the container or broken off in order to preserve the natural form of community. Small balls of filamentous algae were directly transferred to the containers. To obtain the algal group periphyton, the fragments of macrophytes were cut off, or small piece of wood (or small pebbles) showing distinct deposits or the flocks of filamentous algae. Altogether about 40 samples were obtained, which were preserved in 4% formalin. Subsequently, after making the permanent preparations, the qualitative and quantitative analysis were carried out using the light microscope Jenamed 2. Identification of algae and cyanobacteria was done using the algological guides Krammer and Lange-Bertalot (1986, 1991) also Anagnostidis and Komárek (1988). Taxonomical classification of algae was adopted after van Den Hoek et al. (1995). In the compilation of results the system of Lange-Bertalot (1996) was used, which includes the indicative diatom species to following trophic groups: tol – tolerant species, eu – eutrophic species, o – oligotrophic species, oc – oligotrophic species of calciphilous character, od – oligotrophic species of dystrophic character, hal – halophilous species, ae – aerophytic species. Whereas the tolerance ranges of environmental conditions for individual diatom species have been defined on the basis of the scale proposed by van Dam et al. (1994) and by Krammer and Lange-Bertalot (1991).

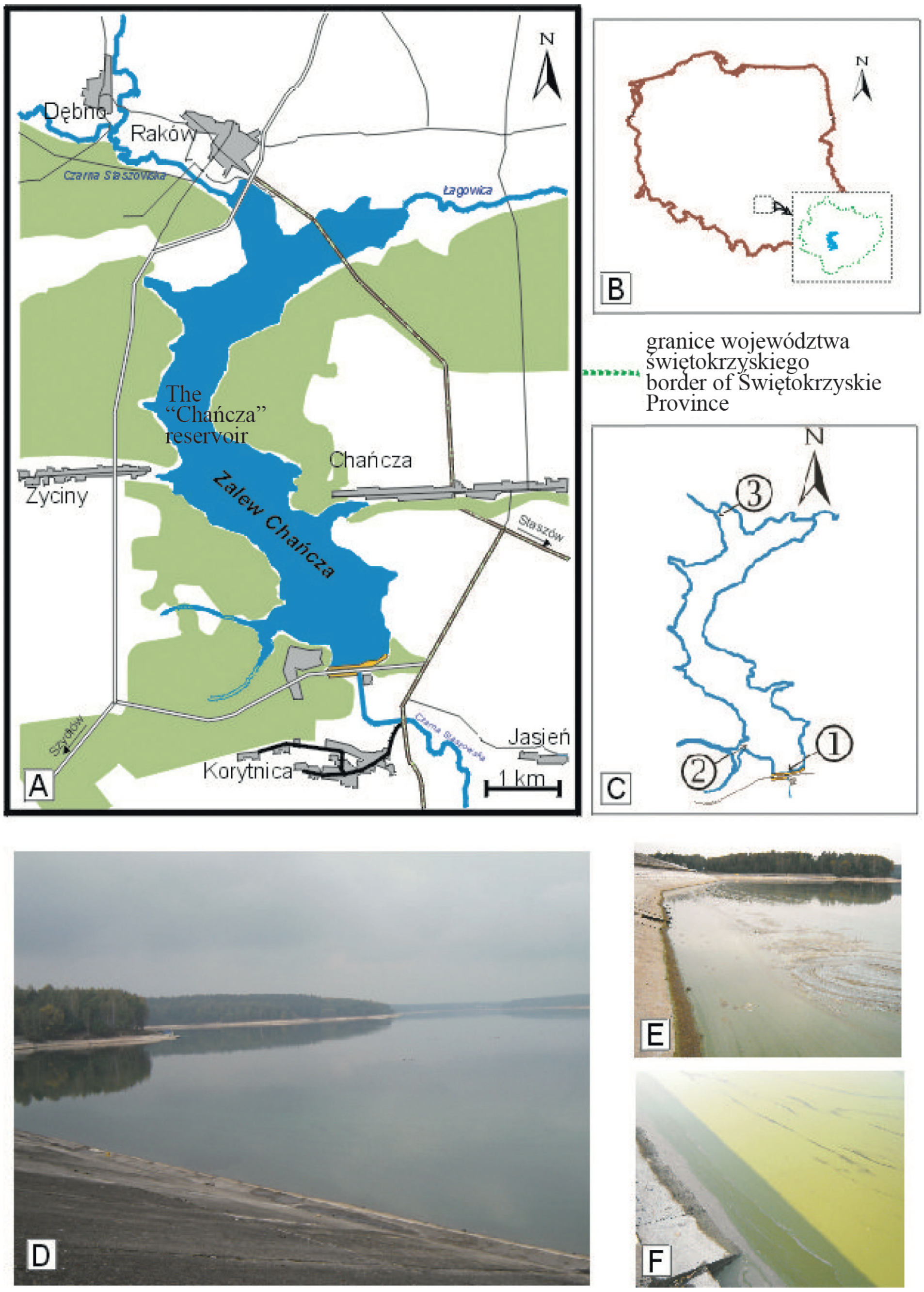
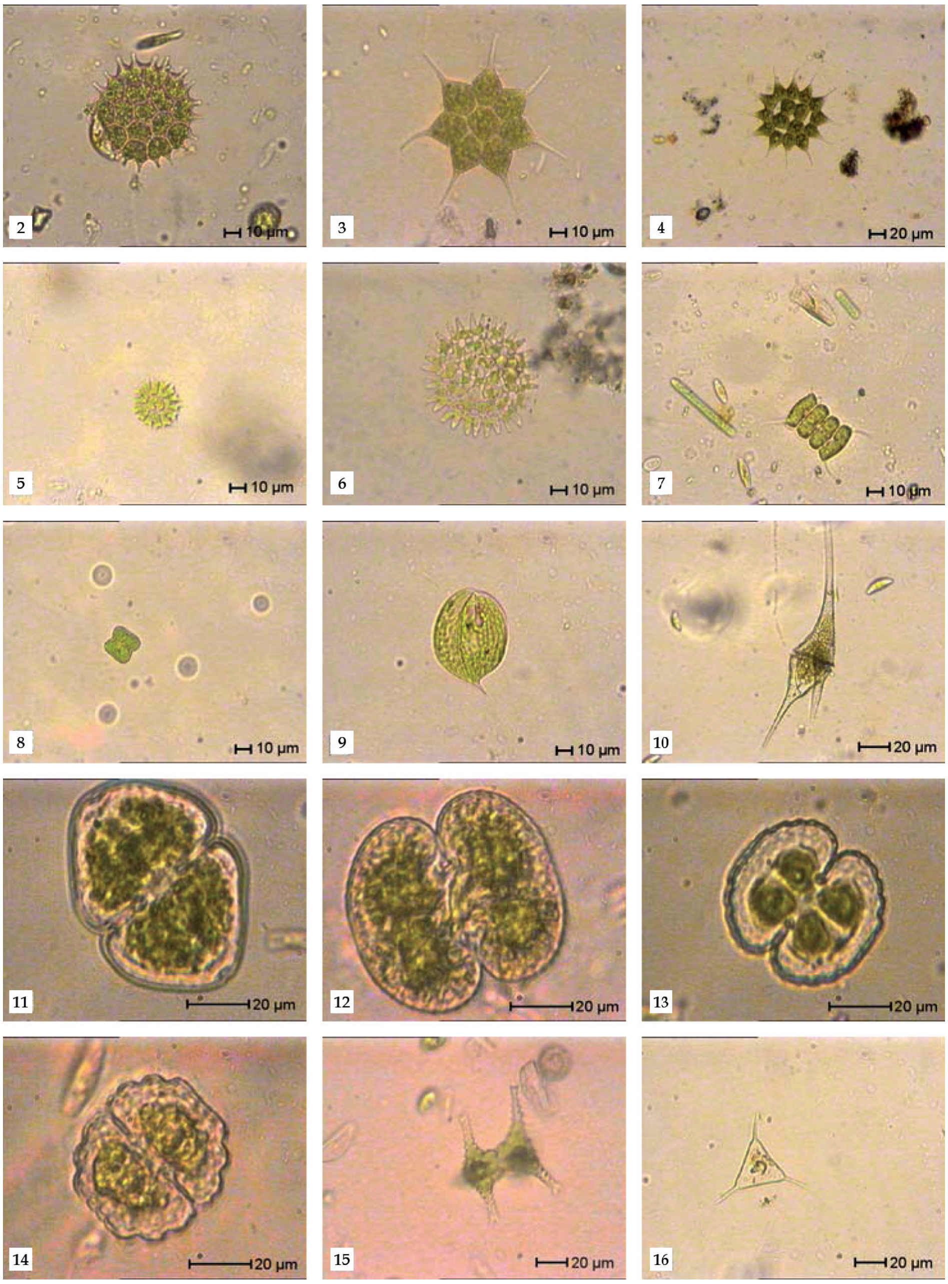


