EFFECT OF ENVIRONMENTAL CONDITIONS ON ROTIFERS AND SELECTED PHYTOPLANKTON SPECIES IN THREE SUBMOUNTANE DAM RESERVOIRS (SOUTHERN POLAND, CENTRAL EUROPE)

AGNIESZKA POCIECHA, ELŻBIETA WILK-WOŹNIAK

Institute of Nature Conservation, PAS, al. Mickiewicza 33, 31-120 Kraków, Poland; e-mail: pociecha@iop.krakow.pl, wilk@iop.krakow.pl

Abstract

Pociecha A., Wilk-Woźniak E.: Effect of environmental conditions on rotifers and selected phytoplankton species in three submountane dam reservoirs (southern Poland, Central Europe). Ekológia (Bratislava), Vol. 26, No. 2, p. 132–142, 2007.

The investigation of the influence of environmental factors on rotifers and selected species of planktonic diatoms, and green algae were carried out in the three submountane reservoirs: Czorsztyn (**CR**), Dobczyce (**DR**) and Rożnów (**RR**). All reservoirs are located in southern Poland. All three reservoirs are submountane type, but they differ in trophic state, age, shape, depth etc. In these studies, the most abundant species from rotifers, diatoms and green algae were chosen. Additionally, the physico-chemical parameters were used in the statistical analyses. RDA analysis showed effect of environmental factors on rotifer communities but did not show any affect on the chosen algal species. The most important environmental factors which had influence on rotifers were water temperature, Ca and alkalinity.

The following study proves that each type of reservoir contained a variety of rotifer communities, with changes in species composition occurring in relation to changes in environmental conditions.

Key words: rotifer, algae, dam reservoir, physico-chemical parameters, trophy status

Introduction

Field studies have documented seasonal changes in zooplankton community structure, that is, large cladocerans are replaced by small cladocerans, rotifers or copepods (Smith, Gilbert, 1995). Rotifers are a very common group living in the rivers and different water bodies, where they play a very important ecological role. Artificial reservoirs are influenced by the river system, especially after heavy rains, melting of snow etc. Such conditions as a violent influx of river water can cause a change in environmental conditions, which results in the development of rotifer communities (Godlewska et al., 2003), showing a gleaner – opportunist trade-off. Gleaner species have high threshold resource levels and high maximum population growth rates. They will be "winning" species, since they had both the lowest and greatest ability to store resources and ration their use during times of extreme resource scarcity (Kirk, 2002). Obviously, rotifers like other planktonic organisms are influenced by a variety of physical, chemical and biological factors. One of the main problems in ecology is to untangle the interactions among these factors and to measure their relative importance (Lehman, 1991; Devetter, 1998).

In our investigations, based on field studies, we showed an effect of environmental conditions on rotifers but not on chosen planktonic algal species. Defining the dynamics of rotifers is important for broadening our knowledge of the ecology of plankton communities and their response to changes in trophic state. We hypothesize that the trophic state of reservoirs may have an influence on the dynamics, densities and structures of rotifers, thus different reservoirs have different factors influencing rotifer communities. These studies could be useful for predicting the trend of zooplankton development. Furthermore, interactions between physico-chemical features of the reservoir may be crucial for interpreting community dynamics (Threlkeld, 1983; Hayvard, Van Den Avyle, 1986; Urabe, 1990; Betsill, Van Den Avyle, 1994; Pollard et al., 1998; Błędzki, Ellison, 2000).

Material and methods

The investigation was carried out in three submountane reservoirs, which were different in type of trophic state and age (Table 1). The mesotrophic Czorsztyn reservoir (**CR**) was cooler than the meso-eutrophic Dobczyce reservoir (**DR**) and the eutrophic Rożnów reservoir (**RR**) was the warmest one (Mazurkiewicz-Boroń, 2002). All of reservoirs are located in S Poland (C Europe) (Fig. 1). They are dimictic and stratified from May until September. The sampling sites in all reservoirs were located in the deepest, central part.

