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COMPARISON OF PHYTOPLANKTON AND ZOOPLANKTON COMMUNITIES VERSUS ABIOTIC CONDITIONS IN MEANDERING AND ANASTOMOZING SECTIONS OF A LOWLAND RIVER

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ABSTRACT

An aim of the research was to compare composition of phytoplankton and zooplankton communities in meandering and anastomozing sections of a lowland Narew River in relation to water quality and flow rate. We assumed that transition of the meandering channel into 5 active parallel anastomozing channels with different morphometric parameters, macrophyte cover and flow rate, causes variations in plankton parameters. Our results showed that parallel channels despite of a similar water quality differed in plankton parameters (species composition, number of species, total biomass and Shannon index). Our results also confirmed that in the anastomozing section of the Narew River species composition of zooplankton changes more than that of phytoplankton. In this section there was observed an increase of contribution of littoral rotifers and crustaceans. At the same time, in phytoplankton the main dominant from summer to autumn was typical planktonic species *Planktothrix agardhii*. *P. agardhii* creates toxic water blooms in a shallow hypertrophic Siemianówka dam reservoir that was established on upper course of the Narew River. Only in the spring and early summer the predominance over Cyanobacteria received other groups (mainly Cryptophyta, Bacillariophyceae, Chlorophyceae or Euglenophyta) more characteristic for potamoplankton.

Keywords: phytoplankton, zooplankton, meandering and anastomozing river, water quality

1 INTRODUCTION

Only a few large and medium European rivers preserved their natural character (Mioduszewski et al. 2004; Goździejewska et al. 2016). Most rivers were subjected to varying regulations which consisted mainly of straightening river beds through the liquidation of meanders, channelization, construction of embankments or dam reservoirs. Effects of those human activities reduce or eliminate the essential linkages between the river and its floodplain margins. In regulated rivers decrease of biodiversity and increase of productive processes is observed (Wetzel 2001). The negative biological consequences of river regulation may be visible far away from the dam (Grabowska and Mazur-Marzec 2011; Grabowska 2012). For example, the hypertrophic Siemianówka dam reservoir (SDR) is a rich permanent source of toxic cyanobacteria for the downstream Narew River (Grabowska and Mazur-Marzec 2011, 2016).

The structure of fluvial plankton is largely determined by both hydrological factors, water quality and aquatic vegetation (Agostinho et al. 2004; Pasztaleniec et al. 2013; Bortolini et al. 2016; Goździejewska et al. 2016; Grabowska et al. 2014a; Zieliński et al. 2016).

We assumed that transition of the meandering channel into 5 active parallel anastomozing channels with different morphometric parameters, macrophyte cover and flow rate, causes variations of water quality and plankton parameters.

2 STUDY AREA AND METHODS

The Narew River (NR) is the largest tributary of the Vistula River in NE Poland. The NR is one of Europe's few multi-channel rivers. Within the study area of the Narew National Park (NNR), the NR converts one meandering riverbed into a unique anastomozing system (Banaszuk and Wysocka-Czubaszek 2005).

The study was carried out in the years 2010-2011, at six riverine stations (S1-6). First station (S1) was located in the mainstream of the meandering channel and next five (S2-6) in active parallel anastomozing ones (Table 1). The channel with S6 is the main channel of the anastomozing section of the NR due to the largest flow rate (Table 2). During our study the width of 5 parallel channels ranged between 11 m (S4) and 35 m (S2) and they were relatively deep (>1.5 m). The parallel channels (S2 and S3) are characterized by denser macrophyte cover whereas the main channel (S6) by the weakest one. At the stations S1 and S2 the nympheids (e.g. *Nuphar lutea*, *Potamogeton natans*) and submersed macrophytes (e.g. *Elodea* *canadensis*, *Potamogeton lucens*) formed the most abundant populations. In the anastomozing section of the NR macrophyte cover was inversely correlated with flood intensity (Table 1, 2). Banks of the river channels and wetlands between them are largely vegetated with *Phragmites australis* which is an invasive species in the NNP due to decline in agricultural activities (Banaszuk and Wysocka-Czubaszek 2005). In August 2010, during the lowest water level in the NR, the machine cutting down of reed was carried out on the wetlands. In 1992 on the upper course of the NR there was constructed the shallow Siemianówka Dam Reservoir (SDR). The first station (S1) is located 88 km below the dam.

