Polish J. of Environ. Stud. Vol. 19, No. 6 (2010), 1269-1277

Original Research

The Spatial Changes of Phytoseston and Microbiological Parameters in Lowland Rivers during the Summer Period

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Received: 2 February 2010
Accepted: 9 June 2010

Abstract

The composition and distribution of the phytoseston communities and heterotrophic bacteria from the Wełna and Nielba rivers before and behind the cross-rivers were analyzed from June to September 2007. In both rivers the highest concentration of algae biomass were recorded in July and September, which was connected with concentrating the periphytic and benthic species in phytoseston, during which the influence of the increasing water level were transported into the lower part of rivers. Algae such as *Gomphonema parvulum*, *Tychonema granulatum, Cryptomonas ovata, Aulacoseira granulata, Cocconeis placentula, Monoraphidium contortum, Planctolyngbya limnetica, Cyclotella radiosa,* and *Fragilaria ulna* var. *angustissima* were the most common species for all examined sites. Furthermore, the results indicate that at sites located along the Wełna and Nielba rivers a trend of diatom increase in the biomass was observed behind the crossing. In this study we found that diatoms and green algae dominated in the Nielba river, while cyanobacteria domination was typical for the Wełna mainly before the crossing rivers. The analysis of the number of psychrophilic and mesophilic bacteria indicated the greater number of bacteria in the Wełna river compared to the Nielba. We think that the process of mixing waters of two rivers are responsible for the reduction in bacterial cell numbers in the Wełna water.

Keywords: phytoseston, heterotrophic bacteria, lowland rivers, spatial changes, summer period

Introduction

During the past few years it has been shown that microorganisms and their role in the food web of aquatic ecosystems are important [1-3]. The way in which the effects of season and trophic status interact to influence the structural composition of phytoseston communities and the function of microorganisms in the ecosystem has yet to be defined. Since the Wełna and the Nielba river crossing in the town of Wągrowiec is a rare hydrological phenomenon in Poland, studies of the phytoplankton primary production, biomass, and succession of algae species in both rivers are being conducted over the course of a few years [4, 5]. However, these examinations need to be expanded to include microbiological parameters, which would include analyses of the composition and dynamics of the heterotrophic bacteria.

The composition of the algae community in the water of the river is reflecting environmental conditions appearing in it. This phytoseston structure is connected not only with pH and chemical composition [6-8] in river waters, but also with a hydrological factor that is undisturbed flow of water [9-11].

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The last factor is in direct connection with the water level in the river and the intense development of aqueous plants. The Wełna river (Wągrowiec) is hydrologically diverse with the average 3.46 m^3s^{-1} flow of water current and often is characterized by the lowered water level (to 1 m or less) in the summer period (mainly July). Moreover, the Nielba river also has a much lower water level in this period (about 0.5 m) compared to the spring and autumn seasons. Seasonal phytoplankton biomass changes in the Wełna river is connected with phytoseston peaks in the spring and autumn [12] but the intense development of plants can supply the pelagic zone in periphytic species and to contribute to coming into existence the peak of the phytoseston biomass in the summer. Moreover, the slow water movements support the development of cyanobacteria and green algae in the lowland rivers [13].

The Nielba river, which is 7 km long, starts from Lake Rgielskie. Almost in the middle for its length Nielba is crossing with the Wełna river. After water mixing in the transitional zone of crossing rivers, a modification of the species composition of phytoseston was noted [4].

Heterotrophic bacteria are the most numerous group of microorganisms in the aquatic ecosystem. These organisms play an essential role in decomposition of organic compounds suspended in water. It should be noted that bacteria were able to utilize more diverse organic substrates, including carboxylic acids and large polymers than diatoms, which can reduce competition between them [14]. That study described some species of benthic diatoms (i.e. *Nitzschia palea* (Kütz.) W. Smith) that have the ability to utilize a wide range of organic substrates but whose uptake mechanisms are more active under light-limiting conditions. However, such interaction was investigated only *in situ* and still needs to be examined under natural conditions. In addition, the changing in the population of different physiological groups of bacteria reflects the state of the water or reaction to contamination [15]. Waters contaminated by fecal material from men and animals may contain a variety of human pathogenic microorganisms. The densities of the coliform group of the *Enterobacteriaceae* is a significant criterion of the degree of pollution and sanitary quality [16].

The investigation was concentrated on estimation of the changes that, under the influence of the slow water movement during summer months, occur in the qualitative and quantitative structure of phytoseston of the Wełna and Nielba rivers. One from the aims of this study was to describe the distribution of heterotrophic bacteria in both rivers. We wanted also to answer the question of whether the crossing of the rivers leads to changes in the number of bacteria and phytoseston biomass in the water of these rivers.