The samples for analyses of phyto-, zooplankton and physico-chemical parameter were taken monthly from April to October in 1998, at the same time in every reservoir. The following parameters were measured: water temperature, pH, secchi disc depth, oxygen saturation, PO_4^{+3}, P_{tot}, N-NH_4, N- NO_3, SiO_2, Fe, Mg^{+2}, Ca^{+2}, alkalinity. The physico-chemical parameters were determined according to APHA (1992) and Hermanowicz et al. (1976).

T a b l e 1. Morphometric features of the investigated reservoirs.

	Czorsztyn Res.	Dobczyce Res.	Rożnów Res.
River	Dunajec	Raba	Dunajec
Year of filling	1997	1987	1942
Length (km)	11	12	20
Width (km)	0.4–1.75	0.25–1.1	0.3–1.5
Depth average (m)	18.3	10.5	8.3
Max (m)	46	28–30	25–28
Altitude (m a.s.l.)	529	269.9	350
Capacity x $10^6 m^3$	181.2	99.2	79.2
Surface (km^2)	11	10.5	18
Retention time (in days)	111	100	32
Trophic state	mesotrophic	meso-eutrophic	eutrophic

Fig. 1. Location of the reservoirs studied in Southern Poland.

Samples for qualitative and quantitative analyses of algae were taken from the epilimnion (0–2m), preserved with Lugol's solution and concentrated by sedimentation (Starmach, 1955). Algae were counted according to Lund et al. (1958), using a chamber of 0.4 mm in height and 22 mm in diameter.

The zooplankton was collected using a 5-L sampler at the surface and 2 m. Samples were concentrated with a plankton net (mesh 50 µm) and preserved in 4% formaldehyde solution and sub-samples observed microscopically in a chamber (volume 0.5 ml). The taxonomical and quantitative analyses of rotifers were elaborated following the methods used in previous hydrobiological studies (Starmach, 1955; Hillbricht-Ilkowska, Patalas, 1967; Pociecha, Wilk-Woźniak, 2000).

The program CANOCO Version 4.5 was used for statistical analyses (Ter Braak, Šmilauer, 2002). For the statistical analysis only the most abundant or continuously present species were chosen:

– diatoms: *Asterionella formosa* H a s s., *Aulacoseira granulata* (E h r.) S i m o n s e n, *Cyclotella* spp., *Fragilaria crotonensis* K i t t., *Melosira varians* A g a r d h., *Navicula* sp., *Nitzschia* sp.;
– green-algae: *Coelastrum microporum* N a e g., *Elakatothrix acuta* P a s c h., *Lagerheimia* sp., *Oocystis* sp., *Pandorina morum* (O.F. M ü l l.), *Pediastrum boryanum* (T u r p.) M e n e g h., *P. duplex* M e y e n, *P. simplex* M e y e n, *Scenedesmus acuminatus* (L a g e r h.) C h o d., *S. ecornis* (E h r.) C h o d., *S. quadricauda* Tu r p. (B r é b.) sensu C h o d a t, *Tetraedron minimum* (A.B r) H a n s g.;
– rotifers: *Anuraeopsis fissa* (G o s s e), *Asplanchna priodonta* (G o s s e), *Conochilus unicornis* (R o u s s e l e t), *Kellicottia longispina* (K e l l i c o t t), *Keratella cochlearis* (G o s s e), *K. cochlearis* f. *tecta* (G o s s e), *K. quadrata* (O.F. M ü l l.), *Pompholyx sulcata* (H u d s o n), *Polyarthra vulgaris* (C a r l i n), *Synchaeta* sp., *S. oblonga* (E h r.), *S. pectinata* (E h r.).

RDA analysis was chosen to state the effect of environmental conditions on the rotifers and chosen species of diatoms and green algae densities. The aim of the analysis was to show differences in the rotifers and algal communities in relation to different dam reservoirs.

Results

Chemical parameters

All reservoirs are located in the same region of Poland, but they differed in physico-chemical variables (Table 2).

T a b l e 2. Some physico-chemical parameters of water during investigated year in three submountane reservoirs.

