ZOOPLANKTON COMMUNITY STRUCTURE IN SMALL PONDS IN RELATION TO FISH COMMUNITY AND ENVIRONMENTAL FACTORS

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Abstract. The studies were conducted in two small temperate mid-field ponds. The purpose of the research was to determine changes in the zooplankton communities in ponds with diverse ichthyofauna compositions and diverse values of environmental factors. Two research hypotheses were assumed. One pertained to the growth of the number and biomass of *Daphnia* and the loss of illoricate rotifers due to the top predator influence. The other one assumed that the top predators and the value of conductivity indirectly affect the diversity of zooplankton. We assumed that significant differences in the number of *Daphnia* between the ponds result from the regulation of the trophic web from the top down and bottom up, that affect the total zooplankton composition. In the small water bodies where *Daphnia* dominated among cladocerans, the highest numbers belong to loricate rotifers, e.g. *Brachionus sp.* and *Keratella sp.*, whereas in the ponds where the dominance among Cladocera was *Chydorus sphaericus,* illoricate rotifers were abundant, e.g. *Bdelloidea* and *Synchaeta sp.* We concluded that the presence of the top predator caused a significant increase in the species richness and in the biodiversity index for Cladocera. However, the biodiversity index for the whole zooplankton (determined mainly by small rotifers) decreased with the presence of top predator and increased with high conductivity.
Keywords: *biodiversity, biomanipulation, freshwater, plankton, ichthyofauna*

Introduction

The absence or presence of predator fish has a cascade effect on the whole trophic network of the water ecosystem (Hodgson, 2005). An increase in the biomass of predator fish entails a decrease in the biomass of plankton-feeding fish. The decrease in the number of plankton-feeding fish is followed by an increase in the biomass of filter-feeding zooplankton (Carpenter et al., 1985). However bottom up control which refers to the nutrients concentration in the environment and as a consequence food availability is well known to shape the assemblages of zooplankton (Gliwicz, 2002). Moreover, the taxonomic structure, body size and abundance of zooplankton are dependent on its taxonomic composition (Gliwicz and Siedlar, 1980), as well as on the season (Michael, 1969). It is believed that in small water bodies with diverse fish compositions, the mechanisms affecting the structure of the biocenoses from the top of the trophic network will prevail (Lampert and Sommer, 2001), which means that the biggest effect on the composition of species, abundance and biomass of individual zooplankton taxa will be exerted by fish, not by food availability.

The presence of a predator alters the behaviour of small cyprinids. This is manifested by their smaller activity and the preference of young cyprinids to hide in refuges, thanks

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to which daphnids can spend more time feeding in open waters (Romare and Hansson, 2003). Cladocerans such as *Daphnia* normally prevail in small water bodies when they are not randomly limited. Their prevalence results from the exclusion of smaller zooplankton taxa by competition (Diéguez and Gilbert, 2011). The presence of *Daphnia* in a pond may rapidly reduce the number of Rotifera and lead to taxonomic changes in their composition (Gilbert, 1988, 1989; Conde-Porcuna, 1998). *Daphnia* limit the survival of small illoricate rotifers, but has no effect on the survival of adult loricate rotifers (Diéguez and Gilbert, 2011). Despite numerous laboratory experiments, little attention is paid to taxonomic changes in natural small water bodies which may occur as a result of interaction of *Daphnia* with rotifers.

The majority of research in biodiversity and species richness of zooplankton pertained to the effect of trophic conditions on zooplankton (Dodson, 1992; Dodson et al., 2000; Leibold, 1999; Jeppesen et al., 2000; Declerck et al., 2007). Studies of the effect of daphnids on the biodiversity or species richness of zooplankton generally concern invasive species which could displace native crustacean species (Yan et al., 2002; Strecker et al., 2006). But maybe the native species of *Daphnia* have a negative effect on the biodiversity and species richness of rotifers and thus limit the biodiversity of the whole water body? Such a question may be put forward when using biomanipulation as a method for recultivation.

The purpose of this research was to determine changes in the structure of zooplankton communities in small mid-field ponds with diverse ichthyofauna composition and different environmental factors. The following hypotheses were assumed:

1) The presence of a top predator causes an increase in the number and biomass of *Daphnia* and loss of illoricate rotifers.
2) The top predator and the value of electrolytic conductivity correlate with the diversity of the zooplankton.

