Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 44, Issue 3, September 2015
pages (335-342)

ISSN 1730-413X
eISSN 1897-3191

Biodiversity of rotifers in urban water reservoirs of Southern Poland

by

Agnieszka Pociecha[1,*], Elżbieta Wilk-Woźniak[1], Wojciech Mróz[1], Irena Bielańska-Grajner[2], Joanna Gadzinowska[1], Edward Walusiak[1]

DOI: **10.1515/ohs-2015-0032**
Category: **Original research paper**
Received: **February 9, 2015**
Accepted: **April 23, 2015**

[1]*Department of Freshwater Biology, Institute of Nature Conservation, Polish Academy of Sciences, Al. A. Mickiewicza 33, 31-120 Kraków, Poland*

[2]*Faculty of Biology and Environmental Protection, University of Silesia in Katowice, ul. Bankowa 12, 40-007 Katowice, Poland*

* Corresponding author: *pociecha@iop.krakow.pl*

Abstract

Rotifer diversity was studied in three different types of artificial water bodies situated in one of the largest cities in Poland. The bodies of water were as follows: a fountain in a city park, the Nowa Huta dam reservoir, and the Bagry gravel-pit. The lowest number of rotifer species (23) was noted in the urban fountain, and the highest (36) in the Bagry gravel-pit lake. Rotifers' communities in the investigated water reservoirs showed different levels of diversity and density. The most numerous species in the dam reservoir was *Trichocerca similis* (2511 ind. l^{-1}) and in the Bagry gravel-pit lake was *Polyarthra dolichoptera* (2634 ind. l^{-1}). However, the most abundant species in the fountain was *Brachionus urceolaris* (863 ind. l^{-1}). The highest values of Shannon and evenness diversity indices were found in the Bagry gravel-pit lake (H' = 2.521, J' = 0.783), while the lowest in the urban fountain (H' = 0.568, J' = 0.258). The DCA analysis (Detrended Correspondence Analysis) showed that the diversity of rotifers communities in the studied reservoirs was related to the concentration of magnesium and calcium, and to water conductivity.

Key words: diversity, DCA, gravel-pit lake, dam reservoir, fountain, Rotifera, urban environment

DE GRUYTER

The *Oceanological and Hydrobiological Studies* is online at oandhs.ocean.ug.edu.pl

Introduction

Over the last decade, social and ecological researches have paid greater attention to urban environments (Olive & Minichiello 2013), including water habitats. Rapid urbanization leads to ecosystem fragmentation and degradation (Ricketts & Imhoff 2003), which causes a decrease in biodiversity, simplifies species composition and, finally, destroys hydrological systems (Kozłowski & Bondallaz 2013). Urban aquatic ecosystems are particularly exposed to anthropogenic impact such as municipal and industrial sewage (Ejsmont-Karabin & Kuczyńska-Kippen 2001). Moreover, urban water bodies are characterized by a 'distress syndrome', which is described as reduced biodiversity, an increased number of alien species and increased dominance of smaller opportunistic species (Rapport & Whitford 1999, Segers 2008, Skowronek et al. 2012, Hassall 2014, Basińska et al. 2014). In general, studies of rotifer diversity are not new and resulted in a large number of publications (Segers 2007, Segers 2008); however, the problem of plankton diversity (including rotifers) in urban waters is still very important and our knowledge in this field is not sufficient (Kuczyńska-Kippen et al. 2004, Skowronek et al. 2012, Chester & Robson 2013, Hassall 2014, Basińska et al. 2014).

Artificial urban water bodies create a specific and unique aquatic environment and there is a great need their actual and potential biodiversity, which is necessary for various activities related to biodiversity conservation, species adaptation to climate change and spread of alien species (Chester & Robson 2013).

The first and only study of rotifers' diversity in the Kraków urban area was conducted by Wierzejski (1893) and Czapik (1958). Since then the city has been rapidly changing and expanding and the current knowledge about the local rotifers' diversity is very limited.

The aim of this study was to quantify the rotifers' diversity in the most typical anthropogenic urban water bodies, and to determine which water parameters were most important to this diversity. Based on the opinion of many authors, we believe that some ecosystems (mostly those anthropogenically impacted) are more susceptible to colonization by alien species. The results will help to understand the impact of large cities and urbanization on the biodiversity of aquatic organisms and will provide information of the educational value on urban artificial water bodies.