Material and Methods

The study area is situated in Wągrowiec town (the Wielkopolska region) in the catchment area of the Warta River. The flow of the water current clearly diversified rivers: the Wełna 3.44-3.58 $m^3 \cdot s^{-1}$ and Nielba 0.89-1.03 $m^3 \cdot s^{-1}$ [4]. Both rivers flow through the zone of crossing with very little changes of their currents afterwards in the summer period (Fig. 1). The Wełna river's nitrogen (average: NH_4 – 2.31 $mgN \cdot l^{-1}$) and phosphorus (PO_4 – 1.03 $mg \cdot l^{-1}$) load is higher due to sewage discharge in its catchment area than in the Nielba (PO_4 – 0.56 $mg \cdot l^{-1}$; NH_4 – 1.46 $mgN \cdot l^{-1}$). In the drainage area of both rivers includes great charges of nitrogen and phosphorus inflow, both from a surface source as well as from point sources. Charges of nitrogen amount to 241,062 kgN/year in the Wełna, and 143,716 kgN/year in the Nielba, and in the case of phosphorus 5,738 kgP/year and 4,999 kgP/year, respectively. Its phytoplankton is very productive, often achieving high biomasses owing to the high nutrient levels [4, 5].

The Nielba is smaller than the Wełna, with a mean depth of 0.9 m. The mean nutrient content of Nielba waters is lower than those of the Wełna, but still it has waters classified as eutrophic [5].

The research was carried out in the summer season from June to September of 2007 at 2-week intervals from 4 sites (2 before and 2 after river crossings) along the Nielba, as well as the Wełna. The locations of water sample sites is presented in Fig. 1.

In summer the Wełna's maximum depth was 2.0 m (average depth is 1.45 m) while in the Nielba the maximum depth was smaller and gained 1.2 m (the average is 0.72 m). The water samples for biological analyses were taken every time from the surface zone (0-0.3 m). At the same time, physicochemical parameters (pH, conductivity, temperature, dissolved oxygen, reactive phosphorus, nitrate, and ammonium nitrogen) of water were regularly determined according to Standard Methods for Examination of Water and Wastewater (1992). The distribution and flow of water currents along the rivers were estimated using the hydrometric current meter, hydrometric float, fluorescein, and murexide solution [17].

River water samples for microbiological analyses were collected once a month from June to September 2007. All

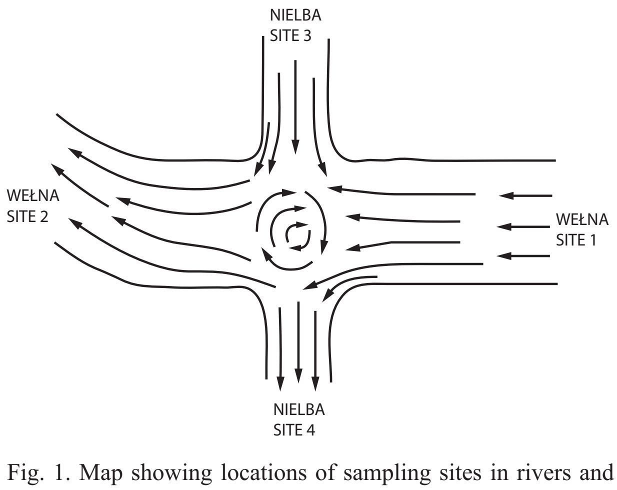

Fig. 1. Map showing locations of sampling sites in rivers and the spatial distribution of water current (according to Kicman [17]) in the area of the Wełna and Nielba river crossing. Each site is 500 m from the crossing.

Table 1. Spatial changes in water depth and flow in the Wełna and Nielba rivers during 2007.

Wełna River		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean depth of water [cm]	Site 1	155	157	230	170	152	152	150	145	150	150	155	150
	Site 2	155	153	230	165	150	145	140	140	145	146	150	145
Flow [$m^3 \cdot s^{-1}$]	low	3.23	3.38	4.34	4.34	2.81	1.12	0.51	0.89	1.40	1.50	2.06	2.65
	mean	4.27	4.96	6.19	6.21	4.31	2.08	1.32	1.48	1.67	1.89	2.62	3.55
	high	5.52	6.63	8.47	8.70	6.07	3.63	2.84	2.68	2.09	2.51	3.22	4.82
Nielba River		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean depth of water [cm]	Site 3	125	137	156	129	108	60	75	90	80	87	80	91
	Site 4	130	137	156	132	117	110	110	120	115	120	125	120
Flow [$m^3 \cdot s^{-1}$]	low	0.55	0.58	0.84	0.82	0.50	0.34	0.27	0.31	0.43	0.44	0.45	0.39
	mean	0.72	0.74	0.96	0.90	0.78	0.58	0.40	0.42	0.51	0.56	0.58	0.70
	high	1.30	1.80	2.21	2.14	1.20	0.73	0.86	0.80	0.90	1.19	1.02	1.10

samples were collected in sterile bottles kept at 4ºC and analyzed. The total number of heterotrophic bacteria (TVC): psychrophilic (TVC 20ºC for 72 h) and mesophilic (TVC 37ºC for 24 h) was determined by the spread plate method according to Csuros and Csuros [15].