Plankton and water samples were taken from the surface layer in the midstream. The detailed methodology of analyses of all parameters was described previously (Grabowska et al. 2013, 2014b; Zieliński et al. 2016). Zooplankton material (20 L) was condensed on a plankton net of 30-μm mesh size. Statistical analyses of the results were carried out using Statgraphics v. 5.0 software.

The index of percentage similarity of community (PSC) (Whittaker and Fairbanks 1958) and Shannon index were used to compare plankton parameters between channels.

3 RESULTS AND DISCUSSION

3.1 Hydrology and water quality

The study was carried out during a period of relatively high water level and discharge except on August 2010 (Table 1). The highest discharge were recorded in the meandering section (S1) and in the main channel (S6) in the anastomozing section of the NR (Table 1, 2). The multiple comparisons test (one-way ANOVA) showed significant differences in discharge between main anastomozing channel S6 and the remaining channels. The lowest discharge in the NR was in August 2010 (Table 2). There were not significant differences in physical and chemical parameters of water between the stations except total phosphorus (TP) in case of S3 and S6 (Table 1). The lowest concentration of dissolved oxygen, soluble reactive phosphorus and pH were noted at S2 and S3 (Table 1). The concentration of TP, N-NH_4 and N-NO3 in the NR were even two times higher than in natural meandering Biebrza River (Grabowska et al., 2014a; Goździejewska et al., 2016) which indicates a high fertility the study river. Despite very similar water quality at all stations the distinct differences in total plankton biomass, species numbers and Shannon indexes in the anastomozing section of the NR were noted (Table 1, 2).

Table 1. Comparison of hydrological, chemical and biological water parameters at 6 stations in the Narew River in 2010-2011; * parameters with significant differences between stations

	meandering NR	anastomozing NR				
parameter	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Discharge* [m^3 s^{-1}]	9.0-16.5	2.40-8.40	0.88-1.32	3.20-3.84	1.04-3.25	14.0-16.0
Color [mg Pt L^{-1}]	41-122	49-94	54-108	50-102	34-123	37-126
EC [μS cm^{-1}]	398-423	401-458	409-452	405-441	403-440	403-446
Temperature [^{0}C]	6.50-27.0	5.80-26.0	5.70-26.3	6.00-28.4	6.10-28.7	5.90-29.3
pH	7.87-8.29	7.58-8.06	7.56-8.04	7.64-8.07	7.69-8.12	7.69-8.16
O_2 [mg L^{-1}]	4.33-9.43	0.90-6.80	1.10-6.92	3.00-8.44	3.60-8.99	3.98-8.64
N-NH_4^+ [μg L^{-1}]	45-70	79-217	35-203	51-101	24-123	22-163
N-NO_3^- [μg L^{-1}]	162-405	249-347	255-315	113-354	98-303	108-462
SRP [μg L^{-1}]	31-106	33-82	26-104	36-103	29-116	27-104
DP [μg L^{-1}]	211-308	161-208	177-214	165-240	201-241	244-295
TP* [μg L^{-1}]	338-469	272-332	187-344	258-325	308-359	302-452
SiO_4^{4-} [μg L^{-1}]	931-3271	1273-3536	1393-3850	1004-4360	1262-3646	1256-3972
$Fe^{2+/3+}$ [μg L^{-1}]	139-1096	181-784	180-983	176-841	163-1017	114-879
Chlorophyll *a* [μg L^{-1}]	1.46 -23.2	1.46-7.32	2.93-5.85	0.98-15.4	1.95-16.1	3.17-17.6
Phytoplankton [mg L^{-1}]	0.65-17.9	0.44-1.20	0.38-1.20	0.39-12.7	0.16- 8.17	0.19-6.94
Rotifers [μg L^{-1}]	5.40-98.6	0.40-19.1	2.90-21.1	2.20-36.5	6.50-41.9	1.60-65.4
Crustacea [μg L^{-1}]	7-47	0-36	0-54	0-17	0-13	11-258

