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The Influence of Environmental Variables on Diversity of Spring Zooplankton in The Artificial Bydgoszcz Channel: A Case Study

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Abstract: The Bydgoszcz Channel is an important artificial channel connecting two of the largest rivers and their catchments in Poland and in central Europe, the Vistula and Odra. It is also the main vector connecting the Noteć River from the East and near the mouth to Brda river from the West. Except for hydrography the Bydgoszcz Channel is also an interesting artificial river from the ecological point of view. In present study we identified and compared the zooplankton community along with physico-chemical and biological properties. Water samples were collected on Bydgoszcz Channel and Noteć Channel monthly during the spring (April 2019 to June 2019). We investigated how the flow of the channel and its tributary affected the various physico-chemical and biological conditions (including water temperature, water transparency, dissolved oxygen, saturation, conductivity, pH, nitrate, phosphate and Chl-*a* concentration). These analysed parameters in turn affected the seasonal variations of zooplankton diversity (T) and density (N). The zooplankton community was dominated by rotifers and crustaceans. During May we recorded the highest rotifer density (N Rot) 2090 ind/L in Bydgoszcz Channel with an average 1256 ind/L and highest rotifer diversity (T Rot) of 20 species. The most dominant were *Keratella cochlearis, Keratella quadrata, Polyarthra dolichoptera.* The highest crustacean density (N Crust) was recorded during June on Bydgoszcz Channel 1420 ind/L with an average of 564.5 ind/L and diversity (T Crust) of 8 species recorded from Noteć Channel. The most dominant species among crustaceans was the cladoceran *Bosmina longirostris*. We assume that the crustacean diversity, density and biomass increased due to increasing temperature. On the contrary, the rotifers species decreased. It follows that adult copepods and their larval stages copepodites could eat small rotifers causing a decline in the number of rotifers. It is also possible that the decline in rotifer numbers could have been caused by competition for food with the Cladocera.

Keywords: zooplankton; community; Bydgoszcz Channel; Rotifers; Crustaceans; water parameters

1. Introduction

The Bydgoszcz channel is very important artificial watercourse, as a part of the international waterway E 70. It connects two largest rivers in Poland – The Vistula and Odra river, through their tributaries: The Brda river, the Noteć river and the Warta river. The total channel length is 24.7 km, of which 15.7 km is located in the catchment of Noteć (tributary of Odra river) and 9.0 km in the Brda (tributary of Vistula river) catchment. The main elements determining the classification of the Bydgoszcz Channel are existing hydrotechnical constructions (sluices), which were characterized on the basis of their water permits [1]. In last two decades much attention has been taken to Bydgoszcz Channel in relation to the study of biological and ecological point of view. The study of freshwater planktonic animals has been a fascinating subject for a long time. The zooplankton organisms play an important role in aquatic ecosystem [2]. The main function of zooplankton communities is to act the primary and secondary tropic level in the food chain – energy transformation, circulation of organic matter, regulation the biomass of phytoplankton and food providing for fish, especially for their larval stages and for fish spawning [3], [4]. The productivity of the aquatic ecosystem is directly

correlated with the density and diversity of zooplankton organisms. The biological diversity of zooplankton is principal to keep ecosystem healthy, because each species may have a particularly different pronounced effects on ecosystem function [5]. Loss of zooplankton diversity may lead to effects on both the community of organisms declines in ecosystem function as well as shifts residing within the ecosystem and on humans to alternate stable states [6], that rely upon the system for water supply [7]. A species, or group of species, may appear to be functionally redundant under one set of environmental conditions, but may differ in their effect on ecosystem processes under a different set of environmental conditions [8]. The Rotifers and crustacean species are suggested as indicators that can be used to identify different physical and chemical gradients or eutrophic increases in freshwater ecosystem [9]. They are highly sensitive to physico-chemical and biological changes of water quality. As a result of these changes the seasonal variations of zooplankton diversity (T) and density (N) can be affected. Last but not least it can provide important indication of hydrological changes or ecosystem disturbances [10]. So far, little work has been done on the zooplankton of artificial channels, especially between the basins of eastern and western Europe However, some similar investigations determining zooplankton species in relation to environmental variables have been carried out [11]–[14]. The aim of study was described and compared a seasonal zooplankton composition along with changes in physicochemical and biological properties. We assumed that zooplankton will be richer in late spring due to increase temperature and probably development of proper food for zooplankton (algae development). We supposed that rotifers density and species diversity decreased, because they could have been the primary food resource for adult copepods and their larval stages copepodites or be the rival in food chain among the Cladocera zooplankton species.

