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Chlorophyta – plants connected with diverse water reservoirs in the Wielkopolska region (western Poland)

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Abstract: The representatives of Chlorophyta (principally Chlorococcales) play an important role in the algal communities in species composition as well as in number structure. Nevertheless, it should be noted that in all cases the species with the broadest distribution in the Wielkopolska reservoirs were: *Desmodsmus subspicatus*, *D. communis*, *Scenedesmus naegeli*, *Monoraphidium contorum*, *Pediastrum boryanum*, *P. tetras*, *P. duplex*, *Staurastrum gracile*, *S. paradoxum*, *Tetraedron minimum*, *T. caudatum*, *T. triangulare*. At present, *Pediastrum simplex*, which until recently occurred commonly in the plankton, is now making a smaller contribution to the algae communities. Green algae play an important role in the formation of the algal biodiversity in the investigated water ecosystems. The highest participation of green algae was observed in both shallow lakes and fish ponds while the lowest was in puddles and soil waters which have a tendency to dry up. Monocultures of representatives of the Chlamydomonadales were characteristic of temporary water habitats. The increase of eutrophication and the decline of aquatic habitats are contributing to the reduction of the green algae biodiversity (particularly desmids) of not only the investigated area, but also throughout the country.

Key words: green algae, Chlorococcales, biodiversity, microalgae, pond, lake, eutrophy

1. Introduction

Chlorophyta is a large algae group, richly diversified and numbering over 20 thousand species (Lee 1999). Green algae are bright grass-green with pigments in the chloroplast. They occur as single cells, as round and flattened colonies, and as filaments. The majority of them live in fresh waters and some taxa from the orders Conjugales and Oedogoniales appear exclusively in fresh waters (Van den Hoek *et al.* 1995). It is possible to find Chlorophyta in lakes, ponds and in puddles, drainage ditches, boggy meadows as well as the soil. Freshwater green algae are mainly cosmopolitan. They are more abundant in ponds and lakes than all other algal groups combined. Physicochemical parameters of water (temperature, pH, water visibility, O_2, N and P concentrations) and time of the year shape species structure, numbers, and biomass of green algae (South & Whittick 1996; Van den Hoek *et al.* 1995). The optimum times for the appearance of this group are the summer and the autumn seasons (Barica 1994; Padisák & Dokulil 1994; Reynolds 1984). For them phosphorus concentration in the water and more importantly the N:P ratio, which when higher than 10, indicates conditions favourable to the green algae development (Barica 1990; Smith 1983). Therefore, the diversity of this group of plants changes depending on the type of the water ecosystem and in rivers is less differentiated and variable than in lakes and reservoirs (Messyasz 2003; Reynolds *et al.* 1994).

The purpose of this work was to describe species richness of green algae and their participation in the creation of algae communities in water reservoirs of the Wielkopolska region. Moreover, the differences in the depth of water is compared between the reservoirs and the differences in taxonomical composition are pointed out.

2. Material and methods

The taxonomic and number structure of green algae in the diverse water ecosystems in the Wielkopolska area were studied from 1998 to 2005. These were continuous studies in two shallow lakes Łekneńskie (Messyasz & Nagengast 2000) and Łęgowskie (Messyasz 2005), ponds from Reserve 'Dębina' near Wągrowiec (Messyasz 2004) but not continuous in other ecosystems such as the deep lakes Kaliszańskie and Kociołek (Messyasz *et al.* 2005b), fish ponds in Kamionki

(Mądrecka 2004; Messyasz *et al*. 2005a) and for 2005 only in soil water from farmland. All data presented in this article are coming from analyses made by the author.

Water samples (1000 ml) from these sites were collected from the surface area of the pelagic zone of lakes, ponds, puddles and meadow ditches. Additionally, phytoplankton samples in the vertical profile were taken at the deepest station situated in each deep lake. Soil samples were collected from the soil surface (0.5-1.0 cm deep). All non-diatom algae were identified by direct microscopical examination of wet mounts. Biomass of phytoplankton was estimated from cell numbers and specific volumes.

Standard methods were used for physicochemical analyses of water (Siepak 1992). Water temperature, pH, conductivity, concentration of oxygen and nutrients (N, P) were measured in each case.

3. Results

A number of green algae species studied in ecosystems in the Wielkopolska region were compared (Table 1). The highest participation of green algae was observed in both shallow lakes and fish ponds. The number of species was lowest in puddles and soil waters which are subject to drying up.

