

Oceanological and Hydrobiological Studies  
Vol. XXXII, No. 2

Institute of Oceanography

(33-43)  
2003

University of Gdańsk

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Research Article

**SPATIAL DISTRIBUTION OF CHLOROCOCCALEAN GENERA IN  
THE PHYTOSESTON OF THE WEŁNA AND NIELBA RIVERS**

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**Key words:** spatial distribution, rivers, summer period, phytoseston, *Chlorococcales*

**Abstract**

The chlorococcalean flora from two crossed rivers during the summer period (from July to September 2001 and 2002) was examined. Phytoseston communities were collected from the Wełna and Nielba rivers before and behind the cross-rivers as well as from the central place of the cross-rivers. Species belonging to 6 dominant genera: *Scenedesmus*, *Pediastrum*, *Monoraphidium*, *Ankistrodesmus*, *Coelastrum* and *Tetraedron* were found in both rivers. At most of the stations located along the Wełna and Nielba rivers after their crossing a trend of increasing green algae species richness together with an increase in the total species number of cells was observed. Furthermore, it was found that the Wełna river takes over some of the Nielba phytoseston species.

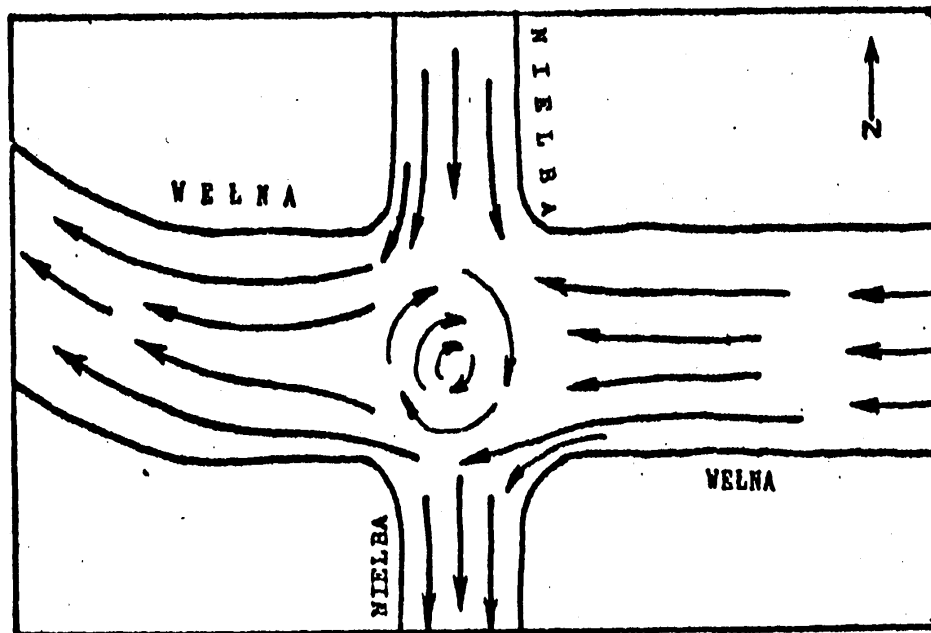
**INTRODUCTION**

The perpendicular intersection of the Wełna and Nielba rivers phenomenon in Wągrowiec (Poland) arose from the land melioration work in the years 1870-1880. This rare phenomenon, observed not only in Poland but also in Europe, is only up to 10% a result of the mixing of Wełna and Nielba waters in the crossing division. After mixing in the transitional zone of crossing rivers the

process of phytoseston self-ordering towards a balanced state in algal populations should take place. The definite mechanisms responsible for such a model of spatial distribution of algae, including *Chlorococcales*, have remained unknown. Some authors proved that changes in the structure of the phytoseston community are connected with differences in density rather than with a modification of the species composition (Georgio *et al.* 1991, Schumann *et al.* 1992, Solari 1995). Others stressed the role of physical factors in phytoseston distribution on temporal and the horizontal scales (Meybeck 1996, Reynolds 1994, Reynolds *et al.* 1994). The changes in the algae structure, concerned the Welna – Nielba model, have still not been the object of analysis.