2. Materials and Methods

The research was conducted during the spring in the year of 2019 and involved the Bydgoszcz Channel, limited by urbanized zone of Bydgoszcz city and the Noteć Channel nearby the rural zone of Nakło city. Water samples were carried out at 5 different sampling spots belonging to 2 sites: site 1 – Bydgoszcz Channel - Jozefinki Channel 53°07'49.7"N 17°38'23.9"E, Osowa Gora sluice 53°08'48.9"N 17°52'49.2"E, Prądy sluice 53°08'38.6"N 17°53'37.8"E, Okole sluice 53°08'11.9"N 17°58'06.1"E, site 2 - Noteć Channel 53°07'56.5"N 17°51'18.1"E. Samples for water quality and zooplankton study were collected once in the month from April to June with a 1 L Patalas' bucket at the depth of ca. 0.5m. The water was filtered through a plankton net with mesh diameter of ca. 25µm. In order to obtain one sample of zooplankton, 10 L of water was filtered. All samples were preserved with Lugol's solution [30], [31]. Altogether, 15 water samples were collected. Identification and measurement of zooplankton was performed with the use of a light microscope Nikon Alphaphot YS2, as well as a Panasonic camera and MultiScan – a software for image analysis. The sample volume (10L) was adjusted to 10 ml, a 1 ml aliquot of well-mixed concentrate pipetted into a Segdwick-Rafter chamber. The zooplankton was counted under a microscope in a Segdwick-Rafter chamber by the sub-sample method [32]. The abundance and biomass of zooplankton was calculated per volume of 1 L of water. The taxonomical identification of zooplankton was made according to the commonly available studies and keys [33]. To characterize the abundance-dominance relationship the Shannon α-diversity index (H') and Pielou evenness index (J') were used. The collection of samples was measured along with the physical and chemical parameters of water, such as: Secchi disk visibility (SD, m), temperature (WT, °C), oxygen concentration (DO, mg. L^{-1}), saturation (SAT, %), conductivity (EC, µm.cm^{-1}), saturation and pH. Measurements of physico-chemical parameters were performed by multimeter WTW Multi 3430SET F (Xylem Analytics, Weilheim, Germany) field probes. The statistical analyses were carried out by software Past 4.03.

3. Results

The highest average temperature during the observed months was 25.3 °C in June and the lowest was 8.3 °C in April. The average water transparency was 0.53 m (from 0.14 m in April to over 1 m in June). The average water pH slightly decreased from 8.5 in April to 6.7 in June.

The EC ranged from 429 μS cm^{-1} (April) to 568 μS cm^{-1} (May). The average DO concentration decreased from 14.9 ml/L to 5.2 ml/L. The average value of saturation ranged from 62 (%) to 124 (%). The highest concentration of DO and saturation was recorded in April and the lowest was in June. The observed average value of chlorophyll during the present study ranged from 9.6 mg/L (June) to 30.9 mg/L (May). The highest was 51.5 mg/L recorded in May and the lowest was 3.3 mg/L in June. The average value of nitrate varied from 0.3 mg/L (June) to 1.2 mg/L (April). The average value of phosphate ranged from 0.1 mg/L to 0.5 mg/L. The highest value of phosphate was 0.89 mg/L in May and the lowest was 0.03 mg/L recorded in April (Table 1).

Table 1. Physico-chemical and biological parameters during the spring on Bydgoszcz Channel and Notec Channel.

	April		**May**		**June**	
	Mean	Range	Mean	Range	Mean	Range
WT (°C)	8.3	7.6-9.3	14.3	13.8-14.8	25.3	23.0-26.0
SD (m)	0.14	0-0.70	0.40	0-0.60	1.04	0.60-1.30
EC (μS cm^{-1})	429	0-552	519	152-619	316	482-595
DO (ml/L)	14.9	12.1-16.3	12.2	9.6-15.0	5.2	1.9-6.6
SAT (%)	124	101-138	120	93- 150	62	23-80
pH	8.5	8.3-8.9	8.2	7.8-8.4	6.7	6.5-6.7
chl-*a* (mg/L)	25.4	19.8-31.1	30.9	4-51.5	9.6	3.3-14.3
NO_3^- (mg/L)	1.2	0.3-1.7	0.4	0.2-0.6	0.3	0.3-0.4
PO_4^{2-}(mg/L)	0.1	0.03-0.53	0.5	0.06-0.89	0.2	0.1-0.4
Biomass (mg/L)	748.5	320.5-1056.6	2599.9	196.5-10112.0	15682.1	1661.0-26285.2

temperature (WT, °C), Secchi disk visibility (SD, m), conductivity (EC, μS cm^{-1}), oxygen concentration (DO, mg/L), saturation (SAT, %), pH, chlorophyll (chl-*a*, mg/L), nitrate (NO_3^-, mg/L), phosphate (PO_4^2, mg/L), biomass (mg/L).

