ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA
Rocznik Ochrona Środowiska
Tom 14. Rok 2012 ISSN 1506-218X 146–160

Zooplankton of Three Suburban Lakes in Relation to Selected Abiotic Conditions

*Łukasz Sługocki, Robert Czerniawski, Józef Domagała,
Tomasz Krepski, Małgorzata Pilecka-Rapacz
University of Szczecin, Poland*

1. Introduction

The suburban lakes are popular sites of summer active leisure for city dwellers. As a consequence, they are under stronger anthropopressure than the lakes localised far from the cities [13] and their status should be carefully controlled. Hitherto the quality of water in natural water reservoirs has been mainly evaluated on the basis of physicochemical parameters, however, their indications have been found unreliable [4]. Recently, different bioindicators have been proposed for water quality evaluation [24], zooplankton included [20]. The quantitative and qualitative composition of zooplankton depends considerably on the physicochemical and morphological parameters of water reservoirs [5, 6, 11]. The reservoirs of the same trophic status may have zooplankton of different quantitative and qualitative composition. For example a higher species number of rotifers could be found in highly productive waters and with a high trophic status [6, 12, 20]. Czerniawski and Pilecka-Rapacz [8] have reported that species diversity and abundance is higher in rivers which flow out from lakes which had a high trophic status like e.g. from suburban lakes and small dam reservoirs. This high species diversity and abundance refers mainly to rotifers. Ejsmont-Karabin and Kuczyńska-Kippen [13] has obtained similar results in the lakes of Poznań agglomeration. These authors observed that urban lakes favour rich rotifer species groupings. Rotifers exceptionally well multiply in polluted and highly euthropic environment, the abundance of indicatory species can reach even a few ten thousand in litre [26]. Often these are ubiquitous species highly tolerant to environmental factors [30]. In view of the above we can put forward a hypothesis that despite the same trophic status of lakes and their similar urban or suburban localisation, they can differ in the zooplankton composition because of the influence of biological conditions, physicochemical and morphological character of the lakes studied.

2. Methods

The study was performed on three suburban lakes located in north-western Poland: Adamowo (GPS N 53° 12' 38" E 15° 44' 53"), Grażyna (GPS N 53° 13' 20" E 15° 45' 55") and Klasztorne (GPS N 52° 53' 4" E 15° 31' 54"), all these lakes were classified as eutrophic [7, 9]. Lakes mentioned above belongs to the Noteć River catchment area. Lake Adamowo occupies an area of 120.4 ha. It a flow lake, eutrophicated, located in the buffer zone of the Drawa National Park, on the River Drawa. Its north-eastern shore adjoins a small town Drawno. The small town Drawno does not have a complete sewage system and besides some municipal sewage the lake also gets discharges from a drainage ditch. The lake Adamowo is divided into two distinct parts: the flow-through part (eastern pool) adjoins the town, has flat banks, rather poor bottom sculpture and depth reaching about 7.5 m. The south-western part of the lake (western pool) is more distant from the town, the bottom has steep slopes and the depth reaches 34 m. In this pool the water division into three thermal strata: epilimnion, metalimnion and hypolimnion is well-marked. To the east Lake Adamowo is directly connected with Lake Grażyna. Lake Grażyna occupies an area of 75.8 ha, it is flow-through and surrounded by meadows and arable fields. Its western bank adjoins the town Drawno and is connected with Lake Adamowo. Its maximum depth reaches 4.2 m. The lake bottom is covered with macrophytes to about 70%. The bottom is silted up [16, 22]. Lake Klasztorne is a small reservoir occupying 20 ha in the Dobiegniewskie Lake District. From the west the lake adjoins the town of Strzelce Krajeńskie, while from the east it is surrounded by intensely fertilised arable fields. Into the lake water from carp-farm is seasonally discharged. It has a rather poor bottom sculpture and reaches a maximum depth of 6.6 m in the south-eastern part, while its mean depth is 3.3 m.

The samples were collected in each season, starting from the 2nd, 3th of August, 2007 during the summer stratification, then during the autumn mixing (4th, 5th of Nov. 2007), during the period of winter stagnation (6th, 7th of Feb. 2008) and during the spring mixing (1st, 2nd of May, 2008). Samples for zooplankton investigation were obtained by filtering 50 dm^3 of water through a mill gauze of the mesh size 25 µm. The calculation and identification of zooplankton was performed in the Sedgewick-Rafter chambers with the use of a microscope Nikon Eclipse 50i. Zooplankton was calculates in 5 subsamples. The number of individuals representing particular systematic groups of crustaceans and rotifers was counted, their species were identified using the keys of Rybak i Błędzki 2010 [29], Kutikova [25], Radwan 2004 [28]. In each sample the lengths of at least 30 individuals representing each species were measured using the Pixelink Camera Kit 4.2 computer program. If the number of individuals representing a given species was lower than 30, the lengths of all individuals were measured. The results of these measurements were the basis for zooplankton biomass estimation, the conversion of the length into wet mass was made with the use of the tables proposed by Radwan 2004 [28] and Starmach [32].