Materials and methods

The study was conducted in Kraków, which is the second largest city in Poland, with ca. 800 × 10^3 inhabitants and 327 km² of the urban area (http://www.stat.gov.pl). Although, there is a significant number of water bodies, we have selected three different stagnant water reservoirs for the studies, the most typical type of water bodies in the city, with anthropogenic origin: a fountain (defined as a temporary water body), a small dam reservoir, and a gravel-pit lake (both defined as permanent water bodies (Fig. 1, Table 1). No conservation program has been developed for any of the anthropogenic water reservoirs in Kraków to date.

Samples for physico-chemical and biological parameters were collected in 2011-2013 from the pelagic zones (dam reservoir – Nowa Huta and gravel-pit – Bagry) and from an open water in the fountain (Park Krakowski). Samples were collected for the spring/summer period (May/June) and the autumn/winter period (September/October).

Physico-chemical parameters of water (conductivity, pH, concentrations of O_2, and nitrate) were measured in situ with a multi-parameter YSI 6600V2 probe. Samples for phosphates, magnesium and calcium concentration were collected at the same time and point, and immediately transported to the laboratory. They were analyzed within 48h using ion chromatography (DIONEX ICS 1000).

Samples collected for biological parameters were analyzed for rotifers' composition and density of their communities. They were collected from the surface and the bottom with a 5-l water sampler and then mixed. Ten liters were pooled and filtered through a plankton net of 30 μm mesh size and fixed with 4% formalin. Twelve samples from each water body were collected. In the laboratory, rotifers were observed in 0.5 ml chambers and counted using a Nikon H550L microscope at 100×-400× magnification. Density of rotifers was counted per one liter. Taxonomic analyses of zooplankton were conducted according to the following identification keys: Nogrady, Pourriot & Segers 1995, Segers 1995, Nogrady & Segers 2002, Ejsmont-Karabin et al. 2004.

Figure 1

Sampling sites of artificial water bodies in Kraków

The species diversity was assessed according to the Shannon-Weaver diversity index and the evenness index calculated by the MVSP software.

In order to analyze the ordination pattern of the study plots and the species, the Detrended Correspondence Analysis was applied from the PcOrd 6.08 software (Hill & Gauch 1980, McCune & Mefford 2011). The standard DCA settings were used: there was no down-weighting of rare species, and the number of segments for rescaling axes was set as 30. Moreover, the randomization test with 9999 iterations was used to check if the DCA results were worth interpreting and to test the null hypothesis that the first eigenvalue is not stronger than what would be expected by chance. However, taking into account that the eigenvalue applies before detrending and rescaling, the results of the randomization test are more valid for the underlying Correspondence Analysis (CA method) than for the final DCA.

Results

The surveyed water bodies differed in the range of physico-chemical parameters. The most varying parameters were conductivity and the concentration of phosphates and nitrogen (Table 1). A total of 49 species of rotifers were found (Table 2). In the city fountain (temporal water body), the density of rotifers was low in comparison with the two other water bodies and ranged from 2 to 863 ind. l^{-1}. In the Bagry gravel-pit lake and Nowa Huta dam reservoir (permanent water bodies), the annual densities of rotifers over the study period were higher compared to that found in the fountain, and ranged from 1 to 2634 ind. l^{-1} and from 1 to 2511 ind. l^{-1}, respectively. The highest variability in the density of rotifers was found in the Nowa Huta dam reservoir (SD=654) (Table 2).

The dominance of species differed between the studied water bodies. *Polyarthra dolichoptera* was the most numerous (2634 ind. l^{-1}) in the Bagry gravel-pit lake, and its density in the Nowa Huta dam reservoir varied from 6 to 192 ind. l^{-1}, while in the city fountain the species was not found (Table 2). *Trichocerca similis* was the most abundant (2511

Table 1

General description of sampled artificial water bodies with values of some physico-chemical parameters of water (A = area; MD = maximum depth; con = conductivity).