Methods and area of the research

Two mid-field ponds, Żelisławiec and Stare Czarnowo, with different taxonomical and quantitative composition of fish, located in the NW Poland, were chosen for studies (*Fig.1*). The studies were conducted in the spring, summer and autumn 2010 - 2014. The area of the Żelisławiec pond changed over the years and amounted to 0.91 to 0.64 ha and the area of the Stare Czarnowo pond changed from 0.82 to 0.40 ha. The ponds are similar as regards environmental conditions of drainage basin, which is entirely comprised of agricultural areas. Environmental conditions of drainage basin were determined on with the Corine Land Cover 2006 database. Agricultural areas encompass arable lands, permanent crops, meadows and pastures as well as mixed crop zones. Semi-natural areas are forests, semi-natural ecosystems and systems of shrub vegetation. Urban areas are urbanised areas, industrial areas and anthropogenised green areas. The drainage of the Żelisławiec pond was approximately 52 ha whereas the drainage of the Stare Czarnowo – 18 ha. The bed of two ponds was densely covered by macrophytes. Emerged and submerged vegetation occurred in both of the small water bodies. In the Żelisławiec, the emerged plants constituted 70% of the shoreline: *Typha latifolia* – 50% and *Phragmites australis* – 20%, whereas nymphaeid constituted 55% of the bed area: *Potamogeton natans* – 25%, *Persicaria amphibia* – 30%, and pleustophyte represent by *Lemna minor* – 5%. In the Stare Czarnowo pond, the emerged plants constituted 80% of the shoreline:

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Typha latifolia – 15% and *Phragmites australis* – 20%, *Glyceria maxima* – 45%, whereas the submerged plants constituted 80% of the area: *Ceratophyllum demersum* – 80%, and pleustophyte represent by *Lemna minor* – 5%.

The studies of fish fauna were conducted in summer 2010-2014. In order to determine the species composition of the fish fauna and the total body length of individual, the fish were caught using electric fish gear IUP 12 (Poland). In order to exclude a significant effect of the microhabitats on the shape of zooplankton communities, in each pond four different samples collection spots were selected. The samples were collected from the same place on each occasion. The results from the spots were averaged.

At each site 50 l of water were collected with a 5l bucket, which was filtered through plankton net with 25 μm mesh size. The samples were concentrated to 250 ml and were fixed in a 4 % formalin solution. Using the stirred total sample, ten sub-samples (3 mL) were pipetted into a glass Sedgewick-Rafter Counting Chamber. For identification, a Nikon Eclipse 50i microscope was used. Species were identified using the keys (Nogrady et al., 1993; Radwan, 2004; Dussart and Defaye, 2006; Rybak and Błędzki, 2010). In each sample, the body length of at least 30 individuals from each species was measured with the Pixelink Camera Kit 4.2. If the number of individuals representing a given species was lower than 30, the body lengths of all individuals were measured. The body length conversion to wet mass was made with the use of the tables (Ruttner-Kolisko, 1977; McCauley, 1984; Ejsmont-Karabin, 1998). Shannon diversity index and Sørensen similarity for zooplankton were calculated using the MVSP 3.22. The dominance structure was calculated from the mean values from all samplings. The level for dominance was established as 5% of the total abundance of zooplankton. A Mann-Whitney U-test was carried out to test for statistically significant differences, between sites, for environmental parameters, zooplankton communities and fish community. Spearman correlations were used to asses relationships between environmental parameters and between zooplankton and fish characteristics. Statistical analyses were performed using Statistica 10.

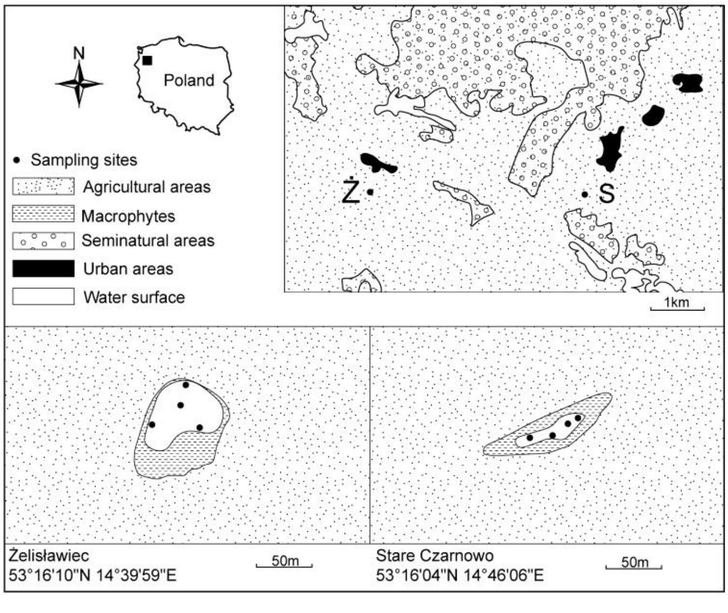

***Figure 1.** Map of the studied small water bodies and land use. Ż – Żelisławiec pond, S – Stare Czarnowo pond.*

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Results

Abiotic factors

As regards abiotic factors in the Stare Czarnowo pond, the value of conductivity was nearly four times higher than in the Żelisławiec pond (P<0.05) (*Table 1*). A nearly twice as high concentration of dissolved oxygen was observed in the Żelisławiec pond than in the Stare Czarnowo pond (P<0.05).