Table. 1. Mean values of physico-chemical variables in examined lakes. SD – visibility of Secchi disc. Value with the same letters not differ significantly

Tabela. 1. Średnie wartości fizyko-chemicznych parametrów wody w badanych jeziorach. SD – widzialność krążka Secchi'ego. Wartości w kolumnach z tymi samymi indeksami literowymi nie różnią się istotnie statystycznie

Lake	SD (m)	Temp (°C)	O_2 (mg L^{-1})	pH	Cond. (µS)	N-NO_3 (mg L^{-1})	N-NO_2 (mg L^{-1})	N-NH_3 (mg L^{-1})	NTOT (mg L^{-1})	P-PO_4 (mg L^{-1})	PTOT (mg L^{-1})
Adamowo	2.9a	10.3a	8.0a	7.9a	296.1a	0.6a	0.023a	0.1a	1.4a	0.5a	1.1a
Grażyna	3.4a	11.5a	9.4a	7.7a	297.5a	0.6a	0.011a	0.1a	0.7a	0.4ab	0.9ab
Klasztorne	1.2a	11.8a	12.9a	7.8a	584.7b	2.3a	0.037a	0.6a	4.2b	0.2b	0.2b

At each site and from each stratum a water sample was collected for determination of selected physicochemical parameters (Table 1). Temperature, pH, electrolytic conductivity and oxygen content were measured by a pH meter and oxygen content meter CX 401 made by Elmetron. The concentrations of N-NO_3, N-NO_2, N-NH_3, NTOT, P-PO_4, PTOT were determined by a colorimeter DR 890 made by Hach Lange (USA). The transparency was determined using Secchi disc. Taxonomic similarity between lakes was evaluated on the basis of the Jaccard index. The statistical significance of the differences in some properties of the zooplankton community between lakes was tested by the non-parametric test of Kruskall-Wallis. In order to determine the influence of the environmental variables on the abundance of zooplankton, the Pearson correlation was applied.

3. Results

The total number of zooplankton taxa in all lakes was 108, including 74 Rotifera, 17 Cladocera and 17 Copepoda (Table 2). The numbers of zooplankton taxa in each lake were 61 in Adamowo, 75 in Grażyna and 59 in Klasztorne, (Table 2). The most abundantly represented were Rotifera: *Keratella cochlearis cochlearis, Keratella quadrata, Synchaeta oblonga,* Cladocera: *Bosmina coregoni* i *Chydorus sphaericus*, and Copepoda: Nauplii Cyclopoida, copepodites of Cyclopoida and *Eucyclops serrulatus*.

In each of the lakes rotifers were by far the most abundant. The highest mean abundance of zooplankton was determined in Klasztorne (1820,12 ind. L^{-1}) of which 96% were Rotifera, 2% Cladocera and 2% Copepoda (Table 3). Statistical analysis did not reveal any significant differences in total abundance an in abundances of particular systematic groups between the lakes studied. Some differences were noted in the total zooplankton abundance and Rotifera abundance, being the greatest in Klasztorne, but these differences were statistically insignificant.
The highest mean biomass of zooplankton was calculated for Adamowo (1.44183 mg dm^{-3}), including 3% Rotifera, 35% Cladocera and 62% Copepoda. In each lake the greatest was the biomass of crustaceans.

According to statistical analysis, the differences in mean biomass of Copepoda and total zooplankton between the theree lakes were significant, see Table 3. As to the biomass of Copepoda, the greatest and statistically significant differences were found between Adamowo and Grażyna as well as Adamowo and Klasztorne; $P = 0.0086$; $P = 0.0218$, the greatest biomass was in Adamowo. A significantly lower biomass of total zooplankton than in Adamowo and Klasztorna was in Lake Grażyna; $P = 0.0035$, $P = 0.00388$. Although the biomass of Cladocera was not statistically significantly different between the three lakes, it was much lower in Adamowo than in Grażyna. Greater abundance of zooplankton was observed in epilimnion than in thermocline, while for biomass this pattern was inverse. However, these differences were insignificant ($P > 0.05$).