Phytoseston is a fraction of passively transported microscopic plant organisms in water, and this is why the current of water can be an effectively selective environmental factor.

Thus, this work was undertaken in order to: (i) determine the spatial distribution of chlorococcalean algae in the surface zone of two rivers during the July - September season of 2001 – 2002, and (ii) identify the role of the water current as the environmental factor controlling the distribution of phytoseston in both rivers.



**Fig. 1.** The spatial distribution of water current in the transitional zone of the Welna and Nielba river crossing (according to Kicman 1894).

## MATERIAL AND METHODS

The study area is situated in the northern part of the Wielkopolska region in the catchment area of the Warta river. The area in which both rivers cross is wet. The studied rivers were hydrologically diverse and were characterised by a distinct speed of the water current: the Wełna  $3.44 - 3.58 \text{ m}^3 \cdot \text{s}^{-1}$  and Nielba  $0.89 - 1.03 \text{ m}^3 \cdot \text{s}^{-1}$ . Both rivers flow through the zone of crossing without changing their currents afterwards (Fig. 1). Behind the Wełna and Nielba intersection the similarity coefficient of algae in 2000 was up to 40% of the total community structure, which suggested that algae communities from both rivers were mixed (Messyasz 2001).

In relation to the level of phosphorus concentration the Wełna river (117 km long) was classified as off-class waters (Szeremietiew 1994, 1997).

The Nielba river, which is 7 km long, starts from Lake Rgielskie and has waters of the second class (Szeremietiew 1994, 1997).

Water samples from the surface zone were taken five times each month in the summer period (July to September) in 2001 - 2002. Sampling stations were assigned 100 m, 50 m and 25 m before and behind the Wełna and Nielba crossing and additionally in the middle of the crossing. The data presented in this article are expressed as weighted averages for three stations before and behind the crossing respectively. Quantitative analyses of phytoseston were conducted using the Kolkwitz sedimentation chamber. Cells were the main counting units. To calculate the biovolume (biomass), the species were approximated to simple geometric or combined forms (Edler 1979, Rott 1981). Species richness was referred to as the number of algal taxa in each sample. Jaccard's similarity coefficient for respective stations was calculated according to Kawecka and Eloranta (1994). The research on the physiochemical features of waters was conducted using the standard methods accepted in this field (Elabanowska *et al.* 1999).

The distribution and speed of water currents along the rivers and in the zone of their intersection were estimated using the hydrometric current meter, hydrometric float, fluorescein and murexide solution (Kicman 1984).

## RESULTS

The temperature of the Nielba water was  $1^\circ\text{C}$  higher in comparison with the Wełna water ( $19 - 22^\circ\text{C}$ ). Behind the middle of the river - crossing, the water temperature increased by several tenths in the Nielba, while in the Wełna it remained unchanged.

**Table 1**

Changes in the concentration of oxygen, total nitrogen and total phosphorus and other environmental variables of Wełna and Nielba waters (July to September 2001 and 2002). The data presented in this table are expressed as weighted monthly averages (2001 and 2002) for three stations before and behind the crossing respectively.

Environmental variables	Wełna before (n = 30)	Nielba before (n = 30)	Wełna behind (n = 30)	Nielba behind (n = 30)
Secchi disk (cm)				
VII	50	30	50	40
VIII	45	40	50	40
IX	70	60	70	60
PH				
VII	7.06	8.07	7.10	8.03
VIII	8.43	8.90	8.25	8.50
IX	8.26	8.70	8.40	8.60
Conductivity ( $\mu\text{S cm}^{-1}$ )				
VII	1233	1396	1245	1340
VIII	1478	1533	1420	1500
IX	1194	1250	1073	1200
Dissolved oxygen (% saturation)				
VII	106.5	98.6	108.4	97.9
VIII	109.3	76.4	114.2	76.7
IX	133.2	108.3	129.6	112.5
Total nitrogen ( $\text{mg L}^{-1}$ )				
VII	9.3	10.2	9.4	9.8
VIII	9.7	12.0	9.8	11.4
IX	6.9	7.4	6.8	7.02
Total phosphorus ( $\text{mg L}^{-1}$ )				
VII	2.1	2.25	2.1	2.15
VIII	2.6	3.0	2.7	2.9
IX	1.6	1.9	1.65	1.8