In both shallow lakes composition of the summer phytoplankton was characterised by large growths of green algae (Tables 1-2). The habitats where members of the Chlorophyta were found were characterised by low light conditions (average Secchi disk transparency 30-50 cm). Furthermore, the average N:P (total nitrogen : total phosphorus) ratio was 1:29 in Lake Łekneńskie and 1:37 in Lake Łęgowskie and indicated the state of the high water fertility. In the structure composition of dominant green algae in both lakes, frequent occurrence of species characteristic of eutrophic waters was ascertained (Table 2).

Table 1. The total number and structural parameters of identified green algae in the Wielkopolska reservoirs

Reservoir	Total number of algae species	Number of Chlorophyta species	H	E
Shallow lakes	210	45-96	3.71	0.85
Deep lakes	107	21-56	2.89	0.62
Fish ponds	187	56-80	3.34	0.79
Astatic ponds	123	9-32	2.53	0.48
Meadow ditch	56	12-22	2.03	0.41
Puddle	17	1-3	0.52	0.09
Soil water	25	3-11	0.86	0.11

Explanations: H – index of diversity of Shannon; E – evenness of Pielou

During the summer period Lake Kaliszanskie (max depth 29 m) was stratified and the metalimnion was located between 7 and 11 m depth. Microscopic observation of the samples showed that the phytoplankton

Table 2. List of dominating green algae (=10 % of total density) in Lake Łekneńskie and Lake Łęgowskie

Species	Lake Łekneńskie	Lake Łęgowskie
Ankistrodesmus falcatus (Corda) Ralfs	•	•
Closterium acutum Breb. in Ralfs	-	•
Coelastrum cambricum Archer	-	•
Coelastrum microporum Nägeli in A. Braun	-	•
Cosmarium regnellii Wille	-	•
Crucigenia tetrapedia (Kirch.) W. et G.S. West	•	•
Crucigeniella rectangularis (Nägeli) Kom.	•	•
Desmodesmus communis (Hegew.) Hegew.	•	•
Desmodesmus subspicatus (Chod.) Heg. et Sch.	-	•
Golenkinia radiata Chodat	-	•
Monoraphidium contortum (Thur.) Kom.-Legn.	•	•
Pediastrum boryanum (Turp.) Meneg.	•	•
Pediastrum tetras (Ehr.) Ralfs	•	•
Scenedesmus acuminatus (Lager.) Chodat	•	•
Staurastrum gracile Ralfs	-	•
Tetraedron minimum (A. Br.) Hansgirg	•	•
Tetraedron caudatum (Corda) Hansgirg	•	•
Tetrastrum staurogeniaeforme (Schr.) Kom.	-	•

contained mostly green algae in the epilimnion and cyanobacteria (*Planktothrix agardhii* (Gom.) Anagn. et Kom., *Aphanizomenon flos-aquae* (L.) Ralfs, *Anabaena spiroides* Klebahn, *Microcystis aeruginosa* Kütz.) in the metalimnion zone (Fig. 1). The epilimnion zone associated green algal community accounted for more than 58% of the total number of phytoplankton species. Chlorophyta contained mainly colony-forming forms of the genus *Scenedesmus*, *Desmodesmus*, *Pediastrum*, *Oocystis* and coccal forms of *Tetraedron*, *Monoraphidium* and *Closterium*.

A similar situation was noted in Lake Kociołek which is located in the Wielkopolski National Park. This lake (max depth 7.8 m) is shallower than Lake Kaliszańskie but also is characterized by strong water stratification during summer. The constant components in phytoplankton composition in Lake Kociołek during summer 2003 were nanoplanktonic green algae: *Scenedesmus* spp., *Desmodesmus* spp., *Lagerheimia*

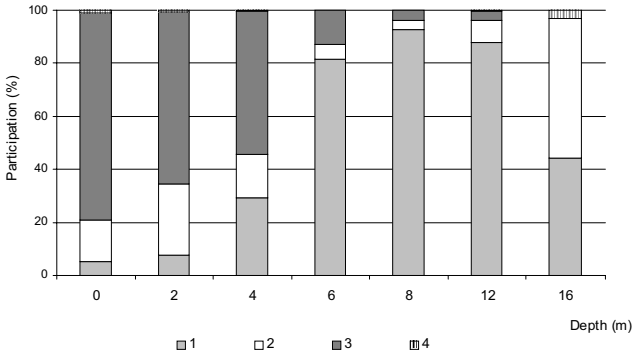

Fig. 1 The percentage vertical distribution of the phytoplankton density in Lake Kaliszańskie in summer 2003
Explanations: 1 – Cyanophyta; 2 – Bacillariophyta; 3 – Chlorophyta; 4 – others

citriformis (Snow) Collins, *Didymocystis planctonica* Korš., *Pediastrum tetras* (Ehr.) Ralfs and *Tetraedron minimum*. The shift within the structure of green alga from small forms to large forms (*Cosmarium*, *Staurastrum*) as common components of phytoplankton was observed during August and September.

