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Meteorite crater ponds as source of high zooplankton biodiversity

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Abstract: Meteor crater ponds are extremely rare types of water body and consequently their environment, along with inhabiting fauna, are poorly recognised. We investigated the zooplankton community structure of three meteorite ponds. Their hydroperiod is usually the longest during the spring season, therefore the study-time covered the months between April and June. Within the craters we found 140 zooplankton species, which contributed to 20% of rotifer, 19% of cladoceran, 15% of copepod and 3% of ostracod Polish species. Our results showed a high diversity of zooplankton inhabiting these temporary ecosystems, even though we examined craters before the optimum of macrophyte development, which supports increase of invertebrate species richness. Only 43% of the species were common for all three ponds, although the meteorite craters were located very close to each other, possess the same catchment area and all were fishless. The high specificity of each pond was underlined by a high number of distinctive species (containing almost 30% of the total taxonomic structure). Zooplankton mainly consisted of eurytopic and common species, with representatives of families Brachionidae, Daphnidae and Cyclopidae having the highest frequency. However, over 10% of all species (e.g., *Lecane elsa* and *Tretocephala ambigua*) were determined as rare in Poland. Therefore these meteorite ponds are of a high conservation value despite the close proximity of a large urban agglomeration.

Key words: biodiversity; Rotifera; Cladocera; Copepoda; Ostracoda; temporary ponds

Introduction

The biodiversity of unique environments is the subject of research of many scientists (Shinde Vinod & More 2013; Kolicka et al. 2015; Nkambo et al. 2015). Many authors indicate a particular role of temporary freshwater systems, such as examined meteorite craters, in maintaining biodiversity of both flora and fauna (Semlitsch & Bodie 1998; Williams 2002; Picazo et al. 2010). The co-occurrence of various organisms, including regionally rare species, may be observed even in ponds under strong anthropogenic pressure (e.g., Lemmens et al. 2013; Pinel-Alloul & Mimouni 2013). The shallowest waterbodies, such us the investigated ponds, are prone to high variation in environmental features, e.g. water level. Their hydroperiod is often the longest during the spring and/or in autumn season due to their drying out in summer and overfreezing to the bottom in winter.

The temporary character of very shallow ponds usually excludes fish (Matthews & Marsh-Matthews 2003). This fishless ecosystem creates favourable conditions for the development of communities of invertebrate predators, which may rebuild the taxonomic structure of smaller zooplankters (Wellborn et al. 1996). The seasonal water level fluctuations may also influence the invertebrate community structure after each dry and overfreezing period (Külköylüoğlu et al. 2010; Lampert et al. 2010). In this case small water reservoirs can be considered as ecological islands in terms of time and space (De Meester et al. 2005).

Among planktonic organisms, many taxa may survive the dry seasons or winters, when small water bodies are frozen to the bottom, due to production of resting eggs as well as quiescent stages such as e.g. diapause or anhydrobiosis (Brendonck 1996; Caprioli et al. 2004; Caprioli & Ricci 2005). Even though the early spring zooplankton communities are usually taxonomically poor compared to the summer period (Lampert & Sommer 2001; Rybak & Błędzki 2010), rotifers and crustaceans awakening from the resting stages may very quickly develop and immediately inhabit water body at the beginning of spring (Tavernini et al. 2005).

Even though the 'Meteoryt Morasko' Nature Reserve has been monitored for years, the results concerning aquatic biocoenotic structure are extremely scarce. Previous scientific studies were mainly focused on geology, mineralogy and morphology (Stankowski 2001; Idzikowski et al. 2010; Karwowski et al. 2011; Pilski et al. 2013), and on the terrestrial flora and fauna of that area (e.g., Stachowiak 2002; Lisiewska 2006). The

Table 1. The total and mean number of rotifer and crustaceans taxa (± standard error) and results of the Kruskal-Wallis test (K-W) in the studied ponds with chosen biotic and morphometric parameters of particular water body.