3.2 Plankton communities

During the studied period, the biomass of phytoplankton (PB) varied between 0.16 and 17.9 mg L^{-1} with summer maximum in August 2010 (Table 1, 2). The highest PB and chlorophyll *a* concentrations were noted in the meandering (S1) and the main anastomozing channel (S6) (Table 1, 2). In 2010 summer and autumn phytoplankton was mainly composed of planktonic species from the hypertrophic SDR. *Planktothrix*

agardhii (Cyanobacteria) was the main dominant at all stations especially during the lowest water level and flow in August 2010 (> 69.9 % PB), but also during periods of relatively higher ones in October 2010 (>63.6 % PB) (Fig. 1a). The previous studies documented that every year *P. agardhii* creates a toxic water blooms in the SDR (Grabowska and Mazur-Marzec 2011; Grabowska et.al, 2014b). These results showed that in August and October at all riverine station share of *P. agardhii* in the PB was slightly lower than in the SDR (av. 90%) (Grabowska et al. 2014b). This study indicated that the hypertrophic SDR is also the rich source of Cyanobacteria for the protected section of the NR in mid-summer and autumn. Only in April and July the predominance of Cryptophyta, Bacillariophyceae, Euglenophyta, Chlorophyceae or Zygnematophyceae over Cyanobacteria was recorded (Fig. 1a, b). It is mainly correlated with the lowest outflow from the SDR (Grabowska 2012). At the time the phytoplankton communities in the NR were the most similar to phytoplankton ones in unregulated lowland rivers. Genuine riverine phytoplankton is mainly dominated by diatoms, green algae and/or cryptophytes due to water turbulence (Grabowska et al. 2014a; Messyasz 2003).
The highest values of Shannon Index were recorded in July 2010 (0.84-1.33) (Table 2) and in April and July 2011 (0.39-1.00). The values of the PSC index used to compare phytoplankton composition between the stations, showed the highest differences between the main anastomozing channel (S6) and S2 (Table 3).