The concentration of nutrients in both rivers was very high and their distinct increase in August was observed (Tab. 1). The inorganic phosphorus concentrations were much higher than the inorganic nitrogen values. During a low flow of water the high concentrations of nutrients (exceeding  $\text{PO}_4 - 1.10 - 3.46 \text{ mg L}^{-1}$ ;  $\text{NH}_4 - 0.10 - 1.45 \text{ mg N L}^{-1}$ ) were observed. In most cases, after the cross – river variations in nutrient concentrations with an inconsiderable decreasing tendency in the Wełna or an increasing tendency in both rivers were observed (Tab. 1).

In the water of both examined rivers, concentrations of dissolved oxygen were small (the lowest values of oxygen saturation reached 76.4 %) during summer and they increased during autumn with the highest average values - 196.2 % in November 2001 (Tab. 1).

146 species of algae were identified in the summer of 2001 and 2002: 96 in the Wełna and 112 in the Nielba river. Diatoms (*Bacillariophyceae*) were the dominant component of the phytoseston community of both rivers almost throughout the year (Messyasz 2001, and unpublished data). In the summer of 2001 the percentage of *Chlorophyta* forms reached the values of 42% (40% in 2002) of the total number of algal cells in the Wełna and 21% (25% in 2002) in the Nielba river. At the same time *Cyanoprokaryota* constituted up to 11% and 41% of the total number of individuals respectively.

At most of the stations located along the Wełna and Nielba rivers after their crossing a trend of increasing green algae species richness together with an increase in the total species number of cells was observed (Tab. 2 and Tab. 3).

**Table 2**

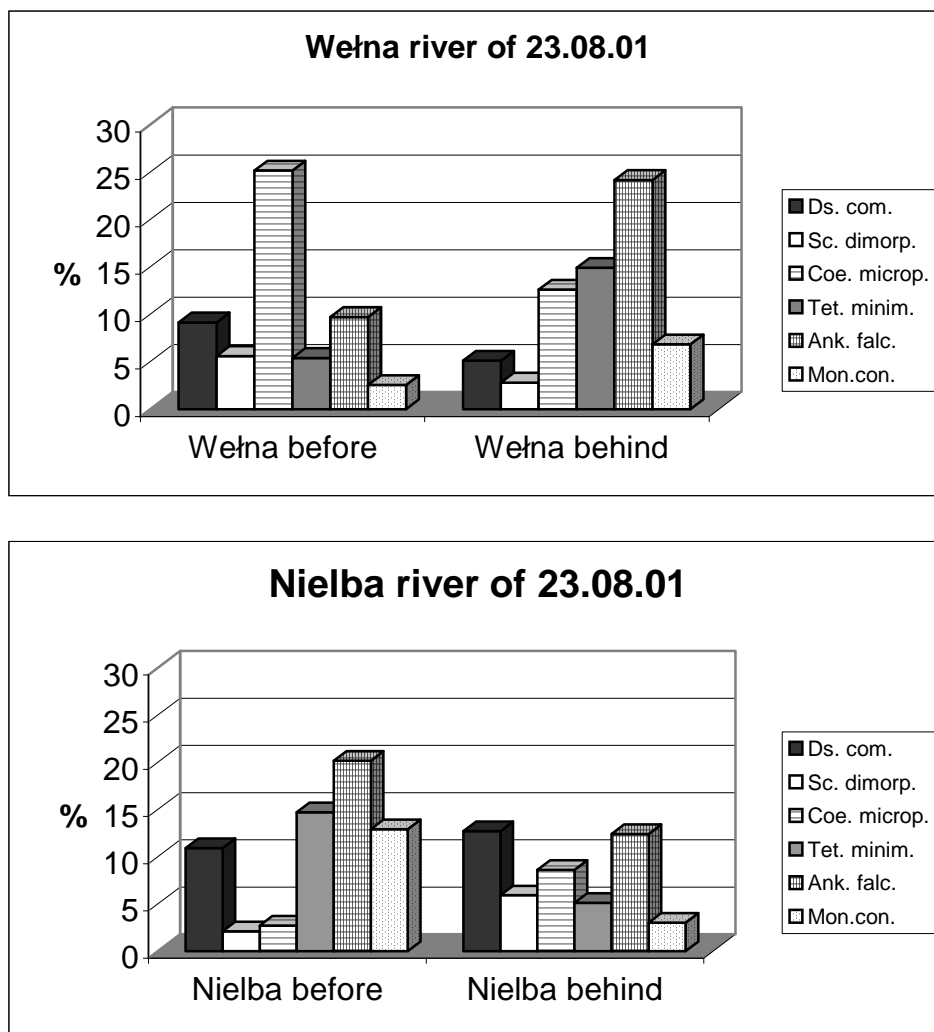
Changes in the Chlorococcales biovolume, percentage participations and species number in the Wełna river (July to September 2001 and 2002). The data presented in this table are expressed as weighted monthly averages (2001 and 2002) for three stations before and behind the crossing respectively (n = 30).

