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STRUCTURE AND SPATIAL DIFFERENTIATION OF THE PLANKTONIC COMMUNITY IN THE GRAVEL PIT LAKE IN OWIŃSKA (WEST POLAND)

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Summary. The study was conducted in August, 2004, at two pelagic sites in the gravel pit lake in Owińska near Poznań (Wielkopolska Lakeland) in order to quantify the carbon biomass of microbial components of plankton and their distribution in the vertical profile. The carbon biomass of the investigated plankton components near the bottom (5.0 m) was about twice as high as in the overlying water layers (0.2 and 2.5 m). The contribution of phytoplankton to the total carbon biomass was the highest, ranging from 52 to 86% (mean 71%), and it decreased alongside with the depth. The mean contribution of bacteria to the total carbon biomass was 15.5%, that of crustaceans – 10.5%, whereas of the other studied plankton components i.e. ciliates, heterotrophic flagellates and rotifers, only 2.5%, 0.5% and 0.3%, respectively. Co-occurrence of small phytoplanktonic organisms and *Daphnia* species testifies to effective carbon flux between the microbial loop and the higher trophic levels.

Key words: picophytoplankton, bacteria, heterotrophic flagellates, ciliates, metazooplankton, microbial loop

INTRODUCTION

For many years, research has concentrated on the complex interactions that are typical for the basis of the food web, and comprise phytoplankton, bacteria, proto- and metazooplankton, but particular attention has been paid to the microbial loop [Weisse and Stockner 1993, Havens and East 1997, Wiąckowski *et al*. 2001]. However, most of the publications related to this topic describe the planktonic communities of natural lakes or dam reservoirs on rivers. Other water bodies, such as flooded clay pits, peat lakes, gravel pit lakes, have been seldom studied. They are usually small and shallow water bodies, frequently with steep slopes of the water basins, which are favourable for thermal stratification in summer. Due to this, they have diverse conditions for the development of plankton, and favour biodiversity within the entire water column.

The aim of this study was to recognise the species composition of phyto- and zooplankton communities and to estimate the total carbon biomass contained in chosen plankton components and its distribution in the vertical profile during the summer stratification of a man-made gravel pit lake, situated in Owińska, north-east of Poznań.

STUDY AREA, MATERIAL AND METHODS

Study site

The water body in Owińska was created in the 1980's as a result of gravel extraction. It has a surface area of 12.5 ha, maximum depth of 6 m, and several distinctly separated basins. It is situated near the north-eastern border of the city of Poznań. Carlson's trophic state index, based on Secchi disc transparency, chlorophyll *a* and total phosphorus values, showed that in the studied period the gravel pit lake was meso-eutrophic [Szeląg-Wasielewska and Gołdyn 2005]. Their study indicated that its waters were characterised by an alkaline pH, low values of water colour and turbidity, and medium level of mineralization. Inorganic nitrogen concentrations were quite high, exceeding 0.3 mg l^{-1} at all depths, and all analysed forms of inorganic N were always detected. Also orthophosphates were present at all depths. The vertical variation in water temperature and oxygen content in the pelagic zone in the study period attested to incomplete thermal stratification, i.e. presence of epi- and metalimnion and a significant decrease in oxygen content with increasing depth. In the eastern basin of the gravel pit (station 1), the epilimnion was 2 m thick and the metalimnion was characterised by a steep thermal gradient. In the central basin (station 2), the epilimnion was 3 m thick, the metalimnion had a gentler thermal gradient, and water temperature at the bottom was 2.5ºC. higher. At station 1, oxygen content and saturation were slightly lower than at station 2, but at the depth of 5 m oxygen content and saturation were close to zero.