FIG. 1. Localization of study area and general view of the "Chańcza" water reservoir (A-B, D), C – distribution of sites studied (1, 2, 3), E, F – water blooms composed by cyanobacteria

RESULTS AND DISCUSSION

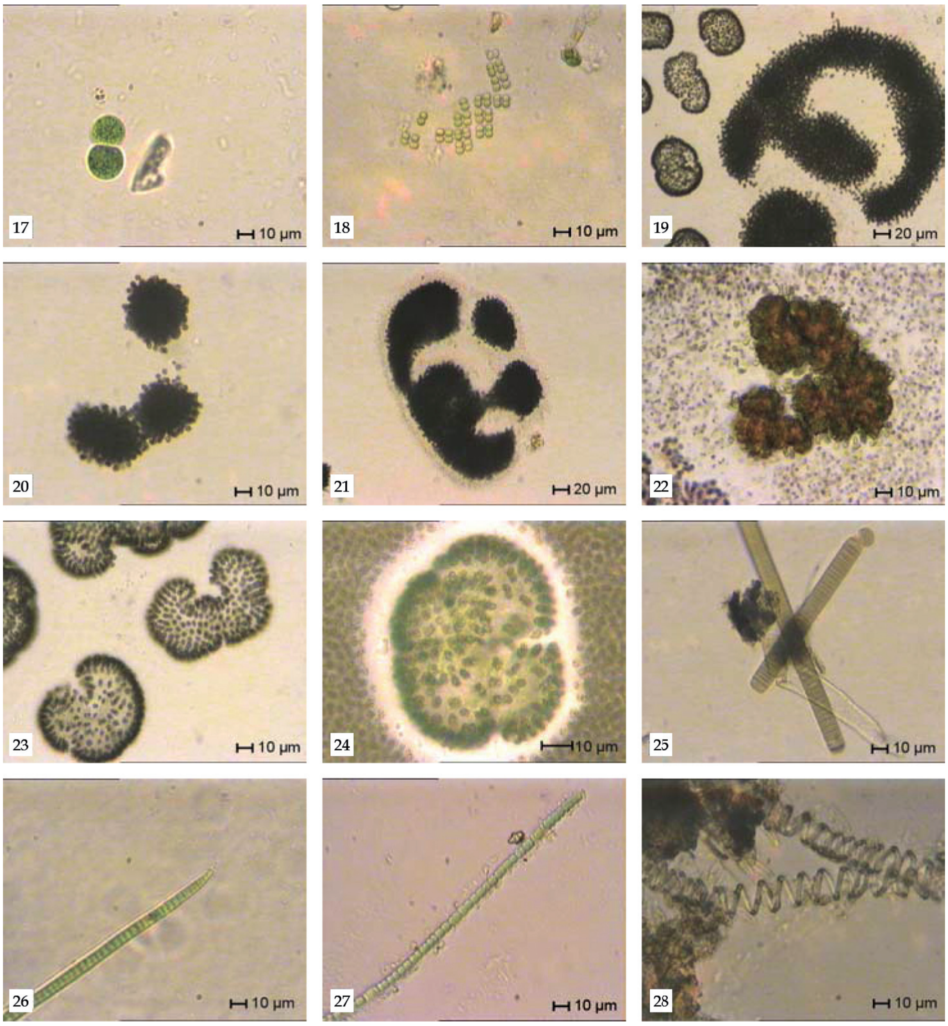
In the "Chańcza" water reservoir 82 algal species and cyanobacteria were identified (occurring both in the water and coastal habitats). Among the algae the diatoms (Bacillariophyceae) were dominant, which amount to 59% of all species found. The most frequently occurring were the following: *Amphora ovalis*, *Asterionella formosa*, *Caloneis amphisbaena*, *Cymatopleura solea*, *Cymbella cistula*, *Encyonema ventricosum*, *Fragilaria virescens*, *Gyrosigma atenuatum*, *Navicula* cf. *viridula*, *Nitzschia palea*, *Pinnularia viridis*, *Surirella ovalis*. The green algae (Chlorophyceae) represented 16% of all identified taxa. Prevailing species were: *Microthamnion kutzingianum*, *Pediastrum boryanum*, *P. duplex*, *Scenedesmus armatus*, *Tetraedron caudatum*. The attention deserve also the presence of desmids, and amongst them: *Cosmarium botrytis*, *C. granatum*, *C. subcrenatum*, *Staurastrum gracile*. The occurrence of representatives of group Zygnematophyceae is all the more surprising that pH of the reservoir waters fall into the range 6.2-7.5, whereas the desmids usually prefer the acidified waters. The most of algae and cyanobacteria species were found in spring and in early summer. It was observed that diatoms were the first