Month/station	VII 01/02 before crossing	VII 01/02 behind crossing	VIII 01/02 before crossing	VIII 01/02 behind crossing	IX 01/02 before crossing	IX 01/02 behind crossing
Number of species	27	31	29	34	28	31
Number of cells [ind. · cm <sup>-3</sup> ]	1570	1640	1830	1915	1659	1720
Number of cells [%]	38.14	40.27	41.75	42.08	33.52	34.36
Biovolume [mg · dm <sup>-3</sup> ]	0.279	0.302	0.430	0.653	0.441	0.495
Biovolume [%]	3.45	3.78	6.12	7.94	5.37	6.46

**Table 3**

Changes in the Chlorococcales biovolume, percentage participations and species number in the Nielba river (July to September 2001 and 2002). The data presented in this table are expressed as weighted monthly averages (2001 and 2002) for three stations before and behind the crossing respectively (n = 30).

Month/station	VII 01/02 before crossing	VII 01/02 behind crossing	VIII 01/02 before crossing	VIII 01/02 behind crossing	IX 01/02 before crossing	IX 01/02 behind crossing
Number of species	19	24	19	22	18	23
Number of cells [ind. · cm <sup>-3</sup> ]	745	815	737	892	654	690
Number of cells [%]	19.97	21.08	23.30	25.51	17.26	18.09
Biovolume [mg · dm <sup>-3</sup> ]	0.067	0.084	0.117	0.210	0.054	0.061
Biovolume [%]	1.60	1.93	2.87	3.10	0.91	1.25



**Fig. 2.** Spatial changes in the chlorococcalean structure of species in August 2001 (Ds. com. – *Desmodesmus communis*, Sc. dimorp. – *Scenedesmus dimorphus*, Coe. microp. – *Coelastrum microporum*, Tet. minim. – *Tetraedron minimum*, Ank. falc. – *Ankistrodesmus falcatus*, Mon. cont. – *Monoraphidium contortum*).

Out of 34 taxa of *Chlorococcales* those representing 6 genera were identified. *Desmodesmus communis* (Hegew.) Hegew., *Scenedesmus dimorphus* (Turp.) Kützing, *Coelastrum microporum* Näg. in A. Braun, *Ankistrodesmus*

*falcatus* (Corda) Ralfs, *Monoraphidium contortum* (Thur.) Kom. – Legn., *Tetraedron minimum* (A. Br.) Hansg. and *Pediastrum boryanum* (Turp.) Menegh. reached high densities and revealed a distinct spatial differentiation. The most characteristic situation of the horizontal distribution of these species is shown in Fig. 2. Comparing the densities of the *Pediastrum boryanum* (Turp.) Menegh. cells from stations before and behind the intersection a lack of changes in both rivers was noted.

In the case of the Wełna the species composition of three chlorococcalean genera (*Coelastrum* sp., *Desmodesmus* sp., *Scenedesmus* sp.) was similar irrespective of the sampling station (Fig. 2). It should also be noticed that these values were considerably lower compared to the Nielba river. In the Nielba water behind the crossing zone rapid changes in the density of *Scenedesmus* sp. were observed. However, the rebuild of the remaining green algae species of the Nielba river was observed. An increase in *Coelastrum microporum* and a decrease in the *Monoraphidium contortum*, *Ankistrodesmus falcatus*, *Tetraedron minimum* densities in the Nielba river was noted behind the intersection.