The algal community of forest astatic ponds in the Reserve 'Dębina' was not particularly rich in species. Over four years (1999-2002) of investigations, the total number of species determined was 123 (Table 1). Green algae were a predominant part of the phytoplankton (15-30% of the average total biovolume). The species present were mainly monad forms *Chlamydomonas* spp., coccal forms *Scenedesmus*/*Desmodsmus* spp. and filamentous *Ulotrix* spp, *Uronema confervicolum* Lager.

There were 56 taxa of algae identified for two ditches located in the Reserve 'Dębina' (Table 1). The analyses of phytoplankton samples revealed that most species (22) belonged to Chlorophyta. The most numerous genera among the green algae in the surface water of meadow ditches were *Ankistrodesmus*, *Actinastrum*, *Coelastrum*, *Crucigeniella*, *Monoraphidium*, *Pediastrum*, *Pteromonas*, *Scenedesmus* and *Tetraedron*.

In examined fish ponds Kamionki near Poznań 10 species within genera *Desmodesmus,* 8 species within *Scenedesmus,* 6 within *Pediastrum, Cosmarium, Monoraphidium,* and 3 within *Tetraedron* out of 80 species of green algae identified in these ecosystems were stated. Chlorophyta account for 53% in the Large Pond and 60% in the Small Pond of all identified phytoplankton taxa. The dominant species analysis of the green algae density revealed that the higher biomass was found in Pond Large than in Pond Small which was dominated by cyanobacteria (Table 3).

In the investigated soil, Chlorophyta belonging to the genera *Cladophora*, *Characium*, *Chlamdomonas*, *Macrochloris*, *Scenedesmus* and *Ulotrix* dominated the algae community. Filamentous cyanobacteria (mainly *Lyngbya*, *Oscillatoria*) were also frequently noted in the samples collected from the farmland.

Green algae of puddles were represented by only three taxa: *Chlamydomonas reinhardtii* Dangeard, *Ch. oblongella* Lund and *Ch. intermedia* Chodat.

Table 3. The average biomass of the dominant green algae species in fish ponds in Kamionki in 2003

Ponds	Dominant species	Biomass [mg·l^{-1}]
Large	*Desmodesmus maximus*	25.293
	Pediastrum boryanum	19.992
	Scenedesmus naegeli	10.672
	Pediastrum tetras	7.123
	Desmodesmus subspicatus	3.554
	Desmodesmus communis	3.453
Small	*Pediastrum boryanum*	1.764
	Tetraedron minimum	0.785
	Tetraedron caudaum	0.362

4. Discussion

Wielkopolska is a region with very large numbers of small kettle holes, forest ponds and astatic reservoirs that during hot summers often dry out. It is associated with regular lowering of the groundwater. Parallel to this process of decreasing surface of water, is a concomitant reduction in the species diversity of green algae. Within the Chlorophyta many species do not find the right conditions for their development and different single species monocultures are created, e.g. *Chlamydomonas* sp. This phenomenon is compensated by the rise in abundance of the other groups of algae, mainly of diatoms, which in the form of spores can survive in bottom sediments. Based on the Van den Hoek *et al.* (1995) species of *Chlamydomonas* are well adapted to

the drying out of their habitat and they probably survive in the form of hynozygotes. This phenomenon was described on the example of astatic reservoirs in the Reserve 'Dębina' near Wągrowiec (Messyasz 2004).

Active eutrophication of waters of lakes in the Wielkopolska region is causing a rise in cyanobacteria in the phycoflora structure. Together with the intensity of cyanobacteria blooms, the green algae community is limited to small Chlorococcales green algae, mainly from *Coelastrum*, *Crucigenia*, *Tetraedron, Golenkinia*, *Scenedesmus/Desmodesmus*, *Monoraphidium*, *Oocystis, Pediastrum* and *Treubaria* genera. Numerous occurrences of representatives of the Chlorococcales order are being assigned to unstable environments (Burchardt *et al*. 2003; Reynolds 1984). They are able to survive by such features as fast reproduction, short lifespan and small cell dimensions. Examinations conducted on eutrophic lakes of the Wielkopolska region showed Chlorococcales dominance both in shallow (Lake Łęgowskie and Lake Łekneńskie) as well as deep lakes (Lake Kociołek, Lake Kaliszańskie).