Fountain in Krakowski Park	Situated in the central part of the Krakowski Park, in the city center. Drained for the winter season. A small island with grass, white willow and a small number of mallards in the central part of the fountain. No submerged vegetation. Large populations of insect larvae and big crustaceans (especially *Daphnia magna*). MD = 0.5 m; con = 298 µS; pH= 8.26; O_2 = 9.20 mg l^{-1}; NO_3^{-1} = 0.05-8.48 mg l^{-1}; PO_4^{-3} = 0.03 mg l^{-1}
Nowa Huta dam reservoir	Small dam reservoir (A = 0.07 km^2) situated on the Dłubnia river in the oldest part of the Nowa Huta district, between Av. Solidarności and Bulwarowa street. The dam reservoir is part of the park, which is one of the Nowa Huta recreation areas. A small island with grass and white willow, the site of nesting birds. No submerged vegetation. Red-eared slider alien species present. Polluted due to the presence of birds: mute swans, mallards, Eurasian coots and gulls. Fish: common carp, common bream, common roach, northern pike, pike-perch, wels catfish. MD = 3 m; con = 438 µS; pH= 8.06, O_2 = 12.5 mg l^{-1}; NO_3^{-1} = 1.0-5.07 mg l^{-1}; PO_4^{-3} = 0.04 mg l^{-1}
Bagry gravel-pit lake	Gravel-pit lake (A = 0.314 km^2) surrounded by many houses, gardens and roads. Sand beaches. Recreation place. The littoral zone developed with reed bed of *Phragmites* sp. and *Typha* sp. Polluted due to the presence of birds: mallards and gulls. Fish: tench, common carp, common bream, common roach, crucian carp, common rudd, northern pike, pike-perch. Numerous amphibians (common newt, European fire-bellied toad, European tree frog, pool frog, common frog) and reptiles (grass snake, viviparous lizard). Alien species of freshwater jellyfish *Craspedacusta sowerbii* from Brazil present 2002. MD = 10 m; con = 698 µS; pH=8.12; O_2 = 11.2 mg l^{-1}; NO_3^{-1} = 0.05-0.22 mg l^{-1}; PO_4^{-3} = 0.09 mg l^{-1}

Table 2

List and density of rotifer species collected from Kraków water bodies (+ - density below 1 ind. l^{-1})

Species	Fountain in Krakowski Park		Nowa Huta dam reservoir		Bagry gravel-pit lake	
	2011	2012/2013	2011	2012/2013	2011	2012/2013
Anuraeopsis fissa (Gosse, 1851)	2		50	166	4	2
Ascomorpha ovalis (Bergendal, 1892)					2	6
Ascomorpha saltans Bartsch, 1870				18		
Asplanchna brigthwelli Gosse, 1850						6
Asplanchna priodonta Gosse, 1850					10	8
Bdelloidea n.d.	+	6	4	2	4	
Brachionus angularis Gosse, 1851			38			
Brachionus calyciflorus Pallas, 1766	28		2			
Brachionus diversicornis (Daday, 1883)			16		2	
Brachionus falcatus Zacharias, 1898	+					
Brachionus leydigii Cohn, 1862				1		
Brachionus quadridentatus Hermann, 1783	+					
Brachionus urceolaris (Müller, 1773)	863	5				
Cephalodella auriculata (Müller, 1773)	+	190		18	34	4
Cephalodella catellina (Müller, 1786)		3				2
Cephalodella gibba (Ehrenberg, 1832)	2			6		8
Colurella adriatica Ehrenberg, 1831				18	1	8
Colurella colurus (Ehrenberg, 1830)					2	
Colurella uncinata (Müller, 1773)			2			
Euchlanis dilatata Ehrenberg, 1832			2	6	5	1
Filinia longiseta (Ehrenberg, 1834)						1
Filinia terminalis (Plate, 1886)			2			
Gastropus stylifer Imhof, 1891			4			6
Hexarthra mira (Hudson, 1871)					8	2
Kellicotia longispina (Kellicott, 1879)	+		82			32
Keratella cochlearis (Gosse, 1851)		2	212	4	76	525
Keratella tecta (Gosse, 1851)	+		126	423	5	
Keratella quadrata (Müller, 1786)	5		436		56	146
Lecane bulla (Gosse, 1886)	5		4			
Lecane closterocerca (Schmarda, 1859)	+			4	2	1
Lecane luna (Müller, 1776)		2		10		
Lecane lunaris (Ehrenberg, 1832)	9				2	
Lecane scutata (Harring & Myers, 1926)						
Lepadella acuminata (Ehrenberg, 1834)	+			2	21	
Lepadella ovalis (Müller, 1786)		6	4		6	
Lepadella patella (Müller, 1773)				8		
Notholca labis Gosse, 1887			2			8
Notholca squamula (Müller, 1786)						2
Ploeosoma hudsoni (Imhof, 1891)	182				4	
Polyarthra dolichoptera Idelson, 1925			192	6		2634
Polyarthra longiremis Carlin, 1943					28	
Polyarthra luminosa Kutikova, 1962				120		278
Polyarthra major Burckhardt, 1900	5		2			8
Polyarthra remata Skorikov, 1896	+				20	
Polyarthra vulgaris Carlin, 1943			46		34	
Pompholyx sulcata Hudson, 1885			28		8	4
Testudinella patina (Hermann, 1783)			24	2	1	
Trichocerca iernis (Gosse, 1887)	2			2		
Trichocerca pusilla (Lauternborn, 1898)			140	1695	2	
Trichocerca similis (Wierzejski, 1893)			34	2511	1	13
	SD = 76	SD = 299	SD = 102	SD = 654	SD = 19	SD = 552
Number of species	10(19)	7	23	20	25	23