	Czorsztyn Res.		Dobczyce Res.		Rożnów Res.	
	min.	max.	min.	max.	min.	max.
Temperature ^{o}C	5.8	18.8	6.75	20.7	6.8	20.85
pH	8.1	9.1	8.0	8.94	8.18	8.65
O2 (mg l^{-1})	8.37	11.4	8.61	12.4	5.95	13.52
PO43+ (mg l^{-1})	0.018	0.05	0.02	0.06	0.02	0.123
$P_{tot.}$ (mg l^{-1})	0.04	1.93	0.043	2.9	0.01	1.7
N-NH_4 (mg l^{-1})	0.23	0.26	0.22	0.32	0.22	0.35
N-NO_3 (mg l^{-1})	0.38	1.02	0.7	1.62	0.34	2.04
SiO_2 (mg l^{-1})	0.45	3.9	0.8	4.95	0.73	4.31
Fe (mg l^{-1})	0.04	0.06	0.04	0.25	8.05	9.86
Mg (mg l^{-1})	6.29	7.7	6.2	7.7	0.04	0.125
Ca (mg l^{-1})	31.45	41.05	37.7	42.5	38.41	44.31
Secchi Disc (m)	1.2	3.75	1.5	2.7	0.35	2.0

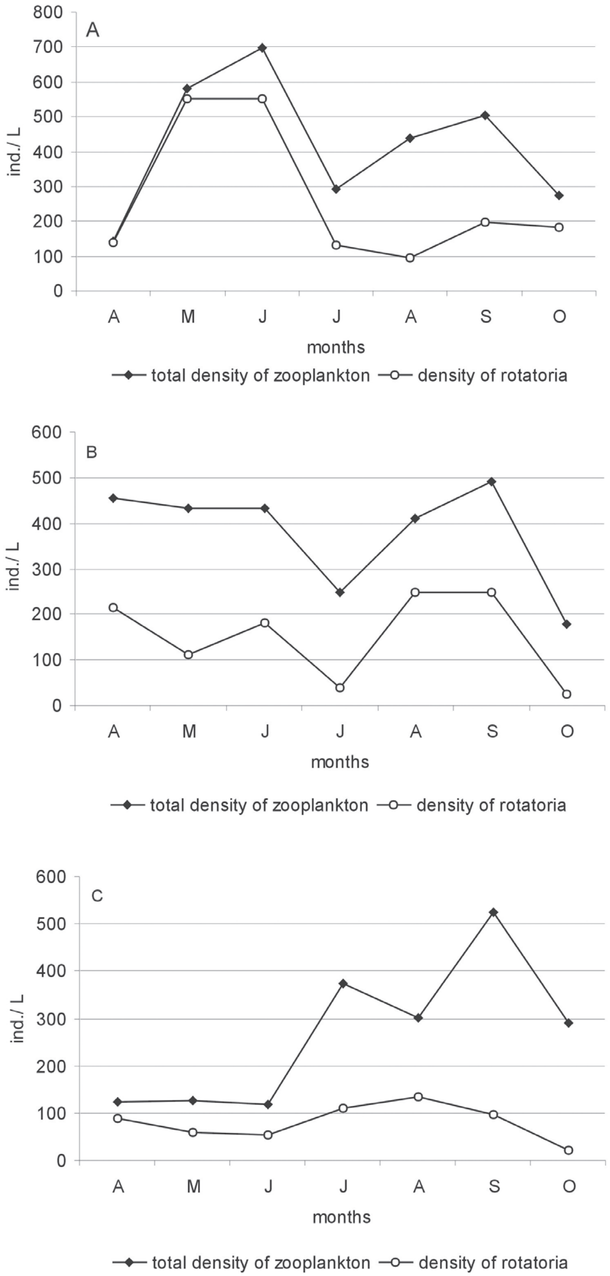

Fig. 2. The dynamics of zooplankton and rotifers in the reservoirs. A) Czorsztyn reservoir, B) Dobczyce reservoir, C) Rożnów reservoir.