Table 2. Taxonomic composition of zooplankton in examined lakes: Adamowo (A), Grażyna (G), Klasztorne (K)

Table 2. Skład taksonomiczny zooplanktonu w badanych jeziorach: Adamowo (A), Grażyna (G), Klasztorne (K)

Takson		
Anuraeopsis fissa AGK	*Lepadella ovalis* AG	*Alona costata* GK
Ascomorpha ovalis A	*Lepadella patella* K	*Alona Guttata* G
Ascomorpha sp.G	*Lepadella quadricarinata* K	*Alona rectangula* AG
Asplanchna brightwelli K	*Mytilina crassipes* GK	Alona sp. G
Asplanchna priodonta AK	*Mytilina ventralis G*	*Alonella nana* G
Brachionus angularis AK	Mytylina sp. G	*Bosmina coregoni* AGK
Brachionus calyciflorus AGK	*Notholca acuminata* GK	*Bosmina longirostris* AGK
Brachionus diversicornis K	*Notholca labis* G	*Ceriodaphnia quadrangula* AGK
Brachionus quadridentatus GK	Notholca sp. G	*Ceriodaphnia reticulata* A
Brachionus urceolaris G	*Notholca squamula* AG	*Chydorus sphaericus* AG
Cephalodella apocolea AG	*Polyarthra dolichoptera* AGK	*Chydorus gibbus* AGK
Cephalodella auriculata G	*Polyarthra euryptera* AGK	*Chydorus sphaericus* K
Cephalodella catellina AG	*Polyarthra longiremis* AGK	*Daphnia cucullata* AK
Cephalodella sp. AG	*Polyarthra major* AK	*Daphnia longispina* AGK
Colurella adriatica AGK	*Polyarthra minor* G	*Peracantha truncata* GK
Colurella colurus GK	*Polyarthra remata* AGK	*Scapholeberis mucronata* G
Conochilus unicornis AK	*Polyarthra vulgaris* AGK	Naupli Calanoida A
Euchlanis deflexa G	*Pompholyx complanata* K	Naupli Cyclopoida AGK
Euchlanis dilatata AGK	*Pompholyx sulcata* AGK	Kopepodit Calanoida A
Euchlanis lyra G	Rotifera non det. GK	Kopepodit Cyclopoida AGK
Filinia longiseta AGK	*Scaridium longicaudum* G	*Acanthocyclops robustus* AG
Filinia terminalis AG	*Squatinella rostrum* G	*Cyclops abyssorum* AK
Gastropus sp. G	*Synchaeta kitina* AGK	*Cyclops kolensis* A
Kellicotia longispina AGK	*Synchaeta lakovitziana* K	*Cyclops vicinus* K
Keratella coch. coch. AGK	*Synchaeta oblonga* AGK	*Diacyclops bicuspidatus* A
Keratella coch. hispida AG	*Synchaeta pectinata* AGK	*Eucyclops serrulatus* AGK
Keratella coch. tecta AGK	*Synchaeta tremula* K	*Eudiaptomus gracilis* A
Keratella coch. Tricinensis AG	Syncheata sp. G	*Eudiaptomus gracilloides* A
Keratella quadrata AGK	*Syncheata stylata* AG	*Mesocyclops leuckarti* AK
Lecane closterocerca AGK	*Testudinella mucronata* G	*Thermocyclops crassus* A
Lecane flexilis G	*Trichocerca capucina* AG	*Thermocyclops emini* AK
Lecane hamata GK	*Trichocerca elongata* A	*Thermocyclops oithonoides* AK
Lecane ludwigii G	*Trichocerca pusilla* AK	*Thermocyclops rylovi* K
Lecane luna G	*Trichocerca rousseleti* G	
Lecane lunaris G	*Trichocerca similis* AGK	
Lecane scutata K	*Trichotria pocillum* G	
Lepadella acuminata AG	*Acroperus harpae* G	

Table. 3. Mean abundance (ind. L^{-1}) and biomass (mg L^{-1}) of zooplankton in examined lakes

Tabela. 3. Średnia liczebność (osob. dm^{-3}) i biomasa (mg dm^{-3}) zooplanktonu w badanych jeziorach

Taxa	Abundance			Biomass		
	Adamowo	Grażyna	Klasztorne	Adamowo	Grażyna	Klasztorne
Rotifera	49.5	153.9	1784.7	0.0416	0.0126	0.9330
Cladocera	30.6	5.9	36.3	0.5049	0.0672	0.2348
Copepoda	41.1	6.1	40.2	0.8952	0.0233	0.2154
Total zooplankton	121.4	166.1	1861.3	1.4418	0.1031	1.3834

Table. 4. Pearson correlation between abundance of taxonomical groups of zooplankton and physico-chemical variables in waters of examined lakes. Correlations as significant with $P < 0.05$ are marked with bold; correlations as significant with $P < 0.10$ are marked with italics

Tabela. 4. Korelacja Pearson'a pomiędzy liczebnością grup taksonomicznych zooplanktonu a wartościami fizyko-chemicznych parametrów w wodach badanych jezior. Istotne korelacje przy $P < 0.05$ zostały zaznaczone tłustym drukiem, istotne korelacje przy $P < 0.10$ zostały zaznaczone pochyłym drukiem