to appear (mainly: *Cymbella prostata*, *Melosira varians*, *Pinnularia borealis*, *Stephanodiscus* sp. and others), and single desmids species (such as: *Cosmarium subprotumidum*, *Staurastrum glabrum*) (Figs 2-16), in summer the most numerous species were from the classes: Chlorophyceae (usually: *Pediastrum boryanum*,



Figs 2-16.
2 – *Pediastum boryanum*, 3 – *Pediastrum simplex*, 4 – *Pediastum duplex*, 5 – *Pediastrum tetras*, 6 – *Pediastrum duplex* var. *gracillimum*, 7 – *Scenedesmus armatus*, 8 – *Tetraedron caudatum*, 9 – *Phacus curvicauda*, 10 – *Ceratium hirudinella*, 11 – *Cosmarium granatum*, 12 – *Cosmarium botrytis*, 13 – *Cosmarium subcrenatum*, 14 – *Cosmarium subprotumidum*, 15 – *Staurastrum gracile*, 16 – *Staurastrum glabrum*

P. duplex, *P. simplex*, *Scenedesmus armatus*), Bacillariophyceae (e.g. *Gomphonema acuminatum*, *Hantzschia amphioxys*, *Tabellaria floccullosa*) and Cyanophyceae (*Chroococcus turgidus*, *Microcystis wesenbergii*, *Woronichinia compacta*, *Oscillatoria limosa*), whereas in fall the diatoms were again predominating (*Gomphonema parvulum*, *Meridion circulare*, *Pinnularia major*). In July 2007 large quantities of the filamentous green algae of the genera: *Cladophora*, *Mougeotia* and *Spirogyra* occurred. They were floating on the surface of water in a form of green mats. To the rarely reported Bacillariophyceae species belonged: *Gomphonema olivaceum*, *Diatoma vulgaris*, *Nitzschia linearis*, *N. sigmoidea*, *Rhopalodia gibba*.