Table 1. *Physical and chemical characteristic of pond and abundance, biomass, body size of Carassius sp in Stare Czarnowo and Żelisławiec (mean ±SD). Significant differences (Mann Whitney U test) * p <0.05, ** p <0.01, *** p <0.001.*

	n	Stare Czarnowo		Żelisławiec
pH	15	7.31±0.36		7.10±0.48
Conductivity (µS/cm^{-1})	15	406.7±69.8	***	113.8±36.4
Dissolved oxygen (mg/L^{-1})	15	2.61±1.26	**	4.38±1.71
Ammonium (mg/L^{-1})	15	0.34±0.79		0.16±0.12
Nitrate (mg/L^{-1})	15	0.14±0.16		0.11±0.17
Orthophosphate (mg/L^{-1})	15	0.72±0.5		0.72±0.5
Depth (cm)	15	114.1±43.3		103.7±34.6
Abundance *Carassius carassius*	5	1.0±2.2		5±3.3
Abundance *Carassius gibelio*	5	21.0±12.5		10.4±7.6
Biomass *Carassius carassius* (g)	5	42.6±95.2	*	1294.2±853.2
Biomass *Carassius gibelio* (g)	5	859.2±877.1		2247.2±1662.5
Size *Carassius carassius* (cm)	5	2.18±4.87	*	17.64±9.94
Size *Carassius gibelio* (cm)	5	9.56±6.25	*	23.14±3.34

Fish composition

Six fish species (*Carassius carassius*, *Carassius gibelio*, *Tinca tinca*, *Perca fluvitalis, Rutilus rutilus*, *Esox lucius*) were observed in the both small water bodies. All species occurred in the Żelisławiec whereas only *Carassius carassius* and *Carassius gibelio* were observed in Stare Czarnowo. *Carassius carassius* and *Carassius gibelio* in Żelisławiec were characterised by higher mean body mass and higher mean body length than in Stare Czarnowo (P>0.05) (*Table 1*).

Zooplankton taxonomic composition

Altogether 134 zooplankton taxa were observed in the studied ponds throughout the research period. In the Stare Czarnowo 112 taxa were revealed, 85 belonged to Rotifera, 12 Cladocera and 15 Copepoda. In The Żelisławiec 90 taxa were determined, 60 belonged to Rotifera, 16 Cladocera and 14 Copepoda. In Stare Czarnowo the zooplankton communities were dominated by *Bdelloidea* (18%), *Chydorus sphaericus* (37%) and *Eudiaptomus gracilis* (21%), whereas in Żelisławiec: *Keratella quadrata* (37%), *Daphnia longispina* (35%) and *Eudiaptomus gracilis* (27%) (*Table 2*). In Żelisławiec, the dominant rotifers were loricate species, whereas in Stare Czarnowo illoricate rotifers.

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Table 2. *Zooplankton taxa of two studied ponds. + presence, - absence, H-mean abundance in group over 5%, D-dominant in mean abundance of the group.*