The high values of nutrients in these investigated shallow lakes were related to the anthropogenic character of the catchments area and also to the continuous release of nitrogen and phosphorus from sediment. Long-term and very intense cyanobacteria blooms often reduce algae communities to 5-6 species. The permanent component of the community in a eutrophic lake is *Tetraedron minimum*. Representatives of genera *Chlamydomonas* and related genera are common in highly eutrophic waters but are also species that are characteristic of acid waters (Lee 1999; Van den Hoek *et al*. 1995).

The results received from examinations clearly show that green algae play an important role in the formation of the algal biodiversity in deep water reservoirs. The depth at which the major green algae community occurred was characterized by low light conditions, particularly rich in nitrogen, as ammonium. The optimum of green algae development during summer was confirmed by positive correlation between the density of this group and the water temperature (r=0.87 in summer; r=0.86 in autumn). There is a high stability of the water column in this lake that is why small forms (*Scenedsemus*, *Tetraedron*) were replaced with big forms represented by K life strategy species like *Pandorina*, *Cosmarium*, *Closterium* at the end of summer. The similar phenomenon was stated in the case of Lake Kociołek.

Forest ponds are usually small and shallow with homogenous temperature in the water column. The changes of phytoplankton communities including green algae may be a result of physical factors e.g. depth, differential shading or overgrowing by macrophytes (Kuczyńska-Kippen *et al*. 2003). Potential evaporation in this area is higher than the level of precipitation. The water is stagnant and evapouration is high so these ponds exist mainly during the spring period and in the late autumn. Biodiversity of these mid-forest water bodies is strictly connected with the length of the dry period. Sediment affects the quality of the water and the structure of phytoplankton.

The presence of Chlorococcales algae certainly is being strengthened by organically fertilising the fish ponds (spring – autumn). It is enhancing their chance of gaining dominance in very fertile water ponds. Fish ponds are containers which on account of their destiny are quite shallow and because of this continuous mixing up of the entire volume water is occurring. The flora of fish ponds is usually sparse in species, does not penetrate to a great depth and overgrow the bottom. These containers are characterized by high trophy caused by strong mineral or organic fertilizing which is aimed at increase their productivity.

The examined ponds were formed after transforming the natural container. The Large Pond has a surface area of 0.6 ha and a depth of 2 m but the Small Pond is only 0.09 ha and 1.5 m. In both ponds large green algae species were noted. They are in mainly Chlorococcales green algae which are characteristic of small fertile bodies of water but also for big lakes containing high nutrient concentrations (Kawecka & Eloranta 1994; Reynolds 1984). In both investigated ponds high ammonium and low nitrate concentrations were found (Mądrecka 2004). Also, *Scenedesmus/Desmodesmus* can absorb nitrogen in the form of urea (Bucka 1989).

It is interesting to remark that about 2 thousand species of algae are appearing in the soil. They live on the surface or in the subsurface layer of the soil. Intense examinations concern mainly cyanobacteria living in the soil on account of their ability to bind atmospheric nitrogen (Evans & Johansen 1999). Green algae in the soil are a taxonomically difficult group and they must be cultured before identification is possible. Most frequently green algae soil representatives are from the genera: *Characium*, *Chlamydomonas*, *Chlorococcum*, *Closterium*, *Cosmarium*, *Macrochloris*, *Mesotaenium* and *Scenedesmus* (Kadłubowska 1975). Capillary waters in the soil are settled by species from genera *Cladophora*, *Enteromorpha* and *Ulotrix* (Lee 1999). This study confirmed that numbers of green algae were much higher in the surface layer of the soil than the subsurface one are a result of the light accessibility. This habitat needs more detailed investigations in the Wielkopolska region. The correlation of algae density with soil type has not been studied so far (South & Whittick 1996).

Special interest was focussed on places previously little examined for green algae, like e.g. boggy meadow. Similarly, small puddles of waters deep enough that they exist for a few days or also prolonged damp on window-panes favour green algae, but mainly monocultures of Chlamydomonadales representatives. These results

were based on a single dilution assay performed during summer but suggest that length of water habitats in existence is important to the development of differentiation species richness.

4. Conclusions

- Green algae occur in all bodies of water. Their diversity changes according to the nature of the water ecosystem.
- The rise in cyanobacteria in phytoplankton structure causes a rise in the dominance of green algae from the Chlorococcales.
- The reduction of water habitats is contributing to a smaller green algae diversity.
- Ecological characteristics demonstrated that all the explored habitats had dominated by cosmopolitan and eutrophic species.
- Analyses of extreme habitats are missing for the Wielkopolska area. Further and more detailed examinations of these water habitats will contribute probably to a more complete understanding of the diversity of green algae in Wielkopolska.

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