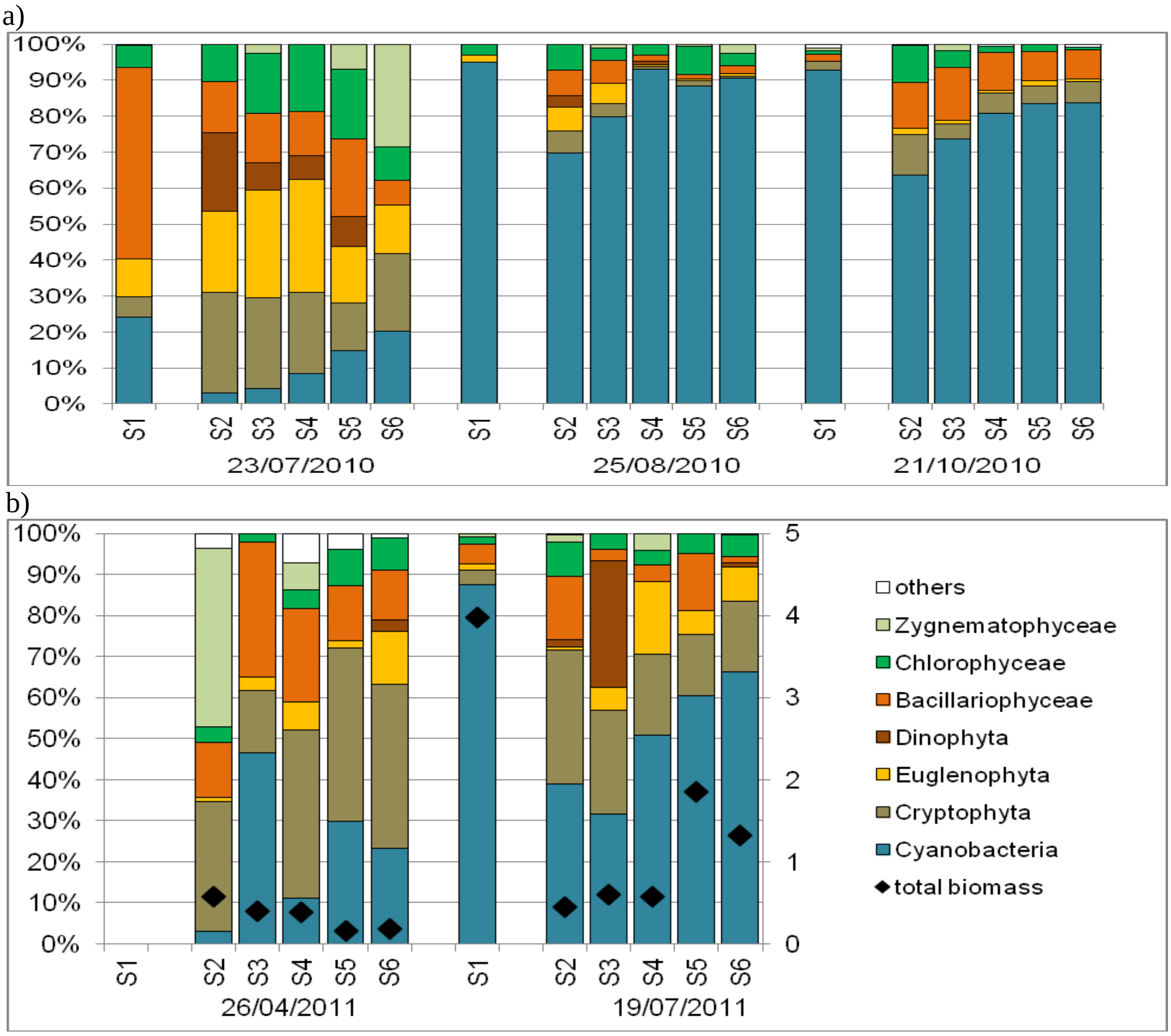

Figure 1. Comparison of the percent contribution of algae groups to the total biomass of phytoplankton at particular stations on five sampling dates a) in 2010 and b) in 2011

General number of rotifer species met during the study was relatively high and accounted for 66. The richest in species and characteristic for littoral microhabitats, genus *Lecane* consisted of 10 species of mostly low density. Nine species of mostly benthic *Cephalodella* were of low density as well. In July all studied stations were dominated by a littoral species, *Colurella uncinata*, which contributed in 26% (S1) to 80% (S2) to the total density of rotifers. The species dominated also in rotifer biomass, except the meandering S1, were large *Euchlanis dilatata* dominated (Fig. 2). The highest biomass of rotifers was observed in August (Table 2). The communities of all stations were more or less dominated by detritophagous *Brachionus angularis*, the species dominating at that time in the SDR. Rotifers from the SDR dominated also in the study stations in October, but the set of dominants was created by the genera *Keratella* and *Polyarthra*.