Rotifer dynamics

Zooplankton dynamics were studied on the basis of density (ind*l^{-1}). Maximum densities of rotifers were combined with maximum density of total zooplankton in all studied reservoirs. In the youngest and mesotrophic reservoir (CR), maximum development of rotifers was observed in May and June, but in the oldest and eutrophic reservoir (RR) maximum development was in August. Only in the middle age and meso-eutrophic reservoir (DR) were two peaks observed: in April and August–September (Fig. 2). Beside the differences in rotifer dynamics, separate species of rotifers reached their highest density, during their peak growth, in all reservoirs. Rotifers reaching the highest density were: (1) in mesotrophic CR – *Asplanchna priodonta, Conochilus unicornis* (May), *Keratella cochlearis, Polyarthra vulgaris* and *Pompholyx sulcata* (June) (Fig. 3a); (2) in meso-eutrophic DR – *Polyarthra vulgaris* (June), *Keratella cochlearis* f. tecta (August), *Polyarthra vulgaris* and *Pompholyx sulcata* (September) (Fig. 3b); (3) in eutrophic RR – *Keratella cochlearis, K. cochlearis f. tecta* and *Keratella quadrata* (August) (Fig. 3c).

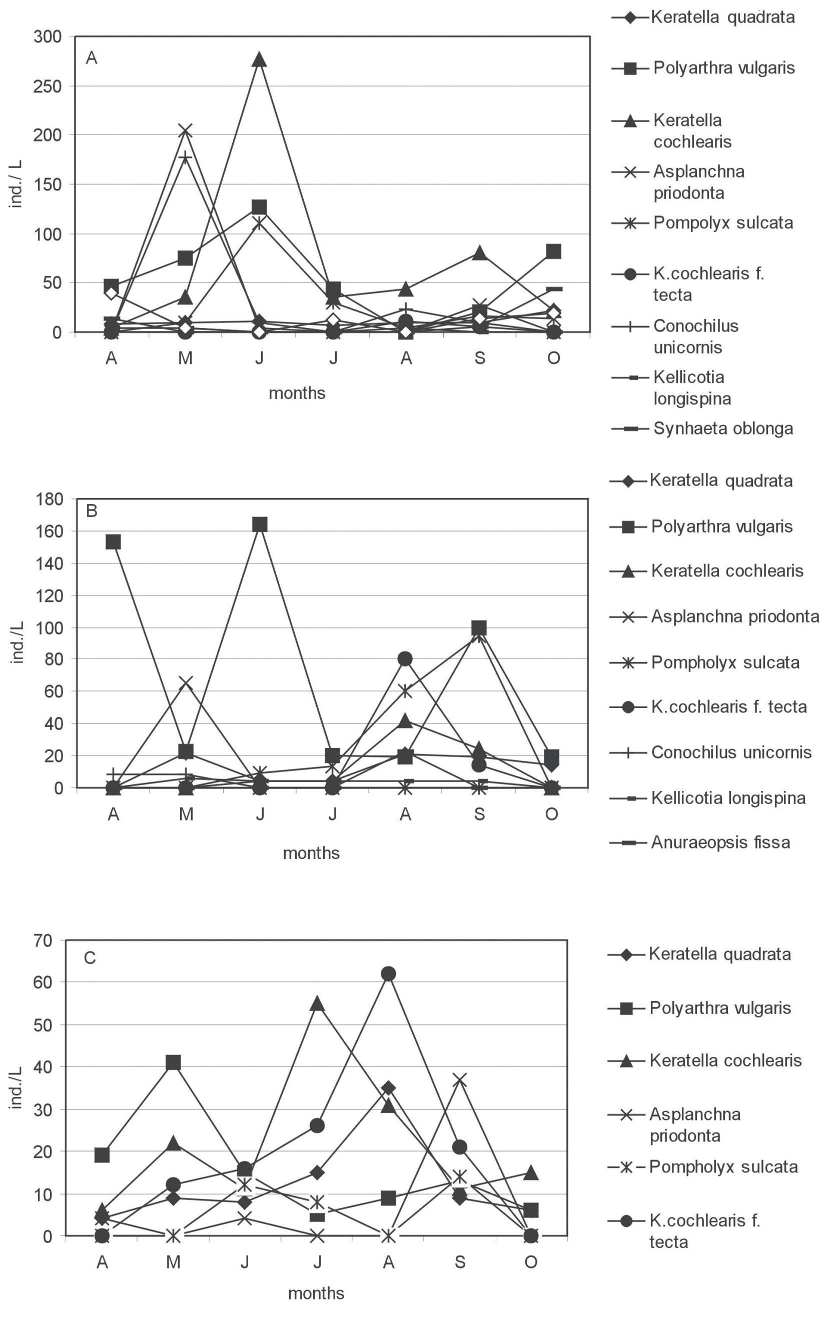

Fig. 3. The dynamics of Rotatoria species (density). A) Czorsztyn reservoir, B) Dobczyce reservoir, C) Rożnów reservoir.

Statistical analysis