	SD	Temp.	O2	pH	Cond.	N-NO3	N-NO2	N-NH3	NTOT	P-PO4	PTOT
Rotifera	*-0.485*	0.006	**0.766**	0.214	0.433	-0.013	**0.781**	0.202	*0.635*	*0.520*	*0.477*
Cladocera	-0.316	-0.140	-0.094	0.417	0.165	-0.133	0.243	0.402	0.050	0.167	0.205
Nauplii	**-0.783**	0.446	0.145	*0.467*	*0.579*	*0.549*	0.142	0.097	*0.488*	0.312	0.058
Copepoda	*-0.452*	0.022	-0.056	**0.780**	0.399	0.312	-0.112	*0.491*	0.339	0.077	0.105

The peak of rotifers abundance in each of the three lakes was observed in May (Fig. 1). Cladocerans were the most abundant and had the greatest biomass in May in Adamowo and Grażyna, while in Klasztorne in February and November, copepods in Adamowo and Grażyna were the most abundant and had the greatest biomass in February and May, while in Klasztorne in August, although in the latter lake 90% of the Copepoda biomass came from nauplii.

According to Pearson correlation tests, the abundance of Rotifera was significantly positively correlated with the concentration of dissolved oxygen and concentration of N-NO2; $P < 0.05$ (Table 4). At the level of significance $P < 0.10$ the abundance of rotifers was positively correlated with phosphorus compounds and water transparency measured by Secchi disk visibility. The abundance of Copepoda Nauplii at $P < 0.05$ was significantly negatively correlated with water transparency measured by Secchi disk visibility. The others positive correlations between Nauplii and NTOT, pH, conductivity, N-NO occurred with $P < 0.01$. The abundance of copepodits and adult Copepoda was statistically significantly positively correlated with pH ($p < 0.05$), and at $P < 0.10$ it was negatively correlated with water transparency and positively correlated with N-NH3.

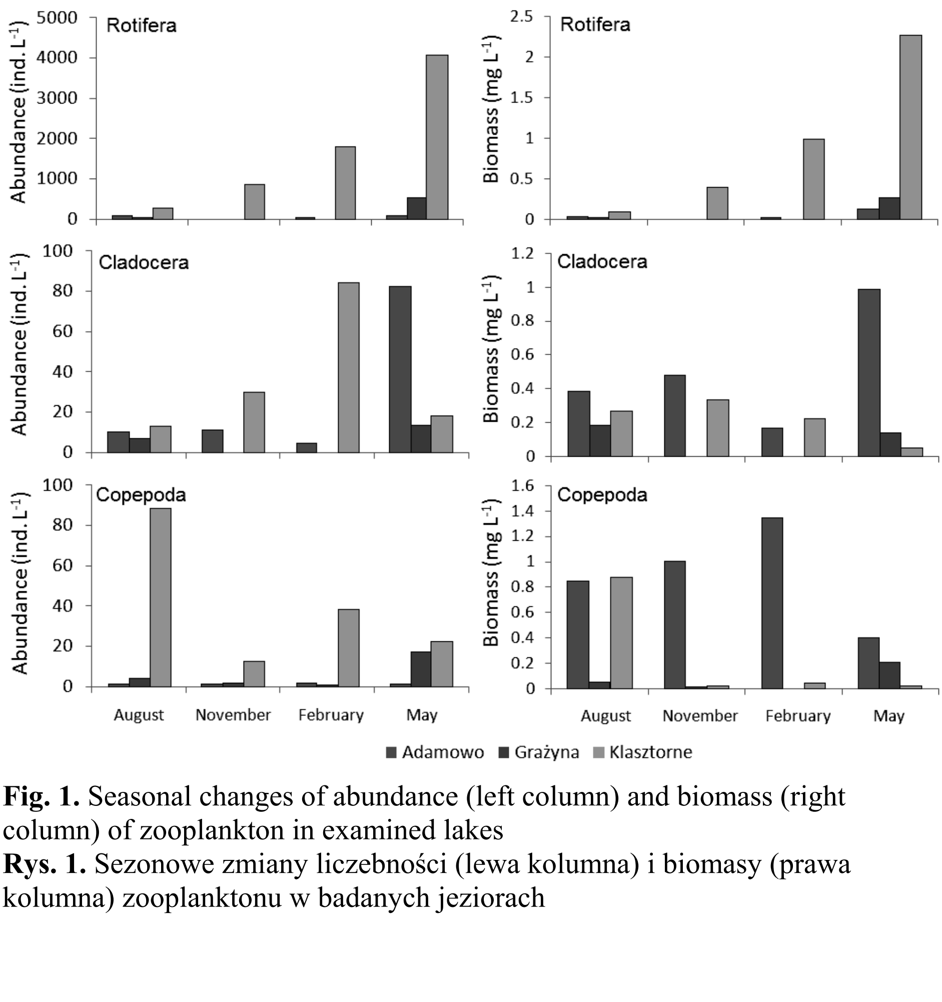

Fig. 1. Seasonal changes of abundance (left column) and biomass (right column) of zooplankton in examined lakes