Table 3

Values of Shannon and evenness indices in the examined water bodies

Water body	2011			2012/2013		
	H'	J'	No. of species	H'	J'	No. of species
Fountain in Krakowski Park	0.730	0.317	10	0.568	0.258	7
Nowa Huta dam reservoir	2.231	0.712	23	1.126	0.383	20
Bagry gravel-pit lake	2.521	0.783	25	1.037	0.331	23

ind. l^{-1}) in the Nowa Huta dam reservoir; in the Bagry gravel-pit lake, the species was found in small density (1-13 ind. l^{-1}), and it was not found in the city fountain. In the case of the city fountain, *Brachionus urceolaris* reached the highest density (863 ind. l^{-1}); the species was not found in any of the above mentioned reservoirs (Table 2).

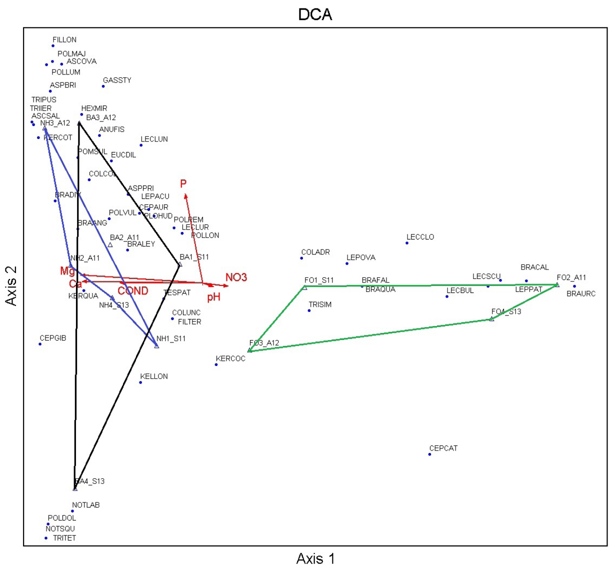

Figure 2

Results of Detrended Correspondence Analysis. The first two axes of the ordination results are presented on the joint biplot together with the crucial environmental variables. The ordination of species (blue points) and samples (triangles) is shown on the graph. The samples from one site are grouped with the following lines: green envelope – temporary waters of Fountain (FO1, FO2, FO3, FO4); blue – permanent waters of Bagry (BA1, BA2, BA3, BA4); and black – permanent waters of the Nowa Huta Reservoir (NH1, NH2, NH3, NH4). Environmental variables are described with red arrows: Mg – magnesium, Ca – calcium, P – phosphates, COND – conductivity, NO3 – nitrates, pH – water acidity

Based on the value of Shannon-Weaver's diversity index (H' = 2.521) and the evenness index (J' = 0.783) (Table 3), the highest species diversity of rotifers was found in the Bagry gravel-pit lake.