The total number of coliform bacteria (TC) was determined by the most probable number method (MPN) [16].

The ability of bacteria to degrade proteins, starch, and lipids were examined by spreading the diluted water onto plates with agar medium supplemented with 0.4% gelatin or 0.2% soluble starch or 0.01% $CaCl_2 \cdot H_2O$ and 1% Tween 80 (oleic acid ester). The plates were incubated for 48 h. The ability to hydrolyze proteins was tested using gelatin-precipitating reagent (15% $HgCl_2$ in 20% [vol/vol] HCl). Amylolitic bacteria were determined using iodine solution. Lipolitic properties of the bacteria were determined on the basis of an opaque halo around bacterial colonies [18].

The qualitative and quantitative composition was ascertained by counting the cells in a Kolkwitz sedimentation chamber. The phytoseston species of algae were determined according to taxonomical books [19-27]. Cells were the main counted units. For filamentous cyanobacteria and green algae, the length unit of 100 µm was taken for one individual. Biovolume calculations were based on cell shape and calculated using the formula for the appropriate geometric shape [28, 29]. The diversity index H'calculations were based on the phytoplankton biomass concentrations and expressed with the Shannon-Weaver method [30].

Statistical analyses [31] was used in order to determine the effect of site on the biomass of algae in the summer period (n=8). For statistical analysis only, those algae species that had a high level of frequency in the examined material were selected. Species of low frequency (below 30%) were not included in the analysis in order to improve the accuracy the final calculations.

Results

The flow of the water currents of both rivers varied slightly temporally and spatially during the study period (Table 1). Generally, the distinct decrease in the flow of water in both rivers (twice in the Nielba and over eight times until spring in the Wełna) in the period of July and August was observed.

At the sampling sites before and behind the crossing, the temperature of the Nielba water was 1ºC higher in comparison with the Wełna water (14-25ºC). At the locations behind the middle of the river crossing, the water temperature increased slightly only in the Nielba river. It reached the maximum in August and decreased to 20ºC in the beginning of September. Behind the middle of the river crossing, the water temperature increased by several tenths in the Nielba, while in the Wełna it remained unchanged.

The concentration of nutrients in the water of both rivers was very high, with the highest concentrations noted in July 2007 (conductivity 1,478 µS/cm, nitrate 2.759 $mg \cdot l^{-1}$, phosphates 1.245 $mg \cdot l^{-1}$ at site 1; and 1,470 µS/cm, nitrate 2.703 $mg \cdot l^{-1}$, phosphates 1.214 $mg \cdot l^{-1}$ at site 2 in the Wełna; and appropriately 894 µS/cm, 0.756 $mg \cdot l^{-1}$, 0.563 $mg \cdot l^{-1}$ at site 3; and 901 µS/cm, 0.793 $mg \cdot l^{-1}$, 0.601 $mg \cdot l^{-1}$ at site 4 in the Nielba). The Wełna was characterized by frequent inflow of fertile waters from its upper sections and their distinct increase in the July-August period was observed. Generally lower concentrations of nutrients were noted in the Nielba.

In the water of both rivers, concentrations of dissolved oxygen were not lower than 65% of saturation during July, and they slightly increased during the following months with the highest average values of 102% in September 2007. During the time of our study, concentrations of dissolved oxygen in the water varied from 65% to 102% at site 1, from 71% to 102% at site 2, from 76% to 100% at site 3, and from 74% to 101% at site 4.