Sampling and enumeration

Water samples were collected on 3rd August, 2004, in the pelagic zone at 2 stations with a 0.5 m-long tube sampler (Toń, 5 l) from three points in the vertical profile: the surface (0.2 m), mid-water (2.5 m) and near the bottom (ca 5.0 m). Samples for bacterioplankton, picophytoplankton (0.2-2μm), and heterotrophic flagellates (HF) were fixed with glutaraldehyde, filtered on black Nuclepore filters and examined by using an epifluorescence microscope (Olympus BX-60) and protocols described by Porter and Feig [1980], MacIsaak and Stockner [1993] and Caron [1983], respectively. Samples for phytoplankton larger than 2 μm and for ciliates were preserved with Lugol solution, concentrated by sedimentation, and counted with an inverted light microscope according to the methods of Wetzel and Likens [1991]. Rotifers and crustaceans were sampled by passing water through a net (40 μm mesh), preserved with Lugol solution, and subsamples were counted by using 0.5-ml Sedgwick-Rafter chambers. Carbon biomass was estimated on the basis of published relationships with cell size, biovolume or dry weight [Amblard *et al*. 1995, Havens *et al*. 2000].

RESULTS AND DISCUSSION

The total carbon biomass of analysed plankton components ranged from 0.363 mg C l^{-1} to 0.983 mg C l^{-1} (Fig. 1). Mean plankton biomass in the water column was higher by 26% in the central basin (station 2) than in the eastern basin (station 1), which may be related to the influence of the drainage basin and the intensity of human impact [Gołdyn *et al*. 2004, 2006].

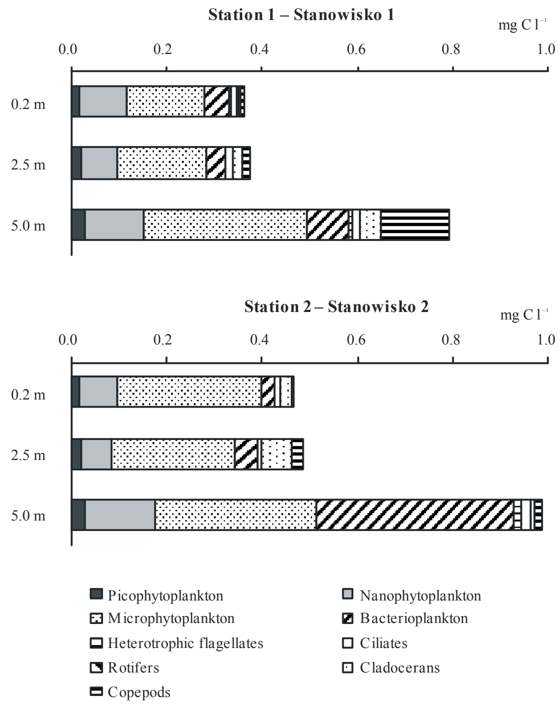

Fig. 1. Vertical distribution of carbon biomass (mg C l^{-1}) in the various plankton components at two stations in the gravel pit lake in Owińska in August, 2004
Rys. 1. Pionowe rozmieszczenie biomasy węgla (mg C l^{-1}) w różnych składnikach planktonu na dwu stanowiskach w żwirowiance w Owińskach, w sierpniu 2004 r.

Phytoplankton

Total phytoplankton biomass (pico-, nano- and micro-) varied from 0.280 to 0.492 mg C l^{-1} (mean 0.351 mg C l^{-1}) at station 1 and from 0.345 to 0.515 mg C l^{-1} (mean 0.420 mg C l^{-1}) at station 2 (Fig. 1). The highest values within both stations were observed in the water layer just above the bottom sediments, mainly due to microphytoplanktonic organisms. The contribution of microphytoplankton to the total phytoplankton biomass in all cases exceeded 50% (mean 69%) (Tab. 1). Mean contribution of nanophytoplankton was about 3-fold lower and constituted only 22% of the total phytoplankton biomass. The most important in this biomass were small-sized green algae (*Oocystis, Chlamydomonas, Scenedesmus*), cryptophytes (*Cryptomonas, Rhodomonas*), diatoms (*Cyclotella*) and haptophytes (*Chrysochromulina*).

Table 1. Relative contribution (%) of the biomass of particular plankton components to their total biomass at two stations in the gravel pit lake in Owińska in August, 2004
Tabela 1. Udział (%) biomasy poszczególnych składników planktonu w biomasie ogólnej na dwu stanowiskach w żwirowiance w Owińskach, w sierpniu 2004 r.