The RDA analysis showed that environmental variables account for 77.6% of the total variability in Rotatoria species composition. The species-environmental effect was statistically significant: p = 0.038 (Monte-Carlo permutation test). The first and second axes explained variability of Rotatoria in 26.8% however, variability in the relationship Rotatoria species-environmental features was accounted for in 48.2%. RDA analysis showed that environmental conditions had a significant effect on the variability of Rotatoria communities in the reservoirs.

The Rotatoria community in the CR differed considerably from the communities in DR and RR, where the communities were similar. The most important environmental factors that influenced rotifers were water temperature, Ca and alkalinity. Rotifers in CR prefered with cool waters with good oxydation, high transparency and low alkalinity, Ca and low concentration of nutrients such as: PO_4, N-NH_4, N-NO_3. In DR and RR Rotifers prefered warm waters, with low concentration of oxygen but with high alkalinity, Ca and nutrients concentration (Fig. 4).

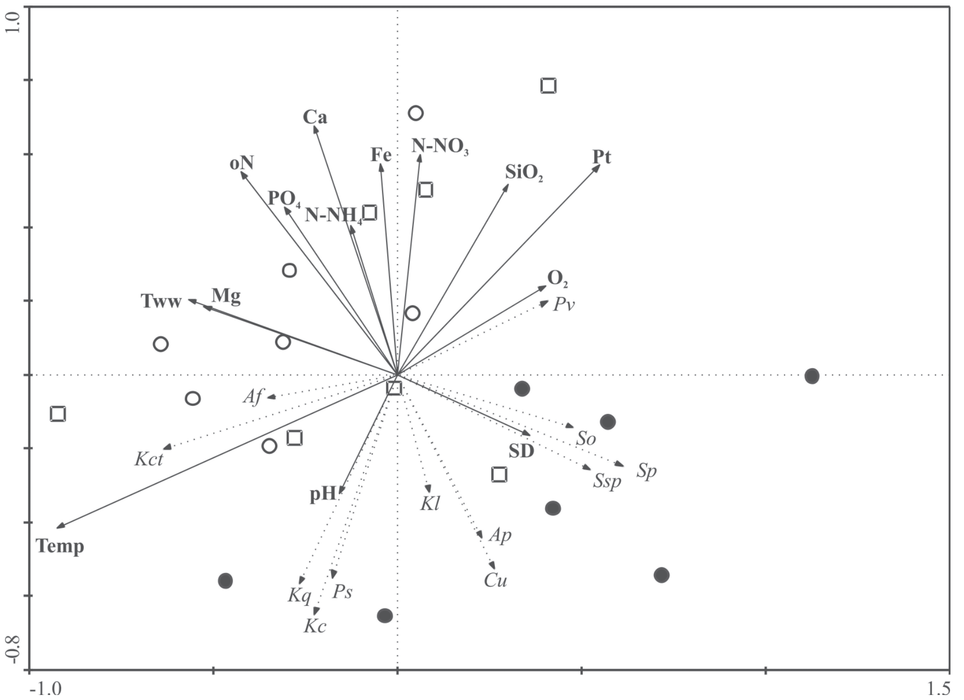

Fig. 4. Rotatoria-environment relationship triplot diagram from the RDA. (solid arrows-environmental variables, dotted arrows-species); figures : squares-Dobczyce reservoir, full circles-Czorsztyn reservoirs, empty circles – Rożnów reservoirs.