	SP		MP		DP			
	Total	Mean ± SE	Total	Mean ± SE	Total	Mean ± SE	K-W	*P*
Biotic parameters								
Rotifera	55	18 ± 2	81	29 ± 3	60	22 ± 2	11.88	< 0.01
Cladocera	18	8 ± 1	16	7 ± 1	16	6 ± 1	3.51	> 0.05
Copepoda	14	4 ± 0.5	13	3 ± 1	12	3 ± 0.3	5.58	> 0.05
Ostracoda	1	0.1 ± 0.0	3	1 ± 0.3	3	1 ± 0.3	12.72	< 0.01
Fish			–	–		–		
Macrophytes			–	*Sium latifolium*		*Lemna minor*		
Morphometric parameters								
Maximum crater diameter		m	16	27		40		
Maximum pond diameter		m	20	25		35		
Maximum pond depth		m	0.5	1		1.5		
Maximum pond water volume		m^3	32	121		924		

Explanations: SP – the shallowest pond; MP – pond of medium depth; DP – the deepest pond.

most detailed study of the biotic parameters (phytoplankton seasonal distribution) of meteorite ponds was conducted by Messyasz in 1996, while the first comprehensive data on zooplankton inhabiting those water bodies was presented by Kuczyńska-Kippen et al. (2013).

In this paper we present the complete taxonomy results of spring investigation on rotifers, cladocerans, copepods and ostracods inhabiting three meteorite water bodies in the 'Meteoryt Morasko' Nature Reserve. The aim of the study was to characterize the specificity of zooplankton assemblage regarding ecological requirements connected with the habitat preference of particular species (benthic, littoral and pelagic). We expected high species richness due to the fishless character of the meteorite ponds and their location within the protected area. Even though the studied ponds may function similarly to other temporary water bodies, we predicted the presence of unique fauna composition owing to the unusual origin of these ecosystems.

Study area

Meteorite craters, located at the northern boundary of the city of Poznań (western Poland), are one of the largest sets of craters, formed about 6000 years ago by a fall of iron meteorites (Hurnik et al. 1976). The whole area is unique in respect to its combination of the occurrence of meteorites and the morphological effects of their fall such as small, but deep craters with steep slopes (Stankowski 2001). Therefore it is protected as a 'Meteoryt Morasko' Nature Reserve. The catchment area is of a mixed character (forest and field), however, the direct surroundings are overgrown by oak-hornbeam forest, which results in immense amounts of leaf deposition on the craters bottom.

There are seven bowl-shaped craters, which are periodically filled by rainwater or dry out and create small ponds of different size usually reaching few dozen square meters (Świdnicki et al. 2016). Meteor crater ponds are located on the highest hill in the region, which is the main reason for their isolation from other water supplies. Their depth range fluctuates, from few dozen centimetres up to 1.5 m. The largest and simultaneously the deepest pond (DP) is characterized by the longest hydroperiod, while the pond of medium depth (MP) and the shallowest pond (SP) are filled with water mainly in the spring season. The sediment structure is dominated by sand. Thus the rain water can fast infiltrate and does not stay within smaller and shallower craters. The temporary character of meteorite ponds is the main reason of fish absence within those water bodies.

During the study period (from the beginning of April to the end of June of 2009), only three out of seven craters were filled with water. The studied meteorite crater ponds were characterised by oxygen deficiencies. Moreover, within the shallowest pond slightly acidic water was also recorded (Świdnicki et al. 2016). Hydromacrophytes were not observed at the beginning of the examination. Only in the pond of medium depth (MP) appeared a small belt of plants (*Sium latifolium*) developed in May. Additionally, in DP we observed a pleustophyte cover (*Lemna minor*) in May and June (Table 1).

Methods

Samples for rotifer, cladoceran, copepod and ostracod analyses were collected weekly from the beginning of April to the end of June of 2009. We collected zooplankton samples in triplicate (3 × 5 L), using a calibrated vessel, from the surface area of each water body (total number of subsamples = 117). We concentrated samples with a 45-μm mesh size net and fixed it immediately with 4% formalin.

We identified species using a key to the Polish fauna of Rotifera (Radwan et al. 2004), Cladocera and Copepoda (Rybak & Błędzki 2010) and Ostracoda (Sywula 1974). According to the literature, we classified taxa inhabiting meteorite crater ponds as pelagic, littoral or benthic organisms (Sywula 1974; Radwan et al. 2004; Rybak & Błędzki 2010).

The frequency of studied taxa was calculated as the percentage proportion of samples, where particular taxa occurred in relation to the total samples.