Microbial components Komponenty mikrobiologiczne	Station 1 Stanowisko 1			Station 2 Stanowisko 1		
	0.2 m	2.5 m	5.0 m	0.2 m	2.5 m	5.0 m
Picophytoplankton	5.0	5.6	3.5	3.3	4.2	2.9
Nanophytoplankton	27.3	20.0	15.4	17.1	13.1	15.1
Microphytoplankton	44.9	49.6	43.3	65.6	53.8	34.4
Bacterioplankton	14.3	10.4	11.6	5.9	9.0	41.8
Heterotrophic flagellates	0.2	0.3	0.6	0.2	0.5	1.3
Ciliates	3.6	3.7	1.9	1.9	1.4	2.2
Rotifers	0.6	0.5	0.1	0.3	0.4	0.1
Cladocerans	2.1	5.4	5.9	4.6	12.4	0.7
Copepods	1.9	4.5	17.6	1.0	5.1	1.4

Phytoplankton, whose cell size was > 2 μm, i.e. nano- and microplankton, was described in detail in an earlier report [Szeląg-Wasielewska and Gołdyn 2005]. It was represented by 135 taxa, belonging to 9 taxonomic groups. The most diverse group among these organisms were chlorococcal green algae. The biomass of these phytoplankton size groups was dominated by flagellates, principally dinoflagellates, euglenophytes and cryptophytes, and in the surface water layer also by filamentous cyanobacteria *Anabaena affinis*.

In turn, picophytoplankton was dominated by cyanobacteria. Picophytoplankton abundance increased together with the depth of sampling and varied between 119×10^6 and 291×10^6 cells l^{-1} (mean 201×10^6 cells l^{-1}) and biomass from 15 to 29 μg C l^{-1} (mean 22 μg C l^{-1}). (Tab. 2, Fig. 1). Picophytoplankton biomass was positively correlated with orthophosphates ($r = 0.84$, $p = 0.036$) and chlorophyll *a* ($r = 0.85$, $p = 0.030$), but weakly with inorganic nitrogen ($r = 0.77$, $p = 0.076$) and negatively with N:P ratio ($r = -0.81$, $p = 0.047$). The sum of biomass of easily grazed phototrophs, i.e. nano- and picophytoplankton, represented as much as 24-42% of total phytoplankton biomass (mean 28%) (Fig. 2).

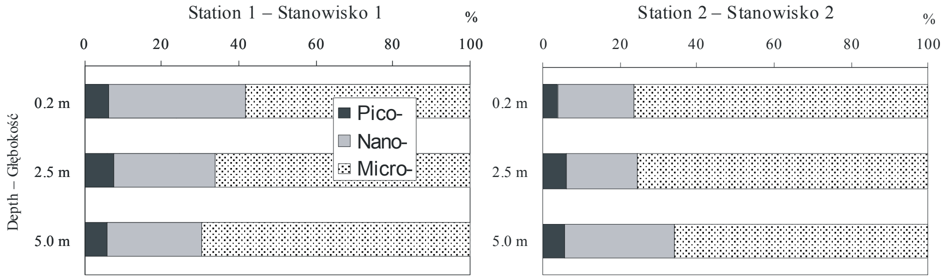

Fig. 2. Vertical variation in the contribution (%) of size groups of phytoplankton to total phytoplankton biomass at two stations in the gravel pit lake in Owińska in August, 2004
Rys. 2. Pionowe zmiany udziału (%) wielkościowych grup fitoplanktonu w ogólnej biomasie fitoplanktonu na dwu stanowiskach w żwirowiance w Owińskach, w sierpniu 2004 r.

In general, more than 50% of the total planktonic carbon biomass was confined in autotrophic plankton communities. It fell within the range from 52 to 86% (mean 71%), and it decreased alongside with the depth. Microphytoplankton dominated the carbon biomass of all phytoplankton and of all plankton in the upper water layers (i.e. at 0.2 and 2.5 m), which is characteristic for eutrophic water bodies (Work *et al*. 2005).