RDA analysis did not show any significant relationships between chosen species of algae and environmental conditions in any of the investigated reservoir.

Discussion

Rotifer dynamics differed in all of the investigated reservoirs. However, the highest density of rotifers, was connected with the peak of zooplankton density. This indicated how important role play the rotifers in the plankton communities of reservoirs. This also showed how important is to have a good understanding of rotifer dynamics and their functioning in artificial water bodies (reservoirs).

It is obvious that rotifer structure and dynamics depends on biotic and abiotic factors, the trophic state of lakes may influence densities and structure of rotifers (Ejsmont-Karabin, 2003). The differences in species structure and their dynamics reflected different trophic states in the three studied reservoirs. Species belonging to *Keratella* peaked in the eutrophic reservoir (RR), whereas *Polyarthra* and *Pompholyx* peaked in reservoirs with a lower trophic state (CR and DR). In field studies, it was shown that *Keratella* seemed to be more susceptible than e.g. *Anuraeopsis* to P limitation (Conde-Porcuna et al., 2002). This might explain why in the eutrophic reservoir (RR), with the highest P concentration, *Keratella* species showed the highest density during the rotifer's peak, but in other reservoirs there were species belonging to another taxon.

The spring/early summer peak in the youngest reservoir might be a result of the influence of the large influx of river water caused by snow melt from the mountain (May) or heavy rains at the beginning of June. Input of allochthonous material is very important for rotifers (Halvorsen et al., 2004). Also, in the middle age reservoir DR, the rotifers' peak was probably a result of large river influx after heavy rains and the result organic matter that was washed into the reservoir. In this reservoir, the increase of rotifer density was observed after flooding during the summer (Pociecha, Wilk-Woźniak, 2000; Godlewska et al., 2003). The second peak might be a result of available organic matter that might have been released from the bottom sediments, during late summer and autumn. This was not possible in CR, because this reservoir was too young (one year after impoundment) to accumulate in bottom sediments. In the oldest reservoir RR, the summer rotifers' peak may have been a result of available of organic matter being released from bottom sediments. The different sources of organic matter (from the river influx or bottom sediment) may have an effect on the species composition and we speculate that different sources were responsible for different species peaks that were observed in RR compared to CR and DR. The data showed that the allochthonous factors played the most important role in the mesotrophic reservoir, whereas in the meso-eutrophic reservoir it was partially allochthonous and partially autochthonous. In the eutrophic reservoir the autochthonous factors played the most important role.

RDA analysis showed that environmental variables were important for rotifer' density and diversity in different type of reservoirs but it did not show any significant relationships between chosen species of green algae and diatoms. Water temperature, Ca and alkalinity were the most important factors for density and variability of rotifers.

Many investigators have shown that water temperature was important for rotifer development (Heesen et al., 1995; Pinel-Alloul et al., 1995; Pociecha, 2002; Michaloudi, Kostecka, 2004). However, Yoshida et al. (2000) observed that in two mesotrophic lakes the population densities of rotatoria changed seasonally with species-specific trajectories, but these dynamics were not related to seasonal variation in water temperature. Although, the relationship between rotifers and water temperatures was shown in the lakes assessed with a high trophic state. This is an interesting phenomenon especially in the oldest and eutrophic reservoir, because in this reservoir the *Keratella's* species were the most important. Xi et al. (2002) showed that total lengths of both *K. cochlearis* f. *tecta* and *K. cochlearis* were negatively correlated with the water temperature. Total length of *K. cochlearis* f. *tecta* may also be influenced by the degree of eutrophication because available of food. Pereira et al. (2002) reported that in a lake with a higher trophic state the temperature was the main controlling factor in species seasonality.