According to the results of DCA analysis, the total variance ("inertia") in the species data was 4.0733. The eigenvalues from the real data (before detrending) were as follows: axis 1 – 0.95995; axis 2 – 0.65259 and axis 3 – 0.46422, and the lengths of gradients: axis 1 – 4.710; axis 2 – 3.357; axis 3 – 3.489. The result of randomization showed the significance of the test with p (for axis 1) = 0.0484; where $p = (n+1)/(N+1)$, where n is the number of randomization with an eigenvalue for this axis > OR = the observed eigenvalue for the axis. N = total number of randomization. It should be noted that because p values for axes other than axis 1 depend on the results of axis 1, the results for the subsequent axes have not been taken into account.

The randomization test allows to reject the null hypothesis that the first eigenvalue is not stronger than in randomized data; therefore, the results are worth interpreting at least for the first axis. As it is shown in Figure 2, the samples from the temporary water body (green envelope) can be very clearly distinguished from those from permanent waters (blue and black envelopes) along the first axis of the DCA chart based only on the species composition of these samples. The diversity of rotifers was correlated with the concentration of magnesium, calcium and water conductivity.

Discussion

It is a well-documented fact that biodiversity is under a significant stress due to habitat fragmentation and loss. However, it is important to remember about the growing awareness among the city planners that future urban development should be sensitive to habitat and wildlife issues (Beatley 2006). There are some possibilities to increase the biodiversity, especially in human-dominated areas like urban centers, parks, and cottage resorts (Olive & Minichiello 2013), which "may refer to reconciliation ecology, or conscious human management of the land" (Rosenzweig 2003). However, it is not possible to preserve the biodiversity in urban waters if we do not have enough information and recognition of the species in aquatic ecosystems.

Biodiversity varies according to the type of aquatic ecosystems, disturbances and chemical factors (Pejler 1995). Ecosystems with high stress (disturbances), such as temporary waters (e.g. city fountains, craters etc.), show lower diversity (Kuczyńska-Kippen et al. 2013) compared to permanent aquatic ecosystems, such as lakes, ponds, pit-lakes, dam reservoirs etc., which was confirmed also in our study. The city fountain showed the lowest diversity of Rotifera species. However, even if the temporary waters are characterized by low diversity, they might be important to beta- and gamma-diversity because of the hot spots for some rare or interesting species. On the other hand, they may also be an 'invasion hub' for alien species. We found two interesting species of rotifers in the fountain: *Trichocerca iernis* and *Brachionus falcatus*. *T. iernis* and *B. falcatus* are rare species in freshwater reservoirs in Poland (Ejsmont-Karabin et al. 2004), whereas *B. falcatus* is associated with tropical and subtropical zones. This species is usually observed in fishponds and its expansion is probably connected with tropical fish introduced there (Ridder 1981, Dumont 1983).

The obtained results demonstrated that the city fountain with frequent disturbances was characterized by a small number of species, low density, and low Shannon-Weaver diversity and evenness indices. The permanent water reservoirs (the Nowa Huta dam reservoir and Bagry gravel-pit lake) were characteried by rotifers communities typical of stagnant water bodies, such as small lakes (Pejler 1995, Ejsmont-Karabin & Kuczyńska-Kippen 2001, Skowronek et al. 2012). The diversity of Rotifera in both reservoirs was higher compared to the temporal fountain habitat, which could be a result of various factors, e.g. disturbances mentioned above, low availability of food resources etc.

We proved that chemical factors that affect the rotifer communities in urban waters (diversity, density, occurrence) were similar to those demonstrated to be important to this group of organisms in lakes and artificial reservoirs in the temperate zone (e.g. Devetter 1998, Ejsmont-Karabin 2003, Pociecha & Wilk-Woźniak 2006, Pociecha & Heese 2007, Illyova & Pastuchowa 2012, Lokko & Virro 2014). The most important factors that affected the density and structure of rotifers in the studied permanent waters were conductivity and concentration of magnesium and calcium. Calcium and magnesium are very important to rotifers, because they affect their lifespan, especially the longevity and the number of offspring (Enesco & Holtzman 1980), and conductivity may significantly influence their diversity. Kling et al. (1992) showed that many rotifers do not tolerate conductivity higher than 400 $\mu S\ cm^{-1}$, and Swadling et al. (2000) showed significantly low richness of rotifer species between 700 $\mu S\ cm^{-1}$ and 1500 $\mu S\ cm^{-1}$.