	Stare Czarnowo	Żelisławiec		Stare Czarnowo	Żelisławiec
Rotifera	85	60	*Polyarthra dolichoptera*	+	+
Anuraeopsis fissa	+	+	*Polyarthra remata*	-	+
Ascomorpha ecaudis	+	+	*Polyarthra longiremis*	+	+
Asplanchna priodonta	+	+	*Polyarthra vulgaris*	-	+
Brachionus angularis	+	H31%	*Rotaria rotatoria*	+	-
Brachionus budapestinensi	-	+	*Scaridium longicaudum*	+	-
Brachionus calyciflorus	+	+	*Squatinella mutica*	+	-
Brachionus leydigi leydigi	-	+	*Squatinella rostrum*	+	-
Brachionus quadridentatus	+	+	*Stephanoceros fimbriatus*	-	+
Brachionus rubens	+	H22%	*Stephanoceros* sp.	+	-
Brachionus urceolaris	-	+	*Synchaeta* sp.	H6%	+
Cephalodella catellina	+	-	*Synchaeta pectinata*	+	+
Cephalodella gibba	+	-	*Testudinella patina*	+	+
Cephalodella sp.	+	+	*Testudinella truncata*	+	-
Cephalodella sterea	+	-	*Trichocerca brachyura*	+	+
Cephalodella ventripes	+	-	*Trichocerca dixon-nuttalli*	+	+
Colotheca sp.	-	+	*Trichocerca iernis*	+	+
Colurella colurus	+	-	*Trichocerca insignis*	+	-
Colurella obtusa	+	-	*Trichocerca intermedia*	+	+
Colurella uncinata	+	+	*Trichocerca musculus*	+	-
Euchlanis deflexa	+	+	*Testudinella patina*	+	-
Euchlanis dilatata	+	+	*Trichocerca porcellus*	+	+
Euchlanis incisa	+	+	*Trichocerca pusilla*	-	+
Euchlanis lyra	+	+	*Trichocerca rattus*	+	+
Euchlanis oropha	+	-	*Trichocerca similis*	-	+
Filinia brachiata	-	+	*Trichocerca tenuior*	+	-
Filinia longiseta	+	+	*Trichocerca tigris*	+	-
Filinia maior	-	+	*Trichocerca weberi*	+	+
Filinia passa	-	+	*Trichotria pocillum*	+	+
Filinia terminalis	+	+	*Trichotria tetractis*	+	-
Hexarthra mira	-	+	Bdelloidea	D18%	+
Keratella cochlearis	+	H8%	**Cladocera**	12	16
Keratella cochlearis tecta	+	+	*Alona guttata*	+	+
Keratella hiemalis	+	+	*Alona rectangula*	+	+
Keratella irregularis	-	+	*Alonella nana*	-	+
Keratella quadrata	H6%	D37%	*Bosmina longirostris*	-	+
Keratella testudo	+	+	*Ceriodaphnia laticauda*	+	-
Keratella ticinensis	+	-	*Ceriodaphnia megops*	+	H7%
Lecane acus	+	-	*Ceriodaphnia pulchella*	-	+
Lecane arcuata	+	-	*Ceriodaphnia quadrangul*	+	+
Lecane bulla	+	+	*Chydorus sphaericus*	D37%	H16%
Lecane closterocerca	+	+	*Daphnia cucullata*	-	+
Lecane cornuta	+	-	*Daphnia longispina*	H11%	D35%
Lecane elsa	+	-	*Oxyurella tenuicaudis*	+	+
Lecane flexilis	+	-	*Peracantha truncata*	+	H12%
Lecane furcata	+	-	*Pleuroxus aduncus*	+	-
Lecane hamata	+	+	*Pleuroxus trigonelus*	-	+
Lecane ludwigii	+	+	*Scapholeberis mucronata*	-	H15%
Lecane luna	+	-	*Simocephalus expinosus*	H12%	+
Lecane lunaris	+	+	*Simocephalus vetulus*	H8%	+
Lecane quadridentata	+	-	**Copepoda**	15	14
Lecane quadridentata	+	-	*Cryptocyclops bicolor*	H9%	+
Lepadella acuminata	+	+	*Diacyclops bicuspidatus*	H13%	-
Lepadella heterodactyla	+	-	*Ectocyclops phaleratus*	+	-
Lepadella ovalis	+	+	*Eucyclops macruroides*	+	H7%
Lepadella patella	+	-	*Eucyclops macrurus*	H6%	H6%
Lepadella qinquecostata	+	-	*Eucyclops serrulatus*	H11%	H18%
Lepadella quadricarinata	+	-	*Eudiaptomus gracilis*	D21%	D27%
Lepadella rhomboides	+	+	*Macrocyclops albidus*	+	+
Lepadella triptera	+	-	*Macrocyclops distinctus*	-	+
Lophocharis oxysternoon	+	-	*Macrocyclops fuscus*	H7%	-
Monommata aequalis	+	+	*Megacyclops viridis*	+	+
Monommata longiseta	+	-	*Mesocyclops leuckarti*	+	H19%
Monommata maculata	+	-	*Paracyclops affinis*	+	H5%
Mytilina bisulcata	+	-	*Paracyclops poppei*	+	+
Mytilina mucronata	+	+	*Thermocylops crassus*	+	+
Mytilina ventralis	+	+	*Thermocylops oithonoides*	-	H5%
Mytilina trigona	+	-	Harpacticoida	H6%	+
Platyias quadricornis	+	+			

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The highest values of taxonomic similarity were recorded for the Żelisławiec pond in spring and summer (0.720), for Stare Czarnowo in spring and summer (0.646) and for both Stare Czarnowo and Żelisławiec in autumn (0.651) (*Table 3*).