Bacterioplankton

The abundance of bacteria varied from 3.6×10^9 to 5.9×10^9 cells l^{-1} (mean 4.5×10^9 cells l^{-1}) and biomass from 29 to 412 μg C l^{-1} (mean 111 μg C l^{-1}) (Tab. 2, Fig. 1). The mean contribution of bacteria to the total carbon biomass was 15.5%. Among many morphological forms of bacteria, the most abundant were curved bacteria, cocci and rods, whose contribution to the total abundance of bacterioplankton was 38, 32 and 29%, respectively. Bacterial carbon biomass was 2-fold higher near the bottom than in the surface water layer at station 1 and six times at station 2. This large biomass of bacteria was caused by the presence, near the bottom, of many large cells of phototrophic bacteria from the genus *Chromatium*, mainly *Ch. weissei*. According to Sorokin [1999], their growth is stimulated by low oxygen concentration and low light intensity. Such conditions were present in the water layer near the bottom of the gravel pit lake in Owińska. The mean biovolume of bacterial cells ranged from 0.048 to 0.103 μm^3 at station 1 and from 0.034 to 0.319 μm^3 at station 2. At both stations a bigger biovolume was demonstrated by bacterial cells in the metalimnion (near the bottom). The correlation of bacterial biomass and chlorophyll *a*, frequently noted in many water bodies [Gołdyn and Szelag-Wasielewska 1995], was not observed in the gravel pit lake in Owińska. Instead of this, a significant and positive correlation was found with pheopigments ($r = 0.96$, $p = 0.02$). This indicated that the increase in bacterial biomass was a result of decay of algal cells. In turn, negative although not significant relationships appeared between bacterioplankton and rotifer biomass ($r = -0.67$, $p = 0.143$), and also between bacterioplankton and cladoceran biomass ($r = -0.41$, $p = 0.422$). This may suggest the inaccessibility of bacteria to both rotifers and cladocerans. These relationships were influenced by the large abundance of heterotrophic bacteria near the bottom sediments, coinciding with small numbers and biomass of rotifers and cladocerans, due to very low oxygen concentrations.

Table 2. Vertical distribution of the abundance of various components of the plankton community at two stations in the gravel pit lake in Owińska in August, 2004
Tabela 2. Pionowe rozmieszczenie liczebności różnych składników planktonu na dwu stanowiskach w żwirowiance w Owińskach, w sierpniu 2004 r.

Microbial components Komponenty mikrobiologiczne	Station 1 – Stanowisko 1			Station 2 – Stanowisko 1		
	0.2 m	2.5 m	5.0 m	0.2 m	2.5 m	5.0 m
Picophytoplankton ($\times10^6$ cells l^{-1})	140.1	192.3	278.9	118.9	182.3	290.5
Nanophytoplankton ($\times10^6$ cells l^{-1})	10.5	9.4	4.1	9.7	8.0	6.9
Microphytoplankton ($\times10^6$ cells l^{-1})	6.0	3.4	2.8	6.5	4.4	2.6
Bacterioplankton ($\times10^6$ cells l^{-1}),	4936	4156	4029	3638	4619	5865
Heterotrophic flagellates ($\times10^3$ cells l^{-1})	44	55	219	44	132	102
Ciliates ($\times10^3$ cells l^{-1})	3.3	2.4	4.1	3.2	2.9	16.5
Rotifers (ind. l^{-1})	387	375	202	240	295	214
Cladocerans (ind. l^{-1})	63	145	170	115	205	29
Copepods (ind. l^{-1})	300	140	344	135	145	120

Protozooplankton

The contribution of heterotrophic protists (HF and ciliates) to the total plankton biomass was small, ranging from 1.9 to 4.0% (mean 3.0%) (Tab. 1). Among the studied plankton components, HF contained the smallest part of total carbon biomass. Its mean value amounted to only 0.5%. The biomass of HF was bigger only near the bottom sediments, as large euglenophytes like *Astasia* and *Rhabdomonas* were present there.

Among ciliates at least 21 taxa were observed (Tab. 3). Their density was low, except near the bottom water layer at station 2 (Fig. 3). At this station, the maximal value of 16.5×10^{3} cells l^{-1} was close to the minimal value recorded by Wiąckowski *et al*. [2001] in a highly eutrophic shallow lake in SW Finland.