Rys. 1. Sezonowe zmiany liczebności (lewa kolumna) i biomasy (prawa kolumna) zooplanktonu w badanych jeziorach

4. Discussion

Urban lakes are usually characterised by higher concentration of nutrients having deteriorating effect on the quality of water and favouring lake eutrophication. Their presence is related to the events of direct discharge of raw wastewater or to altered hydrological conditions [1]. However, the environment and character of the lake can determine the rate of trophic changes in the water of each individual lake and lead to differences in the abiotic and biotic parameters between the lakes.

Abiotic parameters of lakes Adamowo, Grażyna and Klasztorne were found much different. The lowest transparency and the highest content of unfavourable inorganic biogenic compounds and conductivity were noted in Klasztorne. The concentration of the undesirable nutrints was higher in this lake than the mean value of this parameter established in lakes or lake outflows in north Poland [12]. This result was attributed to the fact that this lake has the smallest area and volume and that it is joined by a small watercourse flowing through arable land and carp farm ponds. Czerniawski i in. [7] have proved that a small area of a lake favours eutrophication of its waters. Moreover, after [15] the watercourses flowing through arable land carry high amounts of nutrints and interestingly, as shown by Gołdyn i in. [17] the content of total phosphorus reaching a given watercourse from fish farm ponds may make as much as 70% of total phosphorus determined in this watercourse. Higher transparency and lower content of undesirable nutrients in the other two lakes can be directly related to their greater area and depth, whose effect prevails over the negative influence of many events of discharge of raw municipal or farm wastewater into the waters of Adamowo and Grażyna [12].

In all lakes the content of large Cladocera from the genus *Daphnia*, typical water filtrates, was very low [26] and the lowest in Klasztorne. This observation is interpreted as the effect of high pressure of juvenile forms of carp preferably feeding on them Cladocera [18], known as ichthyo-eutrophication [27]. This is the reason for such a low content of large forms of Cladocera in even as fertile a lake as Klasztorne. The three lakes studied are popular with anglers who much prefer catchment of large and predatory fish then carp [9] and who leave in the water considerable amount of groundbaits which also contributes to the high rate of eutrophication.

The total number of zooplankton taxa identified in the three lakes in the whole period of study was 108 (it was mainly the number of species). Ejsmont-Karabin i Kuczyńska-Kippen [13] have reported 114 species in the water of reservoirs in the city of Poznań. This number of taxa is similar to that given by other authors from the lakes of northern and central Poland. In each of the three lakes studied the greatest number of taxa represented Rotifera, making 60%–77% of all taxa found. Many authors have also reported a much higher number of taxa of Rotifera than Crustaceans [17, 23].

The three lakes studied also differed in the number of taxa and density of zooplankton. According to Dodson [10] the number of taxa increases with increasing area of the lake. This correlation was observed when comparing Adamowo and Klasztorne, but it did not hold true for Lake Grażyna, having the area smaller than Adamowo but showing the highest number of taxa. The specific character of Lake Grażyna follows from the fact that it is joined by the rather large Drawa River, which close to its mouth has a large floodplain whose surface is almost fully covered with macrophytes and, according to Illyova [19], floodplains are rich sources of zooplankton. Lake Grażyna is covered with water vegetation over 70% of its area, which favourable for zooplankton development and may account for its diversity [23]. Kuczyńska Kippen i Nagengast [23], Estlander i in. [14] have reported that water reservoirs with profound mosaic character of vegetation biocenoses and thus offering a great number of ecological niches show a greater richness of zooplankton than water current.

The taxa the most often met in the lakes studied included *Keratella coch. coch., Keratella coch. tecta, Keratella quadrata, Polyarthra dolichoptera, Synchaeta oblonga, Synchaeta pectinata, Bosmina coregoni,* nauplii Cyclopoida, kopepodit Cyclopoida, all of them are often met in strongly eutrophic lakes [20]. It can be claimed that all the three lakes are similar as to the frequency of the above taxa, but these taxa are mostly ubiquitous or typical of eutrophic reservoirs. It could be expected that the lakes arranged in a cascade system would have similar qualitative composition of zooplankton. However, the taxonomic composition of Lake Adamowo zooplankton is more similar to that of Klasztorne than to Grażyna, despite the fact that Lake Grażyna once made one lake with Adamowo. Most probably this difference is attributable to the influence of the Drawa river flowing through Lake Grażyna as well as different morphological and environmental conditions. Lake Adamowo has much deeper south-western pool with thermal stratification, similarly as Klasztorne, offering favourable conditions for plankters typical of stratified lakes. This interpretation is consistent with the results of Cottenie et al. [3] who claim that the greater the environmental similarity of the two reservoirs, the greater is the taxonomic composition similarity between them.