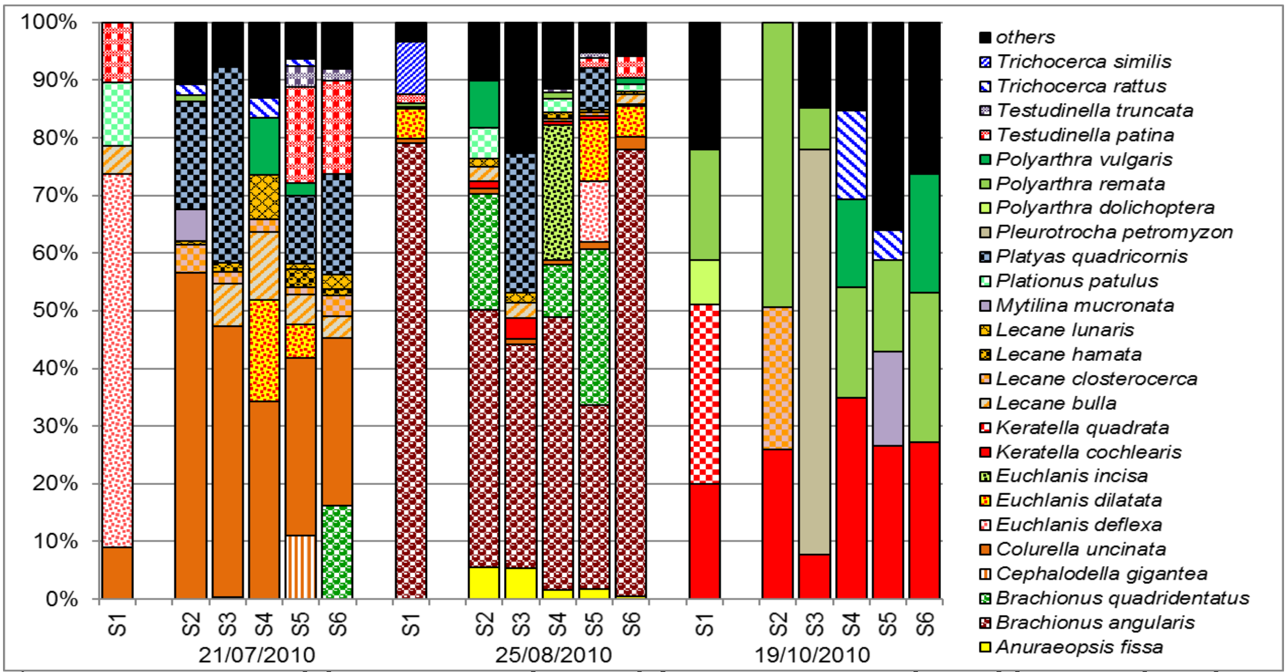

Figure 2. Comparison of the percent contribution of dominant species to the total biomass of Rotifera at particular stations on three sampling dates