The results of the research on the number of heterotrophic psychrophilic (TVC 20ºC) and mesophilic (TVC 37ºC) bacteria in Wełna and Nielba waters are presented in Figs. 2 and 3. The analysis indicated the greatest number of bacteria in the Wełna at the downstream sites (site 1) compared to the upstream sites (site 2). The number of mesophilic bacteria in river water collected at site 1 varied from 1.4 x 10^4 to 2.3 x 10^4 cells/ml, the number of bacteria in river water at site 2 ranged from 7.7 x 10^3 to 9.9 x 10^3 cells/ml. During four months of our research, the mesophilic bacteria occurred in a considerably lower amount than psyhrophilic bacteria. It is estimated that the number of psychrophilic bacteria in the Wełna at site 1 ranged from 8.9 x 10^4 to 1.1 x 10^5 cells/ml, the number of these bacteria in water at site 2 ranged from 5.0 x 10^4 to 7.3 x 10^4 cells/ml. This study indicated the greater pollution of the Wełna water relative to the Nielba. With one exception, the number of mesophilic and psyhrophilic bacteria was slightly lower in the Nielba before crossing the Wełna. The maximum number of bacteria in river water was noted in June. Interestingly, in August the number of mesophilic bacteria in water at site 3 (before crossing) was 4.6 x 10^3 cell/ml, while 2.7 x 10^3 cell/ml at site 4 (after crossing). These higher counts of bacteria in Nielba at site 3 region than site 4 can be explained by the discharge of effluents directly into Nielba near site 3. In the remaining study period (July, August, September), we noted a lower level of bacteria in the Nielba water before crossing the Wełna. The number of mesophilic bacteria in water at site 3 ranged from 2.7 x 10^3 to 4.6 x 10^3 cells/ml, while the number of mesophilic bacteria at site 4 varied from 2.7 x 10^3 to 5.0 x 10^3 cells/ml.

The results of research on the total number of coliform bacteria (TC) indicated that the highest number of these bacteria was in the Wełna at site 1 (Fig. 4). At this site the total number of coliform bacteria (TC) oscillated around 46 x 10^3 cells/100 ml of water. A lower number of coliform bacteria was noted at the upstream sites (2) of the Wełna, where the river did not receive wastewater discharge. The number of coliform bacteria in the Wełna collected at site 2 ranged from 15 x 10^3 cells/100 ml to 24 x 10^3 cells/100 ml. The total number of coliform bacteria in the Nielba river varied from 9.3 x 10^3 to 15 x 10^3 cells/100 ml.

Proteo-, amylo- and lipolytic bacteria were present in Wełna and Nielba water samples collected from four sites. Proteolytic and amylolytic bacteria have represented a considerable fraction of the heterotrophic bacteria living in the Nielba and Wełna (Fig. 5). The least numerous were lipolytic bacteria. Moreover, a significant decrease in the number of bacteria capable of degrading protein was observed along the length of the Wełna (Fig. 4). In summer the number of bacteria hydrolyzing protein was 11 x 10^3 cells/ml in water collected at site 1, whereas in water collected at site 2 it was 7.8 x 10^3 cells/ml. Similarly, we noted a higher number of amylolytic and lipolytic bacteria in water samples of site 1 than site 2. Our results demonstrated that the

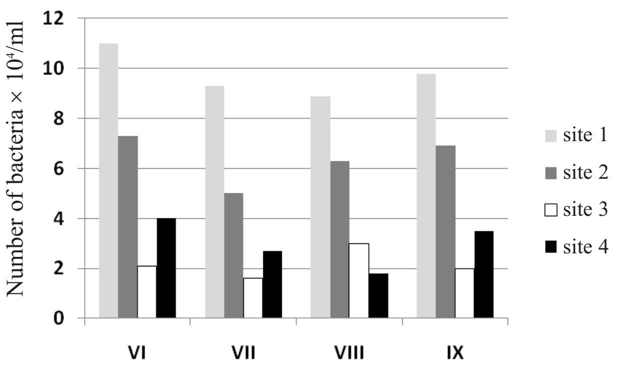

Fig. 2. Total number of heterotrophic bacteria (TVN 20ºC) in water of the Wełna and Nielba rivers.

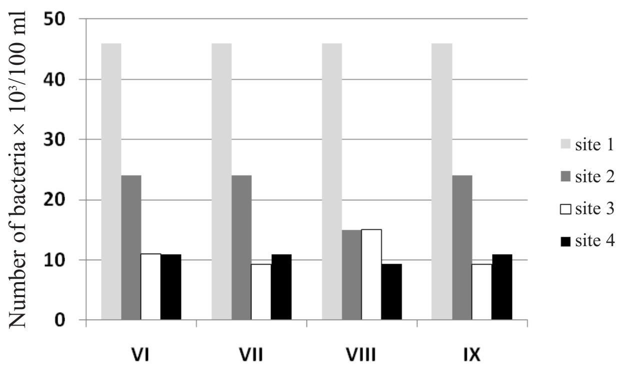

Fig. 4. The total numbers of coliform bacteria (TC) in water of the Wełna and Nielba rivers in the summer period.