Amongst the cyanobacteria in large quantities occurred *Microcystis aeruginosa*, a cosmopolitan species connected with the epilimnion, also present in the saline waters, and in the warm waters and well exposed to the light (Bucka and Wilk-Woźniak 2007). This species created in the investigated reservoir, close to the water surface the blue-green water blooms (sometimes long lasting, observed from June until November). *Microcystis* colony shape was highly variable depending on the place of occurrence and stage of its growth (Figs 17-28).



Figs 17-28.
17 – *Chroococcus turgidus*, 18 – *Merismopedia glauca*, 19 – *Microcystis aeruginosa*, 20 – *Microcystis flos-aquae*, 21 – *Microcystis wesenbergii*, 22 – *Woronichinia compacta*, 23 – *Woronichinia naegeliana*, 24 – *Woronichinia naegeliana*, 25 – *Oscillatoria limosa*, 26 – *Oscillatoria* cf. *tenuis*, 27 – *Anabaena planctonica*, 28 – *Spirulina* sp.

This species in the years 2007-2008 also occurred in the Brodzkie Lake which is one of eight reservoirs constructed on the Kamienna River and located within borders of the Staropolski Industrial District (Maciejczak and Czerwik-Marcinkowska 2010). In the waters of the "Chańcza" reservoir the water blooms were also created by *Microcystis wesenbergii*, and sporadically by *Anabaena flos-aquae*. The latter species usually commonly occurs in the plankton of stagnant waters and it is included to the potentially toxic cyanobacteria producing anatoxins from the group of neurotoxins (responsible for the damage of central and peripheral nervous system). However, no negative influence of this taxa on the fauna of the reservoir was observed. While it was noticed that the shape of filament and the thallus, also the size of individual cells were changed. The most frequently found species among cyanobacteria was *Oscillatoria limosa*; it was encountered in the stagnant slowly flowing and usually polluted waters. It is recognised as a common holoplanktonic species (Bucka and Wilk-Woźniak 2007). During the conducted field investigations the trophy status was determined for 32 representatives of the Bacillariophyceae class. In the reservoir the eutrophic species were the most frequently occurring (14 taxa, among the others: *Achnanthes minutissima*, *Caloneis amphisbaena*, *Cocconeis placentula*, *Cymbella affinis, C. prostata*, *Navicula cincta*, *N. cryptocephala*). The tolerant status reached nine species (e.g. *Amphora ovalis*, *Cymbella cuspidata*, *Gyrosigma attenuatum*), and four species were of the halophilous status (i.e. *Denticula tenuis*, *Fragilaria ulna*, *Nitzschia sigma*, *Pleurosigma salinarum*). According to van Dam et al. (1994) 30 diatom species were selected to which the values of ecological indicators were assigned (Table 2). As many as 17 taxa were alkaliphilous, present in the waters of the pH over 7, only eight species in the pH close to 7, whereas the diatom *Tabellaria floccullosa* is the only one classified as the acidophilous. With regards to the salinity, the "fresh brackish" diatom group is dominant, and it comprises 25 diatom species. The group β-mesosaprobic is represented by 19 taxa, and α-mesosaprobic by seven taxa. In the "Chańcza reservoir" the prevailing species are classified by van Dam as eutraphent (as many as 17 taxa). This is probably

Table 2. List of algae and cyanobacteria species recorded in the "Chańcza" water reservoir (ecological indicators values of freshwater diatoms acc. to Van Dam et al. 1994)