Table 3. Genera and species of ciliates and planktonic rotifers and crustaceans with abundance >10 ind. l^{-1} in the gravel pit lake in Owińska in August, 2004
Tabela 3. Rodzaje i gatunki orzęsków oraz planktonowych wrotków i skorupiaków o liczebności >10 osobn. l^{-1} w żwirowiance w Owińskach, w sierpniu 2004 r.

Ciliates	Metazoa
Prostomatida	Rotifera
Acineria uncinata	*Ascomorpha* sp.
Ascenasia volvox	*Chromogaster* sp.
Balanion planctonicum	*Collotheca* sp.
Coleps hirtus	*Conochilus unicornis*
Coleps spetai	*Keratella cochlearis*
Holophrya discolor	*Polyarthra remata*
Urotricha agilis	*Polyarthra vulgaris*
Urotricha armata	*Pompholyx sulcata*
Oligotrichida	*Synchaeta* sp.
Codonella cratera	*Trichocerca similes*
Halteria grandinella	*Trichocerca* sp.
Strombilidium humile	Cladocera
Strombilidium sp.	*Ceriodaphnia* sp.
Strombidium	*Daphnia cucullata*
Pelagostrombidium sp.	*Diaphanosoma brachyurum*
Peritrichida	Copepoda
Trichodina pediculus	*Eudiaptomus gracilis*
Vorticella sp.	*Mesocyclops leuckarti*
Scuticociliatida	*Thermocyclops oithonoides*
Cinetochilum margaritaceum	
Uronema sp.	
Others – Inne	
Metopus sp.	
Spathidium sp.	
Undetermined	

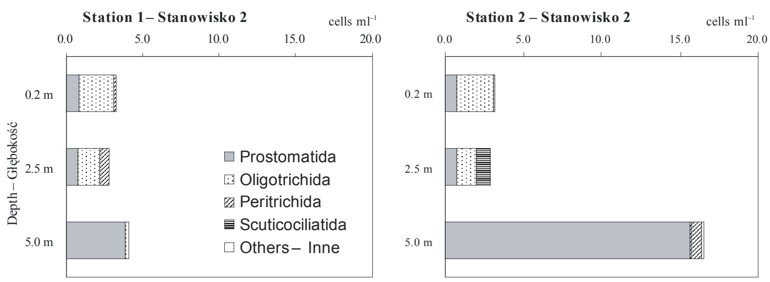

Fig. 3. Vertical variation in the abundance (cells ml^{-1}) of taxonomic groups of ciliates at two stations in the gravel pit lake in Owińska in August, 2004
Rys. 3. Pionowe zmiany liczebności (kom.$\cdot ml^{-1}$) taksonomicznych grup orzęsków na dwu stanowiskach w żwirowiance w Owińskach, w sierpniu 2004 r.

In the epilimnion, the most abundant were small oligotrichs *Halteria grandinella* and mixotrophic species of *Strombidium*. In the middle water layer, proportions of individual groups were similar, especially at station 2. However, in the lower layer (metalimnion), the prostomatid *Coleps hirtus* predominated. The contribution of ciliates to the total carbon biomass was rather low, the mean value was 2.5%, with a narrow range in the water column (Tab. 1). Their contribution to total zooplankton biomass (HF, ciliates, rotifers and crustaceans) ranged from 7.2 to 42.2%, with a mean value of 24.3%. Total ciliate biomass was positively correlated with bacterioplankton biomass ($r = 0.85$, $p = 0.030$) and weak with picophytoplankton biomass ($r = 0.77$, $p = 0.079$), but no significant relationship between ciliate biomass and chlorophyll *a* was found. On the other hand, there were negative and marginally significant or insignificant correlations between ciliate biomass and biomasses of rotifers, cladocerans and copepods. This indicates weak food pressure of metazooplankton on ciliates in this period.