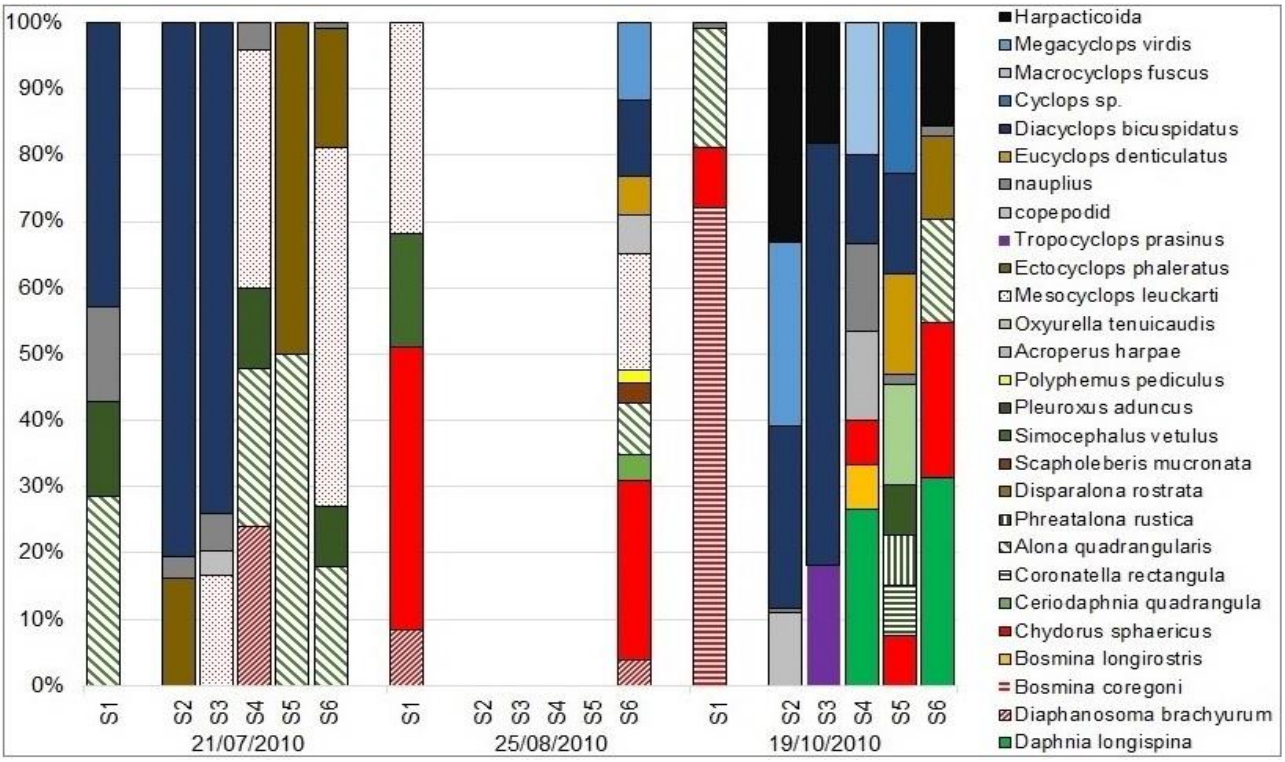

Figure 3. Comparison of the percent contribution of species in the total biomass of Crustacea at particular stations on three sampling dates

Rotifer community from S5 was usually among the most abundant as regards both numbers and biomass, the richest in species and with high species diversity (Table 2).

Species structure of rotifer communities were different in each of the sampling dates. At the same time they were more or less similar in particular stations as regards their dominants (Fig. 2). The communities differed in their lists of accessory species. As a result percentage similarity of communities (for pairs station 6 or 1 versus the remaining stations) was 48 and 46% respectively (Table 3). The highest similarity of rotifer fauna in S6 was observed for the neighboring S5 in June. Only those two stations had *Testudinella patina* in their rotifer communities, whereas the remaining abundant species were common for all stations. In August all stations had rotifer communities dominated by *Brachionus angularis* and PSC values ranged between 41.7 and 51.5%. The range of the values was the highest in October. The rotifer community from S6 was the most similar to that at S4 and both were dominated by *Keratella cochlearis* and *Polyarthra remata*. The lowest PSC was found for pairs S1: S3. It resulted from a strong domination (70%) of *Pleurotrocha petromyzon*, a species absent at all remaining stations.

Rotifer communities from the SDR seem to have marked impact on the communities both in the meandering and anastomozing sections of the NR. As a result the communities are relatively similar. Similar observations were described also for plankton of larger rivers and the connected floodplain lakes (Van den Brink et al. 1994, 1996).

Table 2. Patterns of phytoplankton, rotifer and crustacean communities from 6 stations of the Narew River in 2010; B - total biomass, N - number of species, SI - Shannon Index; n.d. - not determined

			Phytoplankton			Rotifera			Crustacea		
Date	St.	Flow $m^3 s^{-1}$	B mg L^{-1}	N	SI	B μg L^{-1}	N	SI	B μg L^{-1}	N	SI
23.07	S1	16.30	0.65	42	0.96	9.2	12	3.21	7.0	3	0.79
	S2	8.40	0.64	46	1.09	19.1	12	1.96	31.0	2	0.97
	S3	1.32	0.53	47	1.18	21.1	12	2.01	54.0	2	1.01
	S4	3.84	0.97	46	1.23	9.9	10	2.81	16.7	4	1.47
	S5	3.25	0.78	55	1.33	30.1	17	3.18	4.0	2	0.69
	S6	16.00	0.42	42	0.84	20.5	13	2.91	11.1	4	1.56
25.08	S1	9.00	17.9	21	0.17	98.6	13	1.62	47.0	4	0.92
	S2	n.d.	0.98	29	0.70	16.4	15	2.65	0	0	-
	S3	n.d.	1.20	22	0.43	14.8	14	2.78	0	0	-
	S4	n.d.	12.7	27	0.21	36.5	21	2.53	0	0	-
	S5	n.d.	8.72	27	0.33	49.1	20	2.82	0	0	-
	S6	n.d.	6.94	20	0.26	65.4	16	1.50	258	10	1.90
21.10	S1	16.50	6.22	21	0.45	5.4	9	2.55	11.1	3	1.16
	S2	2.40	1.11	23	0,49	0.4	3	1.51	36.2	3	1.45
	S3	0.88	1.20	24	0.53	2.9	4	1.32	11.0	3	1.33
	S4	3.20	0.97	19	0.47	2.2	6	2.38	15.0	6	1.90
	S5	1.04	0.99	20	0.40	6.5	9	2.83	13.2	8	2.16
	S6	14.00	1.01	20	0.39	1.6	4	1.99	12.8	5	1.67