The highest mean abundance of zooplankton, of over 1800 ind. L^{-3} with 96% contribution of Rotifera, was observed in Lake Klasztorne. Other authors have reported similar observations for other lakes similar to Klasztorne in Pomeranian Lake-District, e.g. Szlauer [31] estimated the mean abundance of zooplankton as 2528 ind. L^{-3} in Lake Głębokie in Szczecin. Karabin i Ejsmont-Karabin [21] have reported that in the lakes of the Suwalski Landscape Park the total abundance of zooplankton varied from 117 to 26 420 ind. dm^3. In the above lakes Rotifera contributed 75–90% of the total zooplankton abundance. Although the differences in the mean zooplankton abundance between the three lakes studied were statistically insignificant, the abundance of zooplankton in Klasztorne was much greater than in Adamowo and Grażyna, which illustrates that the higher the lake trophy the greater its zooplankton abundance, which refers in particular to small plankters, mainly Rotifera [28].

From among the three lakes studied, the greatest mean biomass was found in Adamowo (1,4418 mg L^{-3}) of which 3% were contributed by Rotifera, 35% by Cladocera and 62% by Copepoda. Karabin i Ejsmont-Karabin [21] claim that usually the biomass of zooplankton is determined by Crustacea, while Rotifera bring a very small contribution. [12, 20]. Studied zooplankton carried out of natural and artificial water reservoirs and reported that the greatest contribution to biomass was brought by Copepoda and Cladocera and then by large Rotifera. The zooplankton of Lake Adamowo had the greatest biomass determined by a relatively great number of Cladocera from the genus Daphnia and mature forms of Copepoda. Statistical tests have confirmed significant differences in Copepoda biomass between Adamowo and Grażyna as well as Adamowo and Klasztorne. Large crustaceans and rotifers from the *Asplanchna* sp. occurred abundantly only in Adamowo, whose bottom is in the smallest part of the 3 lakes in the littoral area and thus has the smallest number of fish fry feeding on plankton, whose presence according to Chang i in. [2], Czerniawski i Domagała [5, 6] is the most important factor limiting the abundance of large plankters. The greater amount of crustaceans in Adamowo than in the other two lakes was also indirectly related to the trophic and biological relations. The small zooplankton biomass in Lake Grażyna is most probably a result of greater pressure of predators and greater transparency, and as claimed by Estlander i in. [14], the greater the transparency the lower the biomass of crustaceans.

Analysis of Pearson's correlations has shown a negative correlation between the transparency (expressed in terms of Secchi disk visibility) and the abundance of all groups of zooplankton. Rotifera were also statistically significantly correlated with oxygen concentration, which can be related to the excessive production of oxygen by phytoplankton. The greatest abundance of rotifers were noted in Klasztorne, characterised by strong blossoming of algae in summer. The content of Nauplii of Copepoda and Cladocera was significantly positively correlated with the concentration of inorganic nutrients and conductivity. According to many authors these taxa are often met in water of high concentration of nutrients [11]. Many positive correlations between abiotic conditions (especially the presence of nutrients) and the content of Copepoda larvae were found, which indicates Copepoda preferences to water of higher trophy. The positive correlation of abiotic parameters and the content of nauplii suggests that the population of Copepoda increases in the water with fast progressing process of eutrophication.

In conclusion, despite the same trophic status the lakes studied differed in the quantitative and qualitative composition of zooplankton, which was attributed to different environmental conditions of the lakes. As follows from analysis of literature, the quantitative and qualitative composition of zooplankton in the lakes studied was similar to those in other lakes of similar trophic status. The greatest number of taxa of Rotifera relative to the number of the other taxa could support the thesis put forward by Ejsmont-Karabin i Kuczyńska-Kippen [13] saying that the effect of urban anthropopressure on water reservoir not always leads to restriction of abundance of the Rotifer taxa. The qualitative similarity between the zooplankton of the three lakes was not so high, which can be related to the morphological differences between the lakes. In Klasztorne the amount of zooplankton (especially small plankters) was the greatest, which suggests that the smaller the lake area the greater the amount of zooplankton in it. The highest biomass of zooplankton was noted in the largest lake Adamowo, which was attributed to the abundant presence of adult crustaceans. In great lakes with a large pelagial zone, the zooplankton biomass is much greater than in small lakes. Analysis of the relation between the environmental conditions of lakes and the composition of their plankton has shown that the greatest effect on the zooplankton structures have the abiotic conditions, in particular the presence of inorganic nutients. Regarding to the obtained results it can be concluded that the most important factor for the occurrence of zooplankton and concentrations of inorganic nutrients are landscape conditions and morphological conditions of lakes.