Devetter (1998) reported that calcium had little effect of rotifer variability. In our studies, calcium was the factor which had influenced on the density and diversity of rotifer communities in studied dam reservoirs. Also alkalinity which is indirect connected with calcium concentration was very important environmental factor. Similar effect of alkalinity on the rotifers community was noted by another authors, e.g. in nothern Cascade mountains lakes in USA, floodplain lakes in India and in karstic barrage Lake Visovac (Deimiling et al., 1997; Sharma, 2005; Spoljar et al., 2005).

The lack of relationships between chosen species of green algae, diatoms and environmental conditions might be explained by the fact that we should take into consideration the whole groups of algae or functional groups rather than individual species.

Our results showed that the changes in rotifer communities and differences in their dynamics were connected with trophic status of the investigated reservoir. Thus, it cannot be assumed that all reservoirs are equal and the results of this research stress the fact that every reservoir requires a separate investigation.

Conclusion

1. *Keratella* peaked in the eutrophic reservoir, whereas *Polyarthra* and *Pompholyx* peaked in the meso-eutrophic (DR) and mesotrophic reservoirs (CR).
2. Water temperature, Ca and alkalinity were the most important factors which affected the rotifers communities in dam reservoirs.
3. Changes in rotifer communities and their dynamics differed in each reservoir studied.
4. RDA analysis did not show any effect of environmental conditions on the density of chosen species of diatoms or green algae.

Translated by M. Rzepecka

Acknowledgements

Authors thank G. Mazurkiewicz-Boroń for physico-chemical data and Ł. Sobczyk for help in statistical analysis.

References

APHA, 1992: Standard methods for the examination of water and wastewater (18th ed.). American Public Health Association, Washington.

Betsill, R.K., Van Den Avyle, M.J., 1994: Spatial heterogeneity of reservoir zooplankton: a matter of timing? Hydrobiologia, *277*: 63–70.

Błędzki, L.A., Ellison, A.M., 2000: Effects of water retention time on zooplankton of shallow rheolimnic reservoirs. Verh. Internat. Verein. Limnol., *27*: 2865–2869.

Conde-Porcuna, J.M., Ramoz-Rodriguez, E., Perez-Martines, C., 2002: Correlations between nutrient concentrations and zooplankton populations in a mesotrophic reservoir. Freshwater Biol., *47*: 1463–1473.

Deimling, E.A., Liss, W.J., Larson, G.L., Hoffman, R.L., Lomnicky, G.A., 1997: Rotifer abundance and distribution in the northern Cascade mountains, Washington, USA. Arch. Hydrobiol., *138*: 345–363.

Devetter, M., 1998: Influence of environmental factors on the rotifer assemblage in an artificial lake. Hydrobiologia, *387/388*: 171–178.

Ejsmont-Karabin, J., 2003: Rotifera of lake psammon: Community structure versus trophic state of lake waters. Pol. J. Ecol., *51*, 1: 5–35.

Godlewska, M., Mazurkiewicz-Boroń, G., Pociecha, A., Wilk-Woźniak, E., Jelonek M., 2003: Effects of flood on the functioning of the Dobczyce reservoir ecosystem. Hydrobiologia, *504*: 305–313.

Halvorsen, G., Dervo, B.K., Papińska, K., 2004: Zooplankton in Lake Atnsjoen 1985–1997. Hydrobiologia, *521*, 1–3: 149–175.

Hayward, R.S., Van Den Avyle, M.J., 1986: The nature of zooplankton spatial heterogeneity a non-riverine impoundment. Hydrobiologia, *131*: 261–271.

Heesen, D.O., Faafeng, B.A., Anders, T., 1995: Replacement of herbivore zooplankton species along gradients of ecosystem productivity and fish predation pressure. Can. J. Fish. Aquat. Sci., *52*: 733–742.

Hermanowicz, W., Dożańska, W., Dojlido, J., Koziorowski, B., 1976: Physico-chemical analysis of water and wastes (in Polish). Arkady, Warszawa, 846 pp.

Hillbricht-Ilkowska, A., Patalas, K., 1967: Methods of estimating production and biomass and some problem of quantitative calculation methods of zooplankton (in Polish). Ekol. Pol., Ser. B, *13*: 139–172.