We analysed the differences in species richness between studied meteorite water bodies using the nonparametric Kruskal-Wallis test.

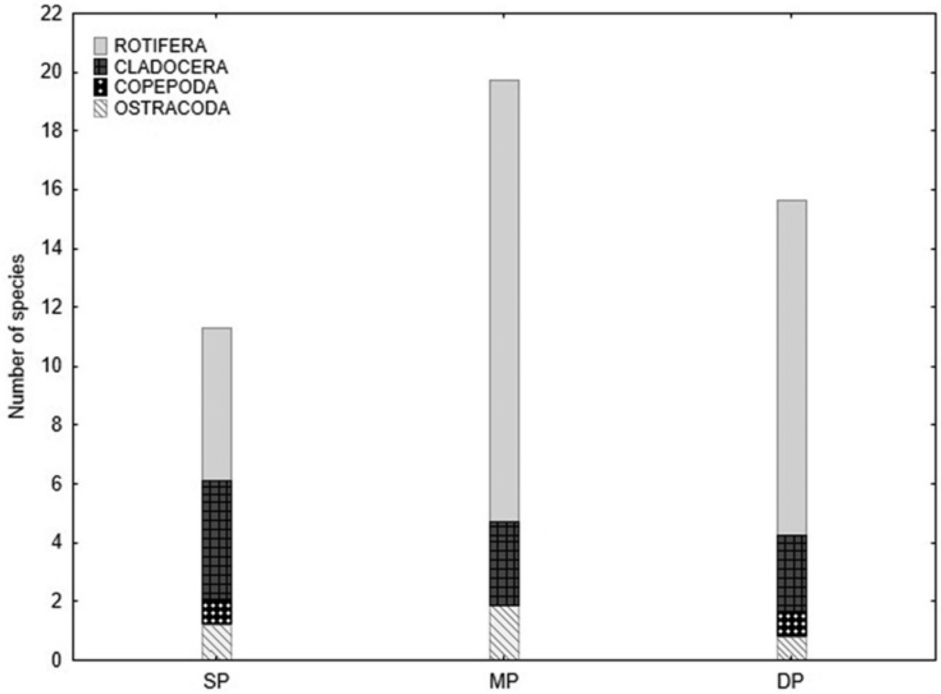

Fig. 1. The total taxa number of rotifer and crustaceans in studied ponds. SP – the shallowest pond, MP – pond of medium depth, DP – the deepest pond.

Results

We identified altogether 140 taxa among rotifers, cladocerans, copepods and ostracods: 89 in the shallowest pond (SP), 114 in pond of medium depth (MP) and 91 in the deepest pond (DP) (Fig. 1). The statistically significant difference was found in the case of rotifer and ostracod species richness ($P < 0.01$) in contrast to cladoceran and copepod communities, which were characterised by similar number of species in each studied water body (Table 1).

The zooplankton community was represented by 23 families (Rotifera: 18, Cladocera: 4, Copepoda: 1, Ostracoda: 3), among which the highest species number was observed in the rotifer families of Lecanidae and Cyclopidae (Fig. 2, Table 2). The family Brachionidae among rotifers was the most frequent and widely distributed (in 97% of samples). Crustaceans were most frequently represented by Daphniidae (95%) and Cyclopidae (100%). The most frequent species, present in more than 75% of all samples were: *Lepadella ovalis* and *Megacyclops viridis*.

As much as 43% of the total observed taxa were found to be common for all ponds. The most similar species structure between particular water bodies was noted for cladocerans, with 76% common species. Among ostracods only the genus *Cyclocypris* was identified in every examined pond. Simultaneously, in each pond we found distinctive species, which did not occur in the other analysed water bodies (6 species in SP, 18 in MP and 12 in DP) (Table 2).

In the examined material we found rare species – 13 rotifers and 3 cladocerans (Flössner 1972; Radwan et al. 2004). Most of those species occurred in single samples and were characterized by low frequency. Only five rare species showed a high frequency: among rotifers *Lecane elsa* (44%) and *Cephalodella tenuiseta* (13%); among cladocerans: *Chydorus ovalis* (36%), *C. gibbus* (18%) and *Tretocephala ambigua* (10%). We noted 38 typically pelagic and 34 eurytopic species (Table 2).