References

1. **Bajkiewicz-Grabowska E.:** *Evaluation of the natural susceptibility of shallow lakes to degradation***.** GeoJurnal, 14, 367–371 (1987).
2. **Chang K.H., Hwang S.J., Jang M.H., Kim H.W., Jeong K.S., Joo G.J.:** *Effect of juvenile fish predation on the zooplankton community in the large regulated Nakdong River, South Korea***.** Korean Journal of Limnology, 34, 310–318, 2001.
3. **Cottenie, K., Michels, E., Nuytten, N., De Meester, L.:** *Zooplankton metacommunity structure: regional vs. local processes in highly interconnected ponds.* Ecology, 84, 991–1000 (2003).
4. **Cromel F.H.J., Carpenter S.M.:** *Plankton community cycling and recovery after drought – dynamics in a basin on a flood plain.* Hydrobiologia, 164, 193–211 (1988).
5. **Czerniawski R., Domagała J.:** *Zooplankton communities of two lake outlets in relation to abiotic factors.* Central European Journal of Biology, 5(2), 240–255 (2010).
6. **Czerniawski R., Domagała J.:** *Similarities in zooplankton community between River Drawa and its two tributaries (Polish part of River Odra).* Hydrobiologia, 638, 137–149 (2010).
7. **Czerniawski R., Pilecka-Rapacz. M., Domagała J.:** *Ocena statusu troficznego jezior przepływowych zlewni Drawy w odniesieniu do warunków środowiskowych terenu. Dynamika procesów przyrodniczych w zlewni Drawy i Drawieńskim Parku Narodowym.* Instytut Meteorologii i Gospodarki Wodnej, Poznań, 27–38 (2010).
8. **Czerniawski R., Pilecka-Rapacz M.:** *Summer zooplankton in small rivers in relation to selected conditions.* Central European Journal of Biology, 6, 659–674 (2011).

9. **Czerniejewski P., Czerniawski R.:** *Analiza wielkości presji wędkarskiej oraz poziomu wprowadzonych biogenów w zanętach na przykładzie niewielkiego jeziora północno-zachodniej Polski.* [W:] Trudy. IX Miedzynarodnoj nauczno – prakticzeskoj konferencyj mołodych uczienych, studentow i aspirantow. Analiz i Prognozirowanije sistiem Uprawlienija. Sankt Petersburg, 27–35 (2008).
10. **Dodson S.:** *Predicting crustacean zooplankton species richness.* Limnol, Oceanogr, 37(4), 848–856 (1992).
11. **Dodson S.I., Newman A.L., Wolf W.S., Alexander M.L., Woodford M.P., Van Ergeren S.:** *The relationship between zooplankton community structure and lake characteristics in temperate lakes (Northern Wisconsin, USA).* Journal of Plankton Research, 31, 93–100 (2009).
12. **Domagała J., Czerniawski R., Pilecka-Rapacz M.:** *Charakterystyka chemiczna i fizyczna wód środkowej i dolnej Drawy w cyklu rocznym 2007/2008.* Rocznik Ochrona Środowiska, Tom 11, 675–686 (2009).
13. **Ejsmont-Karabin J., Kuczyńska-Kippen N.:** *Urban rotifers – structure and densities of rotifer communities in water bodies of the Poznań agglomeration (Western Poland).* Hydrobiologia, 446/447, 165–171 (2001).
14. **Estlander, S., Nurminen, L., Olin, M., Vinni, M., Horppila, J.:** *Seasonal fluctuations in macrophyte cover and water transparency of four brownwater lakes: implications for crustacean zooplankton in littoral and pelagic habitats.* Hydrobiologia, 620, 109–120 (2009).
15. **Falkowski M., Kukułka I., Kozłowski S.:** *Występowanie azotu azotanowego w środowisku łąkowym w świetle literatury i badań własnych*. Roczniki Naukowe AR Poznań, 251, 19–36 (1993).
16. **Filipiak J., Raczyński M.:** *Jeziora zachodniopomorskie (zarys faktografii)*. Szczecin. 2000.
17. **Gołdyn R.:** *Zmiany biologicznych i fizyczno-chemicznych cech jakości wody rzecznej pod wpływem jej piętrzenia we wstępnych, nizinnych zbiornikach zaporowych.* Wydawnictwo Naukowe UAM. Poznań. 2000.
18. **Gołdyn R.:** *Biomanipulacja w zbiornikach wodnych jako metoda rekultywacji.* W: Materiały konferencyjne VI Konferencji Naukowo-Technicznej „Ochrona i rekultywacja jezior", 14–16.06.07 Toruń, 65–76 (2007).
19. **Illyová M.:** *Zooplankton of two arms in the Morava River floodplain in Slovakia.* Biologia, 61, 531–539 (2006).
20. **Karabin A.:** *Pelagic zooploankton (Rotatoria + Crustacea) variation in the process of Lake Eutrophication. I. Structural and quantitative features.* Ekologia, Poska 33, 567–616 (1985).