Kirk, K.L., 2002: Competition in variable environments: experiments with planktonic rotifers. Freshwater Biol., *47*: 1089–1096.

Lehman, J.T., 1991: Interacying growth and loss rates: the balance of top-down and bottom-up controls in plankton communities. Limnol. Oceanogr., *36*: 1546–1554.

Lund, J.W.G., Kippling, C., Le Cren, E.D., 1958: The inverted microscope method of estimating algal numbers and the statistical basis of estimation by counting. Hydrobiologia, *1*: 144–170.

Mazurkiewicz-Boroń, G., 2002: Factors of eutrophication processes in sub-mountan dam reservoirs (in Polish). Acta Hydrobiologica, Suppl., *2*: 1–68.

Michaloudi, E., Kostecka, M., 2004: Zooplankton of Lake Koroneia (Macedonia, Greece). Biologia (Bratislava), *59*, 2: 165–172.

Pereira, R., Soares, A.M.V.M., Ribeiro, R., Goncalves, F., 2002: Assessing the trophic state of Linhos lake: a first step towards ecological rehabilitation. J. Environ. Management, *64*, 3: 285– 297.

Pinel-Alloul, B., Niyonsenga, T., Legendre, P., 1995: Spatial and environmental components of freshwater zooplankton structure. Ecoscience, *2*: 1–19.

Pociecha, A., Wilk-Woźniak, E., 2000: Effect of the summer flood on the ecosystem of the Dobczyce Reservoir (southern Poland). Acta Hydrobiologica, *42*, p. 59–67.

Pociecha, A., 2002: Impact of abiotic and biotic variables on dynamic and structure of zooplankton community in dam reservoir (Dobczycki Dam reservoir, southern Poland) (in Polish). PhD thesis, Uniwersytet Łódzki, Łódź, 106 pp.

Pollard, A.I., Gonzalez, M.J., Vanni, M.J., Headworth, J.L., 1998: Effects of turbidity and biotic factors on the rotifer community in an Ohio reservoir. Hydrobiologia, *387/*388: 215–223.

Sharma, B.K., 2005: Rotifer communities of floodplain lakes of the Brahmaputra basin of lower Assam (NE India): biodiversity, distribution and ecology. Hydrobiologia, *533*: 209–221.

Smith, A.D., Gilbert. J.J., 1995: Relative susceptibilities of rotifers and cladocerans to *Microcystis aeruginosa*. Arch. Hydrobiol., *132*: 309–336.

Spoljar, M., Habdija, I., PrimcHabdija, B., Sipos, L., 2005: Impact of environmental variables and food availability on rotifer assemblage in the karstic barrage Lake Visovac (Krka River, Croatia). International Review of Hydrobiology, *90*, 56: 555–579.

Starmach, K., 1955: Methods of plankton investigations (in Polish). PWRiL, Warszawa, 133 pp.

Ter Braak, C. J. F., Šmilauer, P., 2002: CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power (Ithaca, NY, USA), 500 pp.

Threlkeld, S.T., 1983: Spatial and temporal variation in the summer zooplankton community of a riverine reservoir. Hydrobiologia, *107*: 249–254.

Urabe, J., 1990: Stable horizontal variation in the zooplankton community structure of a reservoir maintained by predation and competition. Limnol. Oceanogr., *35*: 1703–1717.

Xi, Y., Jin, H.J., Xie, P., Huang, X.F., 2002: Morphological variation of *Keratella cochlearis* (Rotatoria) in a shallow, eutrophic subtropic Chinese lake. J. Freshwater Ecol., *17*, 3: 447–454.

Yoshida, T., Ban, S., Takenouchi, T., Aono, T., Ishikawa, Y., Mikami, H., Takano, K., Imada, K., Yasutomi, R., Takeuchi, K., 2000: Top-down control of population dynamics of the dominant rotifers in two mesotrophic lakes in Hokkaido, Japan. Arch. Hydrobiol., *148*, 4: 481–498.

Received 3. 2. 2005