Table 3. *Sørensen's similarity coefficient. S-Spring, Su-Summer, A-Autumn.*

		Stare Czarnowo S	Żelisławiec S	Stare Czarnowo Su	Żelisławiec Su	Stare Czarnowo A
Żelisławiec	S	0.582				
Stare Czarnowo	Su	0.667	0.534			
Żelisławiec	Su	0.519	0.72	0.531		
Stare Czarnowo	A	0.646	0.551	0.569	0.548	
Żelisławiec	A	0.585	0.661	0.569	0.613	0.651

The number of Rotifera taxa ($P<0.01$) (24 to 14), the number of zooplankton taxa ($P<0.05$) (31 to 22), the Rotifera biodiversity index ($P<0.01$) (2.07 to 1.34) and the zooplankton biodiversity index ($P<0.01$) (2.3 to 1.59) were significantly higher in Stare Czarnowo than in Żelisławiec.

Zooplankton abundance

In total zooplankton of both small water bodies rotifers had the highest percentage contribution in abundance. Moreover their percentage indicated growth from spring (Stare Czarnowo 53% and Żelisławiec 51%) to autumn, reaching the maximum of 75% in Stare Czarnowo and 91% in Żelisławiec (*Fig. 2*). In spring the percentage share of crustaceans in both ponds almost reached 50%. Moreover, in spring the proportion of Cladocera in the population was six times higher in Żelisławiec than in Stare Czarnowo. The density of *Daphnia* in Żelisławiec was over fourteen times higher than in Stare Czarnowo ($P<0.05$) (3.2 to 46.9 ind./dm^{-3}) (*Table 4*).

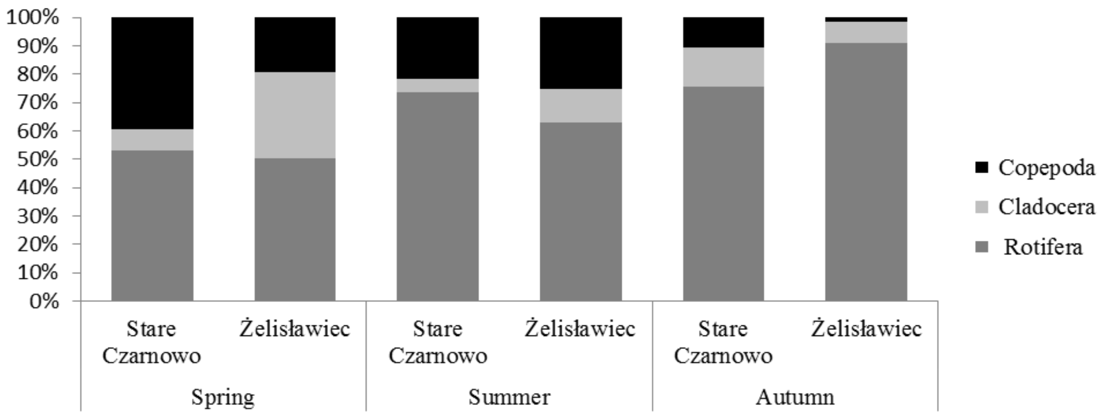

Figure 2. *Percentage of mean abundance of zooplankton in seasons.*

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Table 4. *Value of zooplankton factors (mean ±SD) in ponds. Significant differences (Mann Whitney U test) * p <0.05, ** p <0.01, *** p <0.001.*

	n	Stare Czarnowo		Żelisławiec
Abundance *Rotifera* (ind. L^{-1})	14	94.3±61.5		243.6±272.8
Abundance *Cladocera* (ind. L^{-1})	14	11.0±10.8		74.8±88.1
Abundance *Copepoda* (ind. L^{-1})	14	45.9±54.1		63.7±72.2
Abundance *Copepoda* (mature) (ind. L^{-1})	14	2.9±3.0		4.5±5.3
Abundance All zooplankton (ind. L^{-1})	14	156.8±108.1		358.5±320.9
Abundance *Daphnia sp.* (ind. L^{-1})	14	3.2±8.7	*	46.9±81.2
Biomass *Rotifera* (mg. L^{-1})	14	0.23±0.52		0.36±0.36
Biomass *Cladocera* (mg. L^{-1})	14	0.72±0.66		7.74±10.71
Biomass *Copepoda* (mg. L^{-1})	14	0.53±0.61		0.8±0.87
Biomass All zooplankton (mg. L^{-1})	14	1.3±1.05	*	8.89±11.05
Number of taxa *Rotifera*	14	24.0±9.1	**	14.9±5.8
Number of taxa *Cladocera*	14	4.1±2.5		5.3±3.5
Number of taxa *Copepoda*	14	3.0±2.1		2.4±2.1
Number of taxa All zooplankton	14	31.1±11.1	*	22.6±8.6
Shannon Index *Rotifera*	14	2.07±0.53	**	1.34±0.63
Shannon Index *Cladocera*	14	0.83±0.54		0.79±0.56
Shannon Index *Copepoda*	14	0.81±0.60		0.54±0.53
Shannon Index All zooplankton	14	2.3±0.51	**	1.59±0.64