21. **Karabin A., Ejsmont-Karabin J.:** *Zespoły zooplanktonu jezior Suwalskiego Parku Krajobrazowego.* w: Hillbricht-Ilkowska A., Wiśniewski R. J. (red.): Jeziora Suwalskiego Parku Krajobrazowego. Związki z krajobrazem, stan eutrofizacji i kierunki ochrony. Zesz. Nauk. Komitetu Naukowego PAN Człowiek i Środowisko, 215–242 (1994).
22. **Klessa L., Agapow L., Piekarska A., Grochowska A., Grochowski P., Raginia P.:** *Przyroda województwa gorzowskiego, życie jezior.* Klub Działalności Podwodnej LOK „Marlin". Gorzów Wlkp. 1996.
23. **Kuczyńska-Kippen N., Nagengast B.:** *The influence of the spatial structure of hydromacrophytes and differentiating habitat on the structure of the rotifer and cladoceran communities.* Hydrobiologia, 559, 203–212 (2006).
24. **Kudelska D., Soszka H.:** *Przegląd stosowanych w różnych krajach sposobów oceny i klasyfikacji wód powierzchniowych*. PIOŚ, Warszawa. 1996.
25. **Kutikova L.A.:** *Kolovratki fauny SSSR (Rotatoria). Podklass Eurotatoria (otryady Ploimida, Monimotrochida, Paedotrochida).* Nauka, Leningrad, (in Russian). 1970.
26. **Lampert W., Sommer U.:** *Limnoecology.* Oxford Uniwersity Press Inc., New York. 2007.
27. **Opuszyński K.:** *Sprzężenie zwrotne między procesem eutrofizacji a zmianami zespołu ryb. Teoria ichtioeutrofizacji.* Wiadomości Ekologiczne, 33, 21–30 (1987).
28. **Radwan S.:** *Fauna słodkowodna Polski, Wrotki (Rotifera).* Polskie Towarzystwo Hydrobiologiczne, Uniwersytet Łódzki. 2006.
29. **Rybak J.I., Błędzki L.A.:** *Słodkowodne skorupiaki planktonowe. Klucz do oznaczania gatunków*. Wydawnictwa Uniwersytetu Warszawskiego. 2010.
30. **Szlauer B.:** *Hydrobiologiczna charakterystyka zbiornika ściekowego Zakładów Chemicznych „Police".* AR, Szczecin. 1985.
31. **Szlauer B.:** *Zooplankton Jeziora Głębokiego jako wskaźnik trofii tego zbiornika.* Zeszyty Naukowe AR Szczecin, 171, 19–34 (1996).
32. **Starmach K.:** *Metody badania planktonu*. PWRiL, Warszawa. 1955.

Zooplankton trzech przymiejskich jezior na tle wybranych warunków abiotycznych

Streszczenie

Badania prowadzono w trzech eutroficznych jeziorach położonych w północno-zachodniej Polsce: jeziorze Adamowo, Grażyna i Klasztorne. Z każdego stanowiska pobierano próbę zooplanktonu oraz próbę wody do określenia wybranych parametrów fizyko-chemicznych. W odniesieniu do uzyskanych wyników można uznać, że pomimo takiego samego statusu troficznego badane jeziora różniły się pod względem struktur jakościowych i ilościowych zooplanktonu, na co miały wpływ różne warunki środowiskowe badanych jezior. Podobieństwo jakościowe zooplanktonu pomiędzy jeziorami nie było zbyt wysokie. W najmniejszym jeziorze obserwowano największe liczebności zooplanktonu, szczególnie małych plankterów. Pozwala to wnioskować, że im mniejsza powierzchnia jeziora tym większa jest liczebność zasiedlającego je zooplanktonu. Biomasa zooplanktonu osiągała największe wartości w największym jeziorze Adamowo, co było spowodowane licznym występowaniem dojrzałych skorupiaków planktonowych. Biorąc pod uwagę zależność pomiędzy warunkami środowiskowymi jezior a zagęszczeniem zooplanktonu, stwierdzić można że największy wpływ na kształtowanie struktur zooplanktonu mają nieorganiczne związki biogenne.