Species	Number of site	R	H	N	O	S	T	M
1	2	3	4	5	6	7	8	9
Heterokontophyta/ Bacillariophyceae								
Achnanthes minutissima Kütz.	III	3	2	2	1	2	7	3
Amphora ovalis (Kütz) Kütz.	I, II	4	2	2	2	2	5	1
Anomoeoneis sphaerophora (Ehr.) Pfitz.	II	–	–	–	–	–	–	–
Asterionella formosa Hass.	I, II	4	2	2	2	2	4	1
Caloneis amphisbaena (Bory) Cl.	I	4	3	2	3	3	5	3
Cocconeis placentula Ehr.	II	4	2	2	3	2	5	2
Cymatopleura solea (Bréb.) W. Sm.	II	4	2	2	3	2	5	1
Cymbella affinis Kütz.	I, III	4	2	1	1	2	5	2
Cymbella cistula (Ehr.) Kirchner	I, II	4	2	1	2	2	5	1
Cymbella cuspidata Kütz.	III	3	2	–	–	1	–	–
Cymbella prostata (Berk.) Cl.	I, II	4	2	1	1	2	5	1
Denticula tenuis Ehr.	I	4	1	1	1	1	3	3
Diatoma vulgaris Bory	II	5	2	2	2	2	4	1
Encyonema ventricosum (Agardh) Grun.	I, II, III	–	–	–	–	–	–	–
Fragilaria ulna (Nitzsch) Lange-Bert.	I, II	4	2	2	3	4	7	2
Fragillaria virescens Nitzsch	I, II, III	3	1	1	1	1	2	3
Gomphonema acuminatum Ehr.	II							
Gomphonema olivaceum (Horn.) Bréb.	III	5	2	2	2	2	5	1
Gomphonema parvulum (Kütz) Kütz.	I	3	2	3	4	4	5	3
Gyrosigma attenuatum (Kütz.) Rabenh.	II	5	2	2	3	2	5	1
Hantzschia amphioxys (Ehr.) Grun.	II	3	2	2	2	3	7	4
Melosira varians Agardh	I, II	4	2	3	3	3	5	2
Meridion curculare (Grev.) Agardh	I, II, III	4	2	2	2	2	7	1
Navicula cincta (Ehr.) Ralfs	II	4	2	2	3	3	5	4
Navicula cryptocephala Kütz.	I	3	2	2	3	3	7	2
Navicula rhynchocephala Kütz.	I	4	2	2	4	2	7	2
Navicula cf. *viridula* Kütz.	I, II, III	4	2	2	2	3	5	1
Nitzschia linearis W. Sm	III	4	2	2	2	2	4	3
Nitzschia palea (Kütz.) W. Sm.	II	3	2	4	4	5	6	3
Nitzschia sigma (Kütz.) W. Sm.	II	4	4	2	3	3	5	2
Nitzschia sigmoidea (Nitzsch) W. Sm.	II	4	2	2	3	2	5	2
Pinnularia borealis Ehr.	I, II	3	2	2	1	2	2	4
Pinnularia maior (Kütz.) Rabenh.	I, III	3	2	2	2	2	4	2
Pinnularia viridis Ehr.	I, II	3	2	2	3	2	7	3

Table 2 – cont.