During the spring studies of the Bydgoszcz and the Noteć Channel (58) species of zooplankton were recorded, including (44) Rotifers and (14) Crustaceans. The average zooplankton density was 697 ind/L, including 570 ind/L Rotifers and 127 ind/L Crustaceans. The average zooplankton biomass in present studies was 6343.5 mg/L, including 315.7 mg/L Rotifers and 6027.8 mg/L Crustaceans (Table 2)

Table 2. Total zooplankton diversity and average density, biomass during spring on Bydgoszcz Channel and Noteć Channel.

	Spring season
Tax	58
Tax_{rot}	44
Tax_{crust}	4
N (ind/L)	697
N_{rot} (ind/L)	570
N_{crust} (ind/L)	127
Biomass (mg/L)	6343
$Bomass_{rot}$ (mg/L)	315.7
$Biomass_{crust}$ (mg/L)	6027.8

Tax – number of species, Tax_{rot} – number of rotifers species, Tax_{crust} – number of crustacean species, N – mean number zooplankton (ind/L), N_{rot} –mean number of rotifers (ind/L), N_{crust} –mean number of crustacean (ind/L), biomass – mean (mg/L), $biomass_{rot}$ (mg/L), $biomass_{crust}$ (mg/L).

In average the highest number of zooplankton species (20) was found altogether on Bydgoszcz and Notec Channel, including (17) Rotifers and (3) Crustaceans recorded in the May. The lowest number (15) was recorded in the June, including (9) Rotifers and (6) Crustaceans (Table 3).

Table 3. Total number of species (diversity) and dominants in the zooplankton community during spring on Bydgoszcz Channel and Noteć Channel.

	April	**May**	**June**
Rotifers	16	17	9
Crustaceans	2	3	6
SUM	18	20	15
Dominant species and percent of domination	*Polyarthra dolichoptera* 55%*	*Keratella cochlearis* 90%*	*B. longirostris* 79%**
	Keratella cochlearis 22%*	*Keratella tecta* 5%*	nauplius 12%**
	Keratella quadrata 22%*	*Brachionus calyciflorus* 4%*	*Keratella tecta* 5%*
	nauplius 1%**	nauplius 1%**	*Keratella cochlearis* 4%*

*Rotifer, **Crustacean.

The most (24) zooplankton species were identified on the Bydgoszcz Channel, including (20) Rotifers and (4) Crustaceans. The highest average zooplankton density was 1256 id/L, including 1224 ind/L Rotifers and 32 ind/L Crustaceans recorded during the May (Table 4).

Table 4. Diversity (H'), evenness (J') number of zooplankton species, zooplankton density, density of dominant species during spring on Bydgoszcz Channel.

	April		**May**		**June**	
	Mean	Range	Mean	Range	Mean	Range
H'	1.83	1.33-2.23	1.19	0.98-1.62	1.47	0.51-2.21
J'	0.34	0.21-0.46	0.17	0.11-0.3	0.33	0.11-0.51
Tax	19	18-20	21	16-24	15	13-17
Tax_{rot}	17	17-18	18	15-20	10	6-11
Tax_{crust}	2	1-3	3	2-4	6	4-7
N (ind/L)	1071	467-1376	1256	202-2090	704	298-1460
N_{rot} (ind/L)	1059	461-1356	1224	180-2430	120	40-256
N_{crust}(ind/L)	13	6-20	32	4-56	584	154-1420
*Keratella cochlearis**	160	80-316	975	134-1874	29	4-66
*Keratella tecta**	6	0-6	54	12-116	30	2-82
*Keratella quadrata**	162	66-308	50	10-108	23	0-32
*Polyarthra dolichoptera**	455	62-814	13	1-24	-	-
*Brachionus angularis**	51	18-78	13	1-42	4	0-4
*Bosmina longirostris***	4	0-4	4	1-8	470	100-1310
nauplius**	10	4-20	19	1-32	75	40-138

The most (18) zooplankton species were identified on the Notec Channel, including (15) Rotifers and (3) Crustaceans (Table 4) in the May. The lowest number (13), including (6) Rotifers and (7) Crustaceans was recorded during the June. The highest zooplankton density was 640 ind/L, including 620 ind/L Rotifers and 20 ind/L Crustaceans observed in the May (Table 5). During the spring the diversity index (H') was higher on the Bydgoszcz Channel (H' = 2.2). The evenness index (J') was more equable on the Noteć Channel (J' = 0.45) (Table 4,5). In both of examined channels during the entire research period were dominated three rotifers *Keratella cochlearis*, *Keratella quadrata* and *Polyarthra dolichoptera*. The other rotifer species *Brachionus angularis, Keratella tecta* and crustacean species *Bosmina longirostris*, nauplius were rare in zooplankton community (Table 4,5).