Among rotifers, 51 typically littoral species mostly belonged to the Lecanidae family. Furthermore, 18 species were classified in literature as limnetics. Among them, the greatest number of species was recorded in Brachionidae family. Among cladocerans we observed only two strictly pelagic species and they belonged to families Bosminidae and Sididae. Within the copepod family Cyclopidae, littoral as well as pelagic species were observed. Moreover, ostracods were represented by benthic and littoral taxa (families: Candonidae and Cyprididae) (Table 2).

Discussion

The examined meteor crater ponds were characterised by rich taxa composition. Depending on a systematic position, particular groups of zooplankton revealed different species diversity. Rotifers dominated taxonomically over crustaceans. The total number of 97 Rotifera species, which was noted within the studied ponds, makes up for 20% of Polish rotifer fauna (Radwan et al. 2004). We also noted a relatively high percentage of crustacean species in the case of Cladocera and Copepoda (according to Rybak & Błędzki 2010: 19% and 15% of the total Polish cladoceran and copepod fauna, respectively). Instead of difficulties with taxonomic identification it resulted in finding of 4 taxa of ostracods, which represented altogether

Table 2. List of zooplankton taxa that occurred in particular meteorite ponds.

	SP	MP	DP	Habitat
Rotifera				
Asplanchnidae Eckstein, 1883				
Asplanchna piodonta (Gosse, 1850)	+	+	+	P
Bdelloidea (Hudson, 1884)	+	+	+	L
Brachionidae (Ehrenberg, 1838)				
Anuraeopsis fissa (Gosse, 1851)	+	+	+	P
Brachionus angularis (Gosse, 1851)	+	+	+	P
Brachionus bidentata (Anderson, 1889)*			+	P
Brachionus calyciflorus (Pallas, 1766)	+	+	+	P
Brachionus diversicornis (Daday, 1883)			+	P
Brachionus leydigii (Cohn, 1862)		+	+	
Brachionus quadridentatus (Hermann, 1783)			+	L
Brachionus rubens (Ehrenberg, 1838)		+		P
Keratella cochlearis (Gosse, 1851)	+	+	+	P
Keratella quadrata (Müller, 1786)	+	+	+	P
Keratella testudo (Ehrenberg, 1832)	+	+	+	
Notholca acuminata (Ehrenberg, 1832)	+	+	+	P
Notholca squamula (Müller, 1786)	+	+	+	P
Platyias quadricornis (Ehrenberg, 1832)	+		+	L
Colurellidae (Wesenberg-Lund, 1929)				
Colurella adriatica (Ehrenberg, 1831)	+	+	+	L
Colurella colurus (Ehrenberg, 1830)		+		L
Colurella obtusa (Gosse, 1886)		+		
Lepadella ovalis (Müller, 1786)	+	+	+	
Lepadella patella (Müller, 1773)	+	+	+	
Lepadella quadricarinata (Stenroos, 1898)	+	+	+	L
Lepadella quinquecostata (Lucks, 1912)		+	+	L
Lepadella rhomboides (Gosse, 1886)			+	
Squatinella mutica (Ehrenberg, 1832)		+	+	L
Squatinella rostrum (Schmarda, 1846)		+		L
Dicranophoridae (Harring, 1913)				
Dicranophorus hauerianus (Wiszniewski, 1939)	+	+	+	
Encentrum sp. (Ehrenberg, 1838)	+	+		
Gastropodidae (Harring, 1913)				
Ascomorpha ecaudis (Perty, 1850)		+		L
Gastropus stylifer (Imhof, 1891)	+	+	+	
Euchlanidae (Ehrenberg, 1838)				
Euchlanis dilatata (Ehrenberg, 1832)	+	+		
Filiniidae (Harring & Myers, 1926)				
Filinia longiseta (Ehrenberg, 1834)	+	+	+	P
Hexarthridae (Bartos, 1959)				
Hexarthra mira (Hudson, 1871)	+	+	+	P
Lecanidae (Bartos 1959)				
Lecane arcuata (Bryce, 1891)	+	+	+	L
Lecane bulla (Gosse, 1851)		+		L
Lecane closterocerca (Schmarda, 1859)	+	+