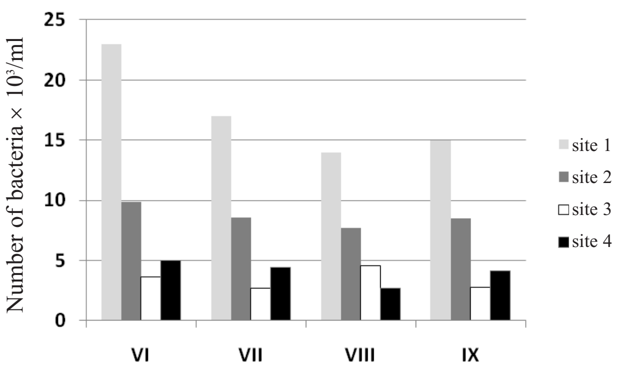

Fig. 3. Total number of heterotrophic bacteria (TVN 37ºC) in water of the Wełna and Nielba rivers.

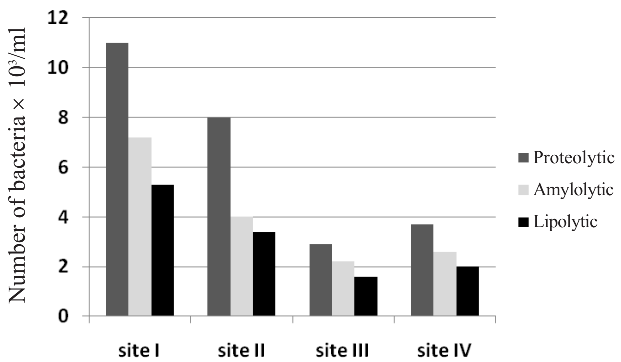

Fig. 5. Physiological groups among bacteria in the Wełna and Nielba rivers in the summer period.

Table 2. Changes of biovolume in the most numerical phytoseston groups in the Wełna and Nielba rivers from June to September 2007 (the data are expressed as weighted month averages for respective stations; n=2).

station		Wełna – site 1	Wełna – site 2	Nielba – site 3	Nielba – site 4
Number of algae species		49	53	50	54
Biovolume of diatoms [$mg \cdot l^{-1}$]	June	2.076	3.593	3.036	3.214
	July	8.871	10.351	9.057	10.038
	August	5.003	5.341	4.692	4.989
	September	7.102	9.715	4.041	4.479
Biovolume of cyanobacteria [$mg \cdot l^{-1}$]	June	3.004	2.791	0.693	0.601
	July	9.297	8.948	3.721	3.648
	August	5.320	5.298	1.451	1.403
	September	9.261	8.597	1.210	1.204
Biovolume of green algae [$mg \cdot l^{-1}$]	June	4.162	3.830	2.459	2.317
	July	11.169	11.201	7.391	7.286
	August	5.139	5.147	2.096	1.531
	September	6.253	5.906	5.103	4.467

number of bacteria degrading proteins, starch, and lipids was slightly higher at site 4 than 3.

The taxonomical structure of phytoseston differed clearly between the examined rivers and particular sites. From all taxonomical groups, 136 species of algae were identified in the summer of 2007: 94 in the Wełna and 118 in the Nielba. Every single time, at sites behind the zone of crossing rivers, on average 4 taxa more in phytoseston community of each river were registering down (Table 2). A group of common species for both examined rivers (sites 1-4) with *Gomphonema parvulum, Tychonema granulatum, Cryptomonas ovata, Aulacoseira granulata, Cocconeis placentula, Monoraphidium contortum, Planctolyngbya limnetica, Cyclotella radiosa,* and *Fragilaria ulna* var. *angustissima* were represented in large numbers among other algae. The Shannon-Weaver biodiversity index was very high in the rivers and reached at sites 1 and 2 the mean values of 3.67 and 3.81, respectively, in the Wełna and 3.70 at site 3 and 4.05 at site 4 in the Nielba.

Diatoms, green algae, and cyanobacteria were the dominant components of the phytoseston community in the rivers during the summer period. The analysis indicated that in both locations of the Wełna river the species *Tychonema granulata, Planctolyngbya limnetica, Desmodesmus communis, D. subspicatus, Scenedesmus acuminatus, Coelastrum astroideum, C. microporum, Ankistrodesmus griffithii,* and *Tetraëdron minimum* occurred in significant biomass. The biomass of phytoseston varied from 9.9-42.8 $mg \cdot l^{-1}$ at site 1 and from 7.5-45.6 $mg \cdot l^{-1}$ at site 2 in the Wełna, as well as 7.4-24.1 $mg \cdot l^{-1}$ at site 3 and 7.2-25.6 $mg \cdot l^{-1}$ at site 4 in the Nielba, with maximum values in July and September 2007 (Fig. 6). Moreover, a temporary rise in green alga *Coelastrum astroideum* and diatoms *Cocconeis placentula*, *Cyclotella meneghiniana,* and some species from the *Gomphonema* participation in the total biomass of phytoseston was stated at site 2. Despite all of this, green algae and cyanobac- teria distinctively dominated site 1 while a remarkable increase of diatoms was recorded at site 2 (Table 2).