The results of this study show only a small fragment of biodiversity in urban aquatic habitats and confirm the importance of those reservoirs for "sustaining aquatic biodiversity in urban landscapes" (Pinel-Alloul & Mimouni 2013). The study also showed the importance of urban waters as being potential 'invasion hubs' for alien species, e.g. in the case of tropical *B. falcatus* recorded in the fountain.

Profound knowledge about the species composition and dynamics is necessary for the development of management and conservation of the urban waters, not only in terms of preserving the α -diversity, but is also important to β- and γ-diversity.

Further research is therefore needed to answer the question: 'What are we doing to keep the water in urban reservoirs in good condition?'

Acknowledgements

This work was supported by a grant from the National Science Centre NN 305 374939 and partly by the Institute of Nature Conservation PAS in Kraków. We thank an anonymous reviewer for the discussions and comments which improved our manuscript.

References

Basińska, A.M., Świdnicki K. & Kuczyńska-Kippen N. (2014). Effect of surrounding trees and dry rush presence on spring zooplankton community in an urban pond complex. *Ann. Limnol. Int. J. Lim.* 50: 315-323. DOI: 10.1051/limn/2014025.

Beatley, T. (2006). Cities and biodiversity. In J. M. Scott, D.D. Goble & F. W. Davis (Eds.) *The Endangered Species Act at Thirty*. Washington, DC: Island Press.

Chester, E.T. & Robson B.J. (2013). Anthropogenic refuges for freshwater biodiversity: Their ecological characteristics and management. *Biological Conservation* 166: 64-75. http://dx.doi.org/10.1016/j.biocon.2013.06.016.

Czapik, A. (1958). Rotifers (*Rotatoria*) of Kraków neighborhood. *Acta Zoolgica Cracoviensis* 3: 123-134. [in Polish].

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

Dumont, H.J. (1983). Biogeography of rotifers. *Hydrobiologia* 14: 19-30.

Ejsmont-Karabin, J. & Kuczyńska-Kippen N. (2001). Urban rotifers: structure and densities of rotifer communities in water bodies of the Poznań agglomeration area (western Poland). *Hydrobiologia* 446/447: 165–171.

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

Ejsmont-Karabin, J., Radwan S. & Bielańska-Grajner I. (2004). *Rotifers. Monogononta - atlas of species*. Polish Freshwater Fauna. Łódź, University of Łódź, 77-447. [in Polish].

Enesco, H.E. & Holtzman F. (1980). Effect of calcium, magnesium and chelating agents on the lifespan of the rotifer *Asplanchna brightwelli. Experimental Gerontology 15: 389-392. DOI:10.1016/0531-5565(80)90046-7.*

Hassall, C. (2014). The ecology of urban ponds. *WIREs Water* 1: 187-206.

Hill, M.O. & Gauch H.G. (1980). Detrended correspondence analysis: an improved ordination technique. *Vegetatio* 42: 47-58.

Illyova, M & Pastuchowa Z. (2012). The zooplankton communities of small water reservoirs with different trophic conditions in two catchments in western Slovakia. *Limnologia* 42: 271- 281.

Kling, G.W., O'Brien W.J., Miller M.C. & Hershey A.E. (1992). The biochemistry and zoogeography of lakes and rivers in artic Alaska. *Hydrobiologia* 240: 1-14.

Kozłowski, G. & Bondallaz L. (2013). Urban aquatic ecosystems: Habitat loss and depletion of native macrophyte diversity during the 20th century in four Swiss cities. *Urban Ecosystems* 16: 543-551. DOI 10.1007/s11252-012-0284-x.

Kuczyńska-Kippen, N. Nowosad P. & Grzegorz G. (2004). Estimation of water quality of lakes in Wielkopolski National Park and Poznań recreational water bodies in spring period. *Roczniki Akademii Rolniczej w Poznaniu*, CCCXIII, 193-200. [in Polish].

Kuczyńska-Kippen, N., Basińska A.M. & Świdnicki K. (2013). Specificity of zooplankton distribution in meteorite crater ponds (Morasko, Poland). *Knowl. Manag. Aquatic Ecosyst.* 409 (08): 1-11. DOI:10.1051/kmae/2013053.