Table 5. Diversity (H'), evenness (J') of zooplankton species, zooplankton density, density of dominant species during spring on Noteć Channel.

	April	**May**	**June**
H'	2.10	1.13	1.84
J'	0.63	0.17	0.45
Tax	15	18	13
Tax_{rot}	12	15	6
Tax_{crust}	3	3	7

N (ind/L)	416	640	94
N_{rot} (ind/L)	380	620	16
N_{crust}(ind/L)	36	20	78
*Keratella cochlearis**	100	486	4
*Keratella quadrata**	92	38	2
*Polyarthra dolichoptera**	48	12	-
*Brachionus angularis**	32	10	2
*Bosmina longirostris***	8	2	29
nauplius**	12	10	35

Shannon–Weaver diversity index (H'), Pielou's evenness index (J'), Tax – mean number of species, Tax_{rot} – mean number of rotifers species, Tax_{crust} – mean number of crustacean species, N – number zooplankton (ind/L). N_{rot} – number of rotifers, N_{crust} – number of crustacean. *Number of dominant species of zooplankton (ind/L). *Number of rotifers (ind/L). **Number of Crustaceans (cladocera) and nauplii (larval stage of copepods) (ind/L).

4. Discussion

The Bydgoszcz Channel is an important artificial channel with specific type of aquatic environment, no encountered in natural conditions. It is characterized by water flow regulation, which cause a high variability of hydrological conditions. Knowledge of these aspects is essential for proper utilization, regulation, physico-chemical parameters and quality of nutrients. However, the pollution from different kind of municipal sewage increased, the quality of water in channel considerably decreased [1]. Generally, the water quality is governed by various environmental variables (physico-chemical and biological parameters) and nutrition availability[15], [16]. These factors are crucial for development of planktonic animals. Especially the zooplankton community structure is influenced strongly by various environmental variables (WT, SD, EC, DO, SAT, pH, Chl-*a*, PO_4^{2-}, NO_3^-, biomass), food competition and predation [16]–[18]. In our study we investigated, that mainly the WT, Chl-*a* concentration and DO regulate the density, diversity and biomass of zooplankton organisms in Bydgoszcz and Noteć Channels. The present results agreed with the previous reported studies [19], [20]. We observed that water temperature was the most favourable for zooplankton density and diversity. For example, the moderate spring temperature (in May) enhanced the growth and feeding rate of many small feeders (rotifers) [21]. However, June water temperature indicated a good conditions for the filter feeders at developmental stage Crustaceans (Copepods larval forms) and significant part of the mature Copepods and Cladocerans [22], [23]. The sudden descent of rotifer species during the June could indicate the competition for food with Cladocera or predation by higher trophic members like planktivorous fishes which regulate the zooplankton population in water body [24]–[26]. Except for WT, Chl-*a* concentration is also very important chemical indicator of water quality and could reflect the algae density. The highest zooplankton diversity and density related with the high concentration of Chl-*a* [27], as well as with high concentration of biogenic compounds PO_4^{2-} and NO_3^- [28]. In addition, these variables documented suitable conditions for biomass development. The zooplankton community showed an increasing trend with DO. The highest concentration of DO was recorded in the month of April and May, when was the highest zooplankton density and diversity. This physical parameter is very important for all aquatic organisms. It may indicate the water purity due to direct diffusion from air and photosynthetic activity of autotrophs [11]. During the studied months the zooplankton diversity significantly differed, compared with total diversity for the whole researched months in both of channels [29]. It was noticeable that rotifers belonged to more dominant zooplankton group and had higher diversity than Crustaceans.

5. Conclusions

The artificial Bydgoszcz Channel and its tributary Noteć Channel provide a case of study how the environmental variables (associated with changes in hydrological conditions) could determine the zooplankton community in seasonal scale. In present study we found out that mainly WT, Chl-*a*

concentration and DO are the most valuable indicators of water quality and zooplankton development. It has been shown that moderate water temperature was the most suitable for rotifer species. Unlike Crustaceans preferred June water temperature. Moreover, the highest zooplankton diversity, density and biomass related with the high concentration of Chl-*a* and DO. This research paper is the first attempt to understand the interaction among zooplankton, phytoplankton and abiotic factors for preserving aquatic biodiversity in observed artificial channels.

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