Analysis of the Nielba river phytoseston com- munity in terms of biomass is in Fig. 6. On both sites diatoms reached the biggest biomass (Table 2) with the distinct dominance of species: *Cocconeis placentula* (mean 0.263 $mg \cdot l^{-1}$; 51% of the biomass of diatoms), *Nitzschia recta* (0.094 $mg \cdot l^{-1}$; 18% of the biomass of diatoms), and *Cymbella minuta* (0.027 $mg \cdot l^{-1}$; 8% of the biomass of diatoms).

The highest biomass of diatoms appeared at sites 2 and 4, behind the Wełna and Nielba crossing zone (Table 2), on account of *Cocconeis placentula's* large participation in the composition of the phytoseston.

The second group of algae of the Nielba in terms of biomass were green algae with the biomass in the range from 1.531 $mg \cdot l^{-1}$ to 7.391 $mg \cdot l^{-1}$ (Table 2). *Coelastrum micropo-*

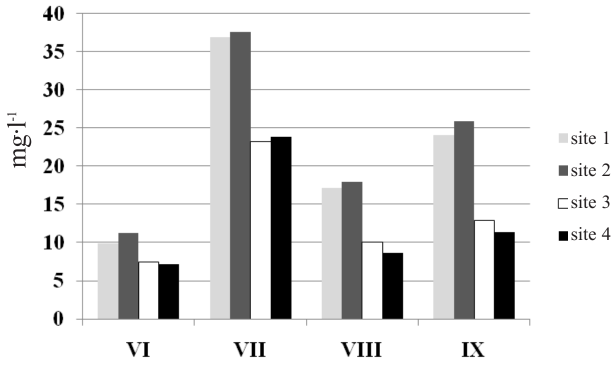

Fig. 6. Mean biomass of phytoseston from June to September 2007 in particular Wełna and Nielba locations.

rum (0.135 mg·l⁻¹; 34%), *Euastrum sublobatum* (0.098 mg·l⁻¹; 24%) and *Pediastrum boryanum* (0.092 mg·l⁻¹; 23%) achieved the distinct dominance in the phytoseston community. At site 3 *Coelastrum microporum* and *Pediastrum boryanum* created large biomass, while at site 4 it was *Coelastrum microporum* and *Euastrum sublobatum*. Cyanobacteria, on account of the little number in the Nielba, reached biomass less significantly for the community of the phytoseston (despite *Planktothrix agardhii* and *Tychonema granulatum*).

At most of the stations located along the Wełna and Nielba after their crossing, a trend of increasing in the percentage share of the total algae biomass was observed (Fig. 7). Out of 136 taxa of summer algae, *Desmodesmus communis, Tychonema granulatum, Leptolyngbya limnetica, Planktothrix agardhii,* and *Cocconeis placentula* reached high densities in both rivers and revealed a distinct spatial differentiation. The most characteristic situation of the spatialal distribution of these species is shown in Fig. 7.

Analysis of the spatial distribution of phytoseston biomass between different rivers sites revealed statistically significant differences (Z=-3.745; p<0.01) (Fig. 8).

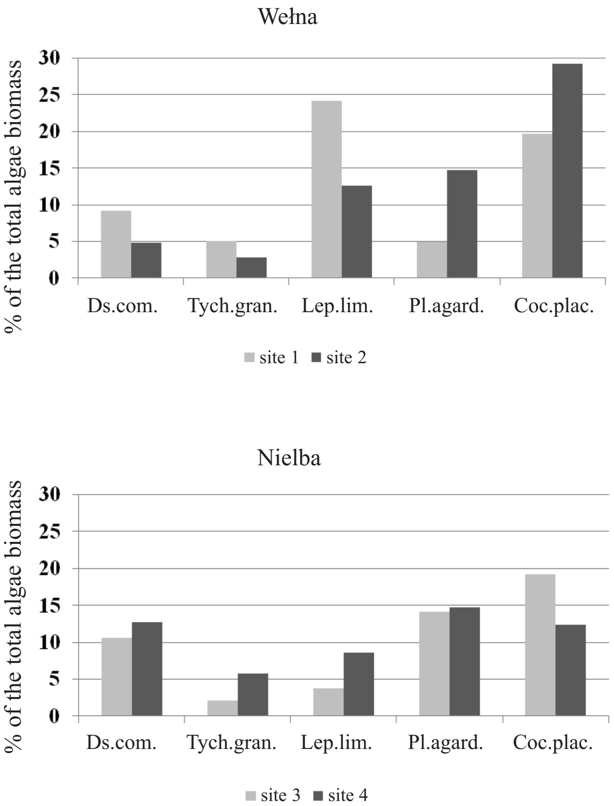

Fig. 7. Spatial changes in the algae biomass structure of species in August 2007.
Ds.com. – *Desmodesmus communis*,
Tych.gran. – *Tychonema granulatum*,
Lep.lim. – *Leptolyngbya limnetica*,
Pl.agard. – *Planktothrix agardhii*,
Coc.plac. – *Cocconeis placentula*.