Zooplankton biomass

In both small water bodies, crustaceans dominated in the zooplankton biomass (*Fig. 3*). In Stare Czarnowo the percentage of Cladocera biomass ranged from 42% in spring to 61% in summer and 50% in autumn. In Żelisławiec, the percentage of Cladocera was higher and amounted to 84%, 91% and 86% from spring to autumn respectively. The percentage of Rotifera biomass in Stare Czarnowo increased from spring (6%) to autumn (34%) whereas in Żelisławiec it remained on a low level and did not exceed 8%. An almost seven times higher mean zooplankton biomass was observed in Żelisławiec than in Stare Czarnowo (P<0.05) (1.30 to 8.89 mg/dm^{-3}).

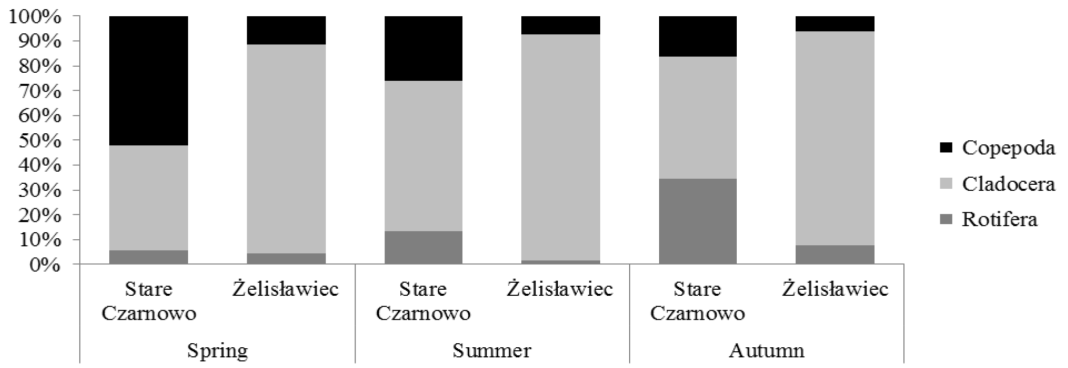

Figure 3. *Percentage of mean biomass of zooplankton in seasons.*

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Correlation between zooplankton composition and environmental factors

The simple correlation indicated that eleven environmental variables correlated significantly with the values of fifteen variables of zooplankton ($p<0.05$) (*Table 5*). The abiotic parameter which correlated the most often with the structures of zooplankton was depth. Further variables correlated with these structures were the content of dissolved oxygen and the value of conductivity. The fish predominantly displayed a significant correlation with Rotifera structures and Cladocera biodiversity index. In the former case, the number of Rotifera taxa was negatively correlated with the number of pike, Prussian carp biomass and pike biomass but was positively correlated with sizes of the crucian carp. In the latter case, the Cladocera biodiversity Index was negatively correlated with the number of Prussian carp and positively correlated with the number of pike.

Table 5. *Significant correlations (p <0.05) of Spearman analysis between the factors of zooplankton and environmental variables.*

	Abundance *Rotifera*	Abundance *Cladocera*	Abundance *Copepoda*	Abundance *Copepoda* (mature)	Abundance all zooplankton	Abundance *Daphnia*	Biomass *Cladocera*	Biomass *Copepoda*	Biomass All zooplankton	Number of taxa *Rotifera*	Number of taxa *Copepoda*	Number of taxa all zooplankton	Shannon Index *Rotifera*	Shannon Index *Cladocera*	Shannon Index all zooplankton
Abundance *Carassius gibelio*														-0.72	
Abundance *Esox lucius*										-0.83				0.74	
Biomass *Carassius carassius*										-0.89			-0.79		
Biomass *Carassius gibelio*									0.79						
Biomass *Esox lucius*										-0.72					
Size *Carassius carassius*										-0.83					
Size *Esox lucius*													-0.79		-0.76
Conductivity		-0.42				-0.54	-0.40		-0.52	0.47			0.44		0.38
Dissolved oxygen		0.39				0.41	0.48		0.57						
Phosphate			-0.38									-0.43			
Depth	0.40		0.49	0.53	0.46	0.53		0.44	0.41		0.47				

Discussion

Results of analyzed data show that the presence of a top predator causes direct and indirect changes on structure of zooplankton namely increase in the number and biomass of *Daphnia* and loss of illoricate rotifers which affect species richness and biodiversity of zooplankton. The results of our research and analysis of the results of other authors (Carpenter et al., 1985; Jeppesen et al., 2000; Hodgson, 2005; Declerck et al., 2007; Diéguez and Gilbert, 2011) confirming our hypotheses.