Lokko, K & Virro T. (2014) The structure of psammic rotifer communities in two boreal lakes with different trophic conditions: Lake Võrtsjärv and Lake Saadjärv (Estonia). *Ocean. Hydrob. Stud.* 43: 49-55.

Olive, A. & Minichiello A. (2013). Wild things in urban places: America's largest cities and multi-scales of governance for endangered species conservation. *Applied Geography* 43: 56-66. DOI:10.1016/j.apgeog.2013.06.004.

McCune, B. & Mefford M.J. (2011). PC-ORD. *Multivariate Analysis of Ecological Data*. Version 6.08. MjM Software, Gleneden Beach, Oregon, U.S.A.

Nogrady, T., Pourriot R. & Segers H. (1995) Rotifera 3. *The Notommatidae and The Scaridiidae.* In Dumont H.J. & Nogrady T. (Eds.) Guides to the Identification of the Microinvertebrates of the Continental Waters of the World 8. SPB Academic, The Hague, The Netherlands, 248 pp.

Nogrady, T. & Segers, H. (Eds) (2002) Rotifera 6. *The Asplanchnidae, Gastropodidae, Lindiidae, Microcodinidae, Synchaetidae, Trochosphaeridae.* In Dumont H.J. (Ed.) Guides to the Identification of the Microinvertebrates of the Continental Waters of the World 18. Backhuys Publishers BV, Dordrecht, The Netherlands, 264 pp.

Pejler, B. (1995). Relation to habitat in Rotifers. *Hydrobiologia* 313/314: 267-278.

Pinel-Alloul, B. & Mimouni E.A. (2013). Are cladoceran diversity and community structure linked to spatial heterogeneity in urban landscapes and pond environments? *Hydrobiologia* 715: 195–212. DOI 10.1007/s10750-013-1484-y.

Pociecha, A. & Wilk-Woźniak E. (2006). The life strategy and dynamics of selected species of phyto- and zooplankton in a dam reservoir during „wet" and „dry" years. *Pol. J. Ecol.* 54: 29-38.

Pociecha, A. & Heese T. (2007). Spatial distribution of zooplankton in a cascade system of Pomeranian dam reservoirs (Hajka, Rosnowo), northern Poland. *Ocean. Hydrob. Stud.* 36: 39 - 51. DOI: 10.2478/v10009-007-0023-4.

Rapport, D.J. & Whitford W.G. (1999). How ecosystems respond to stress. *Bioscience* 49: 193-203.

Ricketts, T. & Imhoff, M. (2003). Biodiversity, urban areas, and agriculture: locating priority ecoregions for conservation. *Conserv. Ecol.* 8 (2): 1.

Ridder, M. (1981) Some considerations on the geographical distribution of rotifers. *Hydrobiologia* 85 (3): 209-225.

Rosenzweig, M.L. (2003). Reconciliation ecology and the future of species diversity. *Oryx* 37 (2): 194-205. DOI: 10.1017/S0030605303000371.

Segers, H. (1995). Rotifera 2. *The Lecanidae (Monogononta)*. In Dumont H.J. & Nogrady T. (Eds.) Guides to the Identification of the Continental Waters of the World 6. SPB Academic, The Hague, The Netherlands, 226 pp.

Segers, H. (2007). Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa* 1564: 1-104.

Segers, H. (2008). Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia* 595: 49-59. DOI: 10.1007/s10750-007-9003-7.

Skowronek, E., Cudak A. & Bielańska-Grajner I. (2012). Effect of Recreation on the Species Richness and Diversity of Rotifers in Ponds. *Journal of Water Resource and Protection* 4: 95-799. DOI:10.4236/jwarp.2012.49091.

Swadling, K.M., Pienisz R. & Nogrady T. (2000). Zooplankton community composition of lakes in the Yukon and Northwest Territories (Canada): relationship with physical and chemical limnology. *Hydrobiologia* 431: 211-224.

Wierzejski, A. (1893). Rotatoria (rotifers) from Galicja. *Rozprawy Wydziału Matematyczno-Przyrodniczego PAU* 26, 160-265. [in Polish].

http://www.stat.gov.pl Position and structure of population and natural migration in territorial section in 2012. Situation on 31st December [in Polish].