## DISCUSSION

The earlier research into freshwater ecosystems has shown that the optimum of the development of Chlorococcales occurs mainly during the summer season in shallow, eutrophic lakes (Kawecka & Eloranta 1994; Padisák and Dokulil 1994, Reynolds 1984). It was also proved that algae communities, including green algae, in rivers are less differentiated and variable than in lake ecosystems (Kawecka & Eloranta 1994; Reynolds 1984). Phytoseston communities in rivers are reflections of the past environmental conditions and carry all information that was imposed in the upper sections of the river. The most important factor is the water current whose speed is requisite for the differentiation and instability of the algae community (Allen 1977, Reynolds 1994, Schumann *et al.* 1992).

Diatoms dominate phytoseston in relation to the turbulence of water in rivers. It involves diatom cells separated from benthos and periphyton as well as transported from old riverbeds, lake lying along the river. Most often centric diatoms (Allan 1995) dominate the phytoseston community. The highest diatom concentration during the autumn period with a raised level of the Wełna and Nielba water was observed (Messyasz, 2002). The data obtained by Antoine and Benson – Evans (1986) and Train and Rodrigues (1998) confirmed the greatest variety and abundance of phytoseston noticed in the community of diatoms in the spring and autumn seasons. As it follows from the tabulated data, it is obvious that chlorococcal algae played an important role in the summer

phytoplankton assemblages in the Wełna river. In the summer of 2001 and 2002 during low water with a decrease in the turbulence of water and increase in phytoplankton cell numbers the dominance of green algae in the Wełna and blue – greens in the Nielba river was observed. The more intensified occurrence of *Cyanoprokaryota* in the Nielba than Wełna river could have been influenced by many factors: a slower flow of water, higher water temperature (Kawecka and Eloranta 1994), and higher nitrogen and phosphorus influx from the catchment area (Lampert and Sommer 1996).

The high nutrient concentration stimulated the development of phytoeston in both studied rivers. Both inorganic N and P are far above the limiting levels, therefore they do not explain the situation connected with phytoeston. Light is frequently considered to be a limiting factor of phytoeston production. The waters of rivers are generally permanently mixed and phytoplankton cells reside through short time in the euphotic zone. Algae can gain very high density and limit the light due to the slow flow of water in the Nielba during the summer season. Additionally, higher phosphate concentrations compared to the nitrogen values indicate an important role of point sources of pollution from the urban agglomeration located along the Wełna and Nielba rivers.

Apart from nutrient concentrations, which are of a great importance for phytoeston, the aspect of the water current and its speed should also be considered. The analyses of phytoeston indicated a horizontal differentiation between the stations in both the Wełna and Nielba rivers. The structure of phytoeston dominance in the Nielba river was more various compared to the Wełna river. A comparison of chlorococcalean communities in the investigated rivers revealed that the Wełna overtakes some of the Nielba species. The Wełna river, which flows two times faster than the Nielba preserved its Chlorococcales structure. The Nielba water moves more slowly than the Wełna river but in a permanent way.

In the central part of the cross-rivers approximately 10 % of the original water was mixed. The obtained results indicate that in the zone of crossing, algae communities were mixed in both rivers. Behind the Wełna and Nielba intersection the similarity coefficient of algae in 2000 was up to 40 % of the total community structure (Messyasz 2001). It was similar during the research period of 2001 and 2002. So the question of a connection between water mixed at a level of 10 % in the middle of the crossing and the similarity coefficient of algae amounting up to 40 % is of particular interest. The current of water may play an important role in the modification of species composition as well as in the density of particular species. A future examination of the river-crossing will aim to better explain the functioning of the Wełna – Nielba model during the whole year, characterised by differences in the density of algae.

## ACKNOWLEDGEMENTS

This work was supported by the State Committee for Scientific Research (grant KBN No. 6 PO4F 045 21).

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