The taxonomic and quantitative composition of zooplankton of the studied ponds is similar to those observed by other authors in similar small water bodies (Radwan, 2004; Segers, 2008). Distinct prevalence of rotifers over crustaceans as regards the number of taxa and their number has been demonstrated numerous times (Karabin, 1985; Herzig, 1987; Kuczyńska-Kippen, 2009).

The studied ponds differed in dominants in the Rotifera and Cladocera groups. A large number of loricate rotifers in Żelisławiec may directly result from the prevalence of specific Cladocera taxa, particularly *Daphnia*. In fishless ponds *Daphnia* may often

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severely limit the abundance of small rotifers by mechanical interference (ingestion and damage after rejection) (Diéguez and Gilbert, 2011). They revealed that adult *Brachionus sp.* avoided fatal consequences of interference with *Daphnia*. This is indicated by the fact that where *Daphnia* prevail, the biggest numbers are demonstrated by loricate rotifers, but where the dominance among Cladocera was *Chydorus sphaericus*, then illoricate rotifers were abundant *(Bdelloidea* and *Synchaeta sp.)*. It is presumed that *Daphnia* also had some effect on the lower number of zooplankton taxa in Żelisławiec than in Stare Czarnowo, including as many as 25 fewer Rotifera taxa.

Differences in the zooplankton communities between spring and summer were observed in both ponds, which may indicate stability in the species composition in both small water bodies. A significantly higher number and biomass of Cladocera (mainly *Daphnia*) in Żelisławiec (with top predator) than in Stare Czarnowo seems to have limited the number of Rotifera taxa and taxa of small cladocerans. A poor population of cladocerans as Dapnia in spring in Stare Czarnowo resulted from the high pressure from small cyprinids, which caused better conditions for development of small crustaceans and illoricate rotifers. In spring and summer, when cyprinids hatch, the pressure on cladocerans is the largest. Zooplankton abundance declined greatly after the peak in fish larval abundance (Welker, 1994). Therefore, in spring and in summer, we could observe different zooplankton structures in both ponds. In autumn, however, high similarity between the two ponds was observed. Perhaps, the autumn fry was too large to significantly reduce the populations of larger plankters in the pond where pike was absent. Fluctuations in zooplankton populations can occur both spatially and temporally and may be caused, in part, by predation from planktivorous fishes (Welker, 1994).

The abundance domination of Rotifera is typical of such small mid-field water ecosystems (Kuczyńska-Kippen, 2009; Mieczan et al., 2016). However, the domination was not evenly distributed in different seasons, as mentioned above. The increase Rotifera percentage in the abundance of zooplankton from summer to autumn may pertain to the feeding on crustacean by fry and consequently increasing the density of rotifers. However, as pointed out above, the proportion of rotifers in the number of zooplankton was smaller in the pond with pike than in the pond without it. The value of zooplankton biomass in both ponds can be justified in a similar manner. Generally the zooplankton biomass is dominated by cladocerans due to their larger sizes, predominantly, when there is no factor which would limit them (Carpenter et al., 1985). Simultaneously, two aspects affected higher biomass in the pond with pike: the altered behaviour of Prussian carp which resulted in reduced pressure on cladocerans and a reduced number of small cyprinids, as well as the reduction of rotifers by the filtration mechanism of large ones (Diéguez and Gilbert, 2011).

Changes in the density of large piscivorous fish results in changes in density, species composition, and behaviour of zooplanktivorous fish. Planktivorous fish select the largest available prey and can rapidly reduce the density of zooplankters (Carpenter et al., 1985; Gliwicz, 2002). So, we believe that the high mean sizes of the Prussian carp in Żelisławiec can be justified by the occurrence of a predator which reduced the number of young individuals of the Prussian carp. In Stare Czarnowo, where pike was absent, the Prussian carp had smaller mean sizes and their number was higher, which might have contributed to the reduction of some zooplankton taxa. Significant differences in the number of *Daphnia* between the small water bodies result from the regulation of the trophic network from the top and affect the whole zooplankton structure. This is a common pattern of biomanipulation which is used as one of the methods for lake

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recultivation (Jeppesen et al., 2007). Top-predators are not always associated with biodiversity benefits. On the basis of research of large land predators, it was proved that the top predator may have a negative effect on endemic species or may reduce other precious smaller species (Allen et al., 2012; Duffy et al., 2007). Duffy et al. (2007) put the question. "What are the community and ecosystem-level consequences of biodiversity loss?". In the case of the small water ecosystems we analysed, the absence of a predator and, simultaneously, the lack of one trophic level cause reorganisation of the zooplankton structure. It also has a different effect on various groups of planktonic organisms, which will be discussed further.