1	2	3	4	5	6	7	8	9
Pleurosigma salinarum Rabenh.	I	4	4	–	–	1	–	–
Rhopalodia gibba Kütz.	III	5	2	1	3	2	5	3
Stephanodiscus sp.	I, II	–	–	–	–	–	–	–
Surirella ovalis Bréb.	II	4	4	2	4	3	5	3
Tabellaria floccullosa (Roth.) Kütz.	I, II, III	2	1	1	1	2	3	3
Dinophyta/ Dinophyceae								
Ceratium hirundinella (O.F. Müller) Bergh	I, II							
Chlorophyta/ Chlorophyceae								
Chlorococcum sp.	I, II							
Desmodesmus armatus (Chod.) Hegew.	I, II							
Microthamnion sp.	I, II							
Pediastrum boryanum (Turp.) Menegh.	I, II							
Pediastrum duplex Meyen	I, II							
Pediastrum simplex Meyen	I, II							
Pediastrum tetras (Ehr.) Ralfs	I, II							
Pediastrum sp.	II							
Scenedesmus quadricauda (Turp.) Bréb.	II							
Tetraedron caudatum (Corda) Hansg.	I, II							
Tetraedron sp.	II							
Tetrastrum triangulare (Chod.) Kom.	II							
Chlorophyta/ Zygnematophyceae								
Cosmarium botrytis Menegh.	I, II							
Cosmarium granatum Bréb. ex Ralfs	II							
Cosmarium subcrenatum Hantzsch.	I, II							
Cosmarium subprotumidum (Kütz.) Bréb.	II, I							
Cosmarium sp.	I, II							
Mougeotia sp.	II							
Spirogyra sp.	II							
Staurastrum glabrum Bréb.	II							
Staurastrum gracile Ralfs	I, II							
Staurastrum sp.	I							
Chlorophyta/ Cladophorophyceae								
Cladophora glomerata (L.) Kütz.	I, II, III							
Cladophora sp.	III							

TABLE 2 – cont.

1	2	3	4	5	6	7	8	9
Cyanophyta/ Cyanophyceae								
Anabaena planctonica Brunnth.	I, II, III							
Anabaena sp.	II							
Chroococcus turgidus (Kütz.) Näg.	I, II							
Chroococcus sp.	II							
Merismopedia glauca (Ehr.) Kütz.	I, II							
Merismopedia sp.	I, III							
Microcystis aeruginosa (Kütz) Kütz.	I, II							
Microcystis flos-aquae (Witrr.) Kirch.	I, II							
Microcystis wesenbergii (Kom.) Kom. in Kondr.	I, II							
Microcystis sp.	II							
Oscillatoria limosa Agardh	I, II							
Oscillatoria tenuis Agardh	I, II, III							
Oscillatoria sp.	I, II							
Phormidium autumnale Agardh	III							
Spirulina sp.	I, II							
Woronichinia compacta (Lemm.) Kom. et Hindák	I, II							
Woronichinia naegeliana (Unger) Elenkin	I, II							
Woronichinia sp.	I							

Explanation of symbols:
R – ph; 2 – acidophilous, 3 – circumneutral, 4 – alkaliphilous, 5 – alkalibiontic.
H – salinity; 1 – fresh, 2 – fresh brackish, 3 – brackish fresh, 4 – brackish.
N – nitrogen uptake metabolism; 1 – nitrogen-autotrophic taxa, 2 – nitrogen-autotrophic taxa, 3 – facultatively nitrogen-heterotrophic taxa, 4 – obligately nitrogen-heterotrophic taxa.
O – oxygen requirements; 1 – continuously high, 2 – fairly high, 3 – moderate, 4 – low.
S – saprobity; 1 – oligosaprobous, 2 – ß-mesosprobous, 3 – ά-mesosaprobous, 4 – ά-meso-/polysaprobous, 5 – polysaprobous.
T – trophic state; 2 – oligo-mesotraphentic, 3 – mesotraphentic, 4 – meso-eutraphentic, 5 – eutraphentic, 6 – hypereutraphentic, 7 – oligo-to eutraphentic.
M – moisture; 1 – never or very rarely, 2 – mainly occurring in water bodies, 3 – mainly occurring in water bodies, 4 – mainly occurring on wet and moist temporarily dry places.

because of the large quantity of nutrients accumulated at the bottom of the reservoir, a close proximity of the holiday resort, and the field crops.

The analysis of the preliminary study on algae and cyanobacteria of the "Chańcza reservoir", conducted herein for the first time, indicates that this reservoir and its closest surroundings should be an object of systematic and thorough studies equivalent to standard monitoring in character (accounting for physicochemical and biological parameters), that would allow for constant analysis of all changes progressing in its aquatic and terrestrial microhabitats.

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