In total 25 species of crustacean zooplankton were found, including 17 species of Cladocera and 8 Copepoda. Most of the species were littoral forms connected with aquatic plants, but also typical pelagic species were found (Fig. 3). Previous studies have shown that zooplankton of the NR below the dam is mainly composed of pelagic species from the SDR: *Chydorus sphaericus*, *Diaphanosoma brachyurum*, *Bosmina coregoni* and *Mesocyclops leuckarti* (Górniak and Karpowicz 2014). These species were still observed as far as 100 km downstream (Grabowska et al. 2013; Karpowicz 2014). Crustacean zooplankton in main river channels (S1 and S6) in all dates had high share of species which were dominants in the SDR (Fig. 3). This indicated high dispersion abilities of pelagic crustacean in river in low and high water level. As a result average percentage similarity of communities in main channels was 54.7% (Table 3).

Parallel channels (S2-5) were strongly dominated by littoral species (e.g. *Diacyclops bicuspidatus*, *Alona quadrangularis*, *Pleuroxus aduncus*, *Megacyclops viridis*) and benthic species (e.g. *Ectocyclops phaleratus* and Harpacticoida species). But the communities differed in their lists of accessory species (Fig. 3). As a result average percentage similarity of crustacean communities in parallel channels was 30.6%. Generally in October there was observed lower similarity of crustacean communities between channels than in July (Table 3). The highest similarity of crustacean fauna (58.3%) was noted for the neighboring stations S2 and S3.

There were significant differences between biomass and diversity of crustacean zooplankton in different dates. Low biomass of zooplankton in all river channels was observed in July and October with high flow rate (Table 2). Diversity of microcrustaceans in all river channels was higher in October than in July (Table 2). In August at low flow rate crustacean zooplankton was absent in lateral channels, but in the main river channel (S6) there was high biomass and diversity of crustacean zooplankton (Table 2).

The values of index of percentage similarity of community (PSC) used to compare plankton composition between stations, showed the higher differences for zooplankton (especially crustaceans) than phytoplankton communities (Table 3). Our results confirmed that in the anastomozing section of the Narew River species composition of zooplankton changes more than of phytoplankton.

Table 3. Comparison plankton communities between meandering (S1) versus anastomozing section (S2-6), and main anastomozing channel (S6) versus other parallel channels (S2-5) using the index of PSC

	Phytoplankton			Rotifera			Crustacea		
St.	Jul.	Aug.	Oct.	Jul.	Aug.	Oct.	Jul.	Aug.	Oct.
					S1				
S2	57.8	92.0	53.9	31.2	51.1	46.7	41.7	-	0
S3	30.9	66.9	63.9	33.9	44.0	19.1	41.7	-	0
S4	31.0	90.8	58.9	44.3	53.2	58.3	58.3	-	25
S5	37.2	91.3	57.6	41.2	38.9	53.5	41.7	-	22.9
S6	42.2	87.6	57.3	41.4	80.7	52.2	58.3	52.5	53.3
					S6				
S2	46.4	71.6	75.9	54.6	51.5	51.8	37.5	-	26.7
S3	48.9	95.1	89.9	55.4	42.8	42.8	37.5	-	26.7
S4	55.3	93.1	90.5	37.5	51.0	51.0	75	-	36.7
S5	57.9	90.4	93.5	66.5	41.7	41.7	75	-	16.3

CONCLUSIONS

Our results confirmed the hypothesis that transition of the meandering river into 5 active parallel anastomozing channels causes variations in plankton parameters despite the lack of differences in water quality. The highest differences between channels were demonstrated for crustaceans. The higher number of rotifer and crustacean species occurring at anastomozing channels than meandering one may be affected by higher diversity of habitats, from which the organisms are washed out.

The manuscript also documents succession of reservoir plankton along protected meandering and unique anastomozing system of the NR. Both the phytoplankton and zooplankton dominants are characteristic for eutrophic and hypertrophic waters. It shows deterioration of water quality at the unique protected section of the lowland river as a result of its damming in the upper course.

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