The strongest negative correlations between the number of Rotifera taxa and the biomass of the Prussian carp and its sizes can be justified by the fact that larger Prussian carps beginning to feed on macro-invertebrates discontinue feeding on cladocerans (Tsoumani et al., 2006) which led to the domination of the largest possible plankters which were not limited by predators. Similar significant correlations were observed between the biodiversity index and the number of the Prussian carp. It is common knowledge that young cyprinids feed on crustaceans and food selectivity (Gliwicz, 2002) may lead to displacement of some species. Therefore, a large number of a predator which limited small plankton-feeding Prussian carp caused a significant increase in the Cladocera biodiversity index. The biodiversity index for the total zooplankton was negatively correlated with total length of pike, which results from the fact that the overall zooplankton biodiversity is mainly shaped by Rotifera, due to their domination in density and the number of taxa. Links between biodiversity and ecosystem function provide compelling reasons for conserving maximal numbers of species in ecosystems (McGrady-Steed et al., 1997). It also has to be noted critically that a different species composition of submerged macrophytes in both ponds could have affected species diversity and biodiversity (Schriver et al., 1997).

The abiotic parameter which correlated significantly positively with the biggest number of taxa was depth. We believe that higher abundance and biomass in high water level result from surface runoff that promote a high re-suspension of sediments into the water column. This hypothesis requires further research.

The zooplankton composition in both ponds could have differentiated in the values of conductivity, which differed significantly the small water bodies. According to Sousa et al. (2008), high values of conductivity is often correlated with high trophy status and among many of the environmental variables, conductivity significantly explains the principal variations in the species composition of the zooplankton community. Similarly, Żurek (1983) did not reveal any significant correlations between conductivity and zooplankton communities. However, in the present study effect of conductivity on the number of zooplankton, species richness and biodiversity index was observed. Bērziņš and Pejler (1989) suggest that species as *Brachionus sp*. stand out for its great tolerance to high conductivity. Diverse value of conductivity in studied ponds were a factor that supports different zooplankton community that we think was mainly shaped by fish community.

Another important variable differentiating both ponds was the concentration of dissolved oxygen. Zooplankton can tolerate lower oxygen concentrations than fish and may use oxygen gradients as refuges against predation (Horppila et al., 2000). Low dissolved oxygen concentration has little influence on zooplankton (Yang et al., 2012). In our study in pond with higher oxygen concentration and lower conductivity (Żelisławiec) we determined low taxa richness and biodiversity of zooplankton. Even

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though oxygen concentration was high no positive effect on taxa richness and biodiversity of zooplankton was observed. We assume that fish community in this study has been a leading factor. Moreover, higher oxygen concentration and lower values of conductivity in Stare Czarnowo may have been caused by the presence of pike. Many authors describing biomanipulation as a target effect demonstrate improvement of physico-chemical conditions (Hodgson, 2005; Jeppesen et al., 2007; Eriksson et al., 2009) which may be related to an increase in dissolved oxygen concentration and a decrease in conductivity values, which were observed in the ponds.

Summary

Changes in density of large piscicorous fish result in changes in density, species composition, and the behaviour of the zooplanktivorous that select largest available prey and can rapidly reduce the density of zooplankters. In the pond with pike, crucian carps were characterised by bigger sizes and a smaller number of individuals, which was attributed to the lower pressure on cladocerans. Significant differences in the abundance of *Daphnia* between the small water bodies result from the regulation of the trophic web from the top and affect the whole zooplankton structure. However bottom up control which refers to the nutrients concentration in the environment and as consequence food availability shape the assemblages of zooplankton. From the other hand high conductivity values could be a factor that promotes some species e.g. *Brachionus sp*. In ponds with top predator, large *Daphnia* severely limited the abundance of small rotifers by mechanical interference (ingestion and damage after rejection). In the pond where *Daphnia* dominated among cladocerans, the highest numbers belong to loricate rotifers, e.g. *Brachionus sp.* and *Keratella sp.,* whereas in the pond where the dominance among Cladocera was *Chydorus sphaericus,* illoricate rotifers were abundant, e.g. *Bdelloidea* and *Synchaeta sp.* The presence of the top predator caused a significant increase in the species richness and in the biodiversity index for Cladocera but higher conductivity values supports higher species richness and biodiversity of all zooplankton. The overall zooplankton biodiversity is shaped by Rotifera which may be limited by large cladocerans, due to the top effect of the top predator on the trophic network.

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