Metazooplankton

Metazooplankton was represented by 41 taxa, among them 27 species of rotifers and 14 species of crustaceans. The taxa, whose density exceeded 10 specimens per 1 l, are presented in Table 3. In the metazooplankton, the abundance of rotifers in a half part of samples prevailed over copepods, with the most frequently observed *Trichocerca*, *Polyarthra* and *Keratella* species. *Daphnia cucullata* and *Diaphanosoma brachyurum* were the most common cladocerans. Adult copepods were present in small numbers, especially at station 2.

Rotifers were not abundant, as their mean total density was only 286 ind. l^{-1}, with small differences between the stations (Tab. 2). Their contribution to the total carbon biomass was lower than 1% at both stations (mean 0.3%). Most of the correlations between rotifers and other studied plankton components were negative. A statistically significant correlation was found only between the biomass of the sum of nano- and microphytoplankton ($r = -0.96$, $p = 0.002$), confirmed by the negative relationship with chlorophyll *a* ($r = -0.88$, $p = 0.020$). It indicated the grazing effect of rotifers on phytoplankton.

Crustaceans were characterised by a bigger contribution to the total carbon biomass. Its mean value was 10.5%, and at station 1 it was somewhat higher (12.5%) than at station 2 (8.4%). Only weak correlation of the biomass of copepods and chlorophyll *a* was found ($r = 0.79$, $p = 0.065$).

CONCLUSIONS

1. The plankton of the gravel pit lake was composed of organisms from various taxonomic groups and the community structure changed significantly with increasing depth. Total phytoplankton biomass increased with depth, but its contribution to total carbon biomass decreased.

2. The highest phototroph biomass was recorded in the water layer just above the bottom sediments, mainly due to the higher abundance of microplanktonic organisms. Among the smallest phototrophs, the most abundant were picocyanobacteria. Their biomass, like the biomass of bacterioplankton, usually increased with growing depth. Bacterial carbon biomass was 2 and 6 times higher near the bottom than in surface water at station 1 and station 2, respectively.

3. Heterotrophic flagellates and ciliates usually did not reach a high biomass. Among 21 taxa of ciliates, the most frequent were Prostomatida and Oligotrichida, i.e. *Coleps hirtus* and *Halteria grandinella*. Among rotifers, the most frequently observed species were *Trichocerca*, *Polyarthra* and *Keratella*s. *Daphnia cucullata* and *Diaphanosoma brachyurum* were the most common cladocerans, and adult copepods were present in small numbers.

4. A relatively high proportion of phototrophs were small-sized phytoplankton, mainly green algae, diatoms and picocyanobacteria. In combination with the dominance of *Daphnia cucullata,* this can form an effective link in the carbon flux between the microbial loop and higher trophic levels in the microbial food web.

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STRUKTURA I PRZESTRZENNE ZRÓŻNICOWANIE PLANKTONOWEGO ZBIOROWISKA W ZBIORNIKU POŻWIROWYM W OWIŃSKACH (ZACHODNIA POLSKA)

Streszczenie. Badania przeprowadzono w sierpniu 2004 roku na dwu stanowiskach w pelagialu żwirowianki w Owińskach niedaleko Poznania (Pojezierze Wielkopolskie). Celem badań była ocena ilości węgla w mikrobiologicznych składnikach planktonu i poznanie jego rozmieszczenia w toni wodnej. Ilość węgla w badanych składnikach planktonu była ok. 2-krotnie większa nad dnem (5,0 m) niż w wyżej położonych warstwach wody (0,2 i 2,5 m). Udział fitoplanktonu w puli węgla był najwyższy, wahając się od 52 do 86% (średnia 71%), przy czym zmniejszał się on wraz ze wzrostem głębokości. Średni udział bakterii w puli węgla wyniósł 15,5%, skorupiaków 10,5%, natomiast pozostałych badanych składników planktonu, tj. orzęsków, heterotroficznych wiciowców i wrotków, odpowiednio 2,5, 0,5 i 0,3%. Występowanie małego fitoplanktonu i *Daphnia cucullata* świadczy o efektywnym przepływie węgla między mikrobiologiczną pętlą a wyższymi poziomami troficznymi.

Słowa kluczowe: pikofitoplankton, bakterioplankton, heterotroficzne wiciowce, orzęski, metazooplankton, pętla mikrobiologiczna