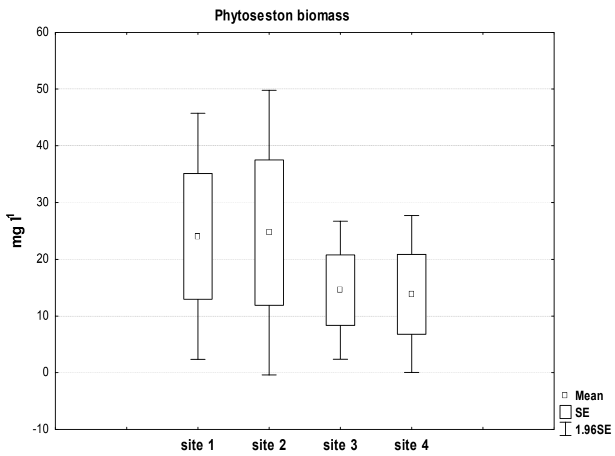

Fig. 8. Difference between values of summer planktonic algal biomass in examined rivers.
site 1 – Wełna before crossing;
site 2 – Wełna behind crossing;
site 3 – Nielba before crossing;
site 4 – Nielba behind crossing.

Discussion

The Nielba is a small lowland river that flows through the area of the city of Wągrowiec. Crossing with the Wełna River constitutes an interesting and rare hydrological phenomenon because the mixing of both river waters in the crossing place is takes out only 10% [4]. Phycological examinations on the two rivers were carried out in the summer period of 2007, on four different locations of the rivers in the area of Wągrowiec.

In the Wełna the flow of water decreased during the summer period, which supported overgrowing the river by aquatic plants (*Sagittaria sagittifolia*, *Callitriche* sp.). The stagnating water created better conditions for the development of both green and blue-green algae, which confirms previous reports on this topic [13]. The phosphorus and nitrogen influx from the catchment area to the river waters plays an important role [32, 33] in phytoseston development, and clearly contributes to the more intensified occurrence of cyanobacteria in the Wełna than the Nielba. Our results clearly show that, the Nielba was less polluted than the Wełna. This might be an effect of pollution from the urban agglomerations located along the Wełna in the upper parts of this river. Moreover, some of our observations in the catchment area of this river suggested inflow of waters from fish ponds along the upper parts of the river in periods of high-flow conditions [5].

Koch et al. [34] indicated that heterotrophic bacteria were largely dependent on allochthonous carbon during summer low flow. Thus the input of raw sewage directly into the Wełna near site 1 is responsible for such a high number of heterotrophic bacteria. A decrease in the number of bacteria was observed in the Wełna at site 2. The reduction in the number of psyhrophilic bacteria in the Wełna after crossing with the Nielba ranged from 30% to 47%, while the reduction of the number of mesophilic ranged from 44% to 57%. This change in the number of heterotrophic bacteria in the Wełna indicated that self-cleaning process of the water occurred. We think that mainly the dilution affect as the consequence of the mixing waters of two rivers are responsible for the reduction in bacterial cell numbers in the Wełna water. As mentioned above, the Nielba river is less polluted than the Wełna. Importantly, we did not observed significant increases of the level of heterotrophic bacteria in Nielba water after crossing the Wełna. In one case we noted higher number of bacteria in Nielba waters before crossing the Wełna. Probably, in this time intensive effluent was a significant source in bacteria to the river. Our study also demonstrated that the total number of coliform bacteria was higher in the Wełna than in the Nielba.

Based on the total biomass of the summer phytoseston community, some similarities were obtained between certain rivers. The analysis indicated that in both rivers the following species occurred in significant biomass: *Tychonema granulata, Planctolyngbya limnetica, Desmodesmus communis, D. subspicatus, Scenedesmus acuminatus, Coelastrum astroideum, C. microporum, Ankistrodesmus griffithii,* and *Tetraëdron minimum*. All species of algae whose populations built the phytoseston biomass belong to cosmopolitan taxa and are tied to eutrophic waters [9, 19, 30].

Parallel in both rivers, the highest concentrations of algae biomass were recorded in July and at the end of summer. Algae could gain very high density due to increased water retention time and decreased vertical mixing intensity (reduced flow velocity) in the Wełna during the summer season. Additionally, high phosphate and nitrogen value concentrations along both rivers indicate that during summer light and temperature were important growth factors for algae. Higher temperature and increased light contributed to rapid phytoplankton growth (noted in June) similar to that observed during spring blooms. On account of the slow water movement with summer in both investigated rivers, the phytoseston was not transported away or sedimented only the biomass was accumulated and reached high levels. Such periodic rapid development was observed for green alga *Coelastrum astroideum* and diatoms *Cocconeis placentula*, *Cyclotella meneghiniana,* and some species from *Gomphonema* (mainly at site 2). These diatoms were mainly included in the periphyton community and in the result of the river current action were torn off and moved to the pelagic water layer. A distinct trend of remarkable increase of diatoms in the Wełna was stated on the site behind the crossing. In the phytoseston community, structure periphytic and benthic species were numerous and under the influence of the increasing water level were transported into the lower part of the Wełna. A similar situation was stated in the case of the Nielba. This agrees with the associations described by other authors [35-37] for shallow and long-retention-time rivers, where periphytic and benthic species are easily torn off by the water velocity and may have been a factor affecting the amount of diatoms in suspension as the phytoseston component. The development of diatoms is also prevented by grazing pressure at the same time [1, 6, 38].

Observations connected with algae distribution in the transect of the Nielba demonstrated the considerable degree of unification of the species structure for all sites. The presence of characteristics for the littoral zone green algae species like *Pediastrum boryanum* and *P. duplex* in the phytoseston of this river also indicated the mixed-up character of the algae community, including representatives of different ecological groups. Algae species *Cosmarium regnellii, Coelastrum microporum, Microcystis aeruginosa, Woronichinia compacta,* and *Planktothrix agardhi,* taken out with the current of the river from Lake Rgielskie, were noted in the quantitative structure of phytoseston on the Nielba before the crossing. Behind the river crossing algae biomass formed by lacustrine species were clearly decreased.

The frequency of green algae demonstrated the slight increase that could be caused by the flow of a certain amount of species from the Wełna, mainly of small cells from the *Scenedesmus/Desmodesmus* genera. The increase of *Closterium moniliferum* participation in the phytoseston community was noted only at the site before and after the river crossing. Similarly *Euastrum verucosum, Closterium ehrenbergianum, Closterium acutum, Closterium acutum* var. *variabile, Closterium pronum*, *Cosmarium variolatum*, and *Cosmarium phaseolus* were characteristic only of these sites. *Coelastrum astroideum*, *Cryptomonas erosa, Euglena pisciformis,* and *Anabaena flos-aque* were the most characteristic species with the high constancy of appearing in the Nielba sites behind the crossing.

Recently, in a study by Antoine and Benson, Evans [39] and Train and Rodrigues [40], in rivers the structure of phytoseston communities varies among particular locations. Similarly, our results indicate that it is not only the dominant species that varies among locations, but also the density of the component species. This investigation demonstrated the dominance of diatoms and green algae in the total phytoseston biomass of individual taxonomical groups of algae in the Nielba, while by these groups a considerable share of cyanobacteria was noticed in the Wełna. Starting from the first site on the river, diatoms were a distinct group dominating in the communities of the phytoseston. Together with direction of the Nielba flow, diatoms preserved their dominance, constituting the greater percentage participation in total biomass every now and then. However, together with the flow diatoms and green algae, participation in biomass increased in both rivers. At the first site in the Wełna (1) and the Nielba (3) a slight participation of remaining taxonomical groups appeared, i.e. Cryptophyta and Dinophyta.

The data obtained from this study showed spatial similarities as well as certain differentiation between the stations in both the Wełna and Nielba rivers. A comparison of phytoseston communities in the investigated rivers revealed that the Wełna overtakes some of the Nielba species as well as inversely. The water current flow was important for the differentiation and instability of the summer algae community [1, 9-11, 36]. Most often diatoms dominate in the phytoseston community of rivers [6, 8, 37, 33]. Diatoms dominated in the summer phytoseston in relation to the turbulence of water in rivers, which involves diatom cells separated from benthos and periphyton in the Wełna, as well as in the Nielba though to the lower scale.

The phytoplankton and heterotrophic bacteria analyses indicate that the Wełna is more polluted than the Nielba. And our studies suggest that the Wełna waters, after crossing with the Nielba, is less polluted. Thus the process of mixing waters of rivers is responsible for the spatial changes of both biological parameters in these lowland rivers.

Acknowledgements

This research was financially supported by the Ministry of Science and Higher Education (Project No. 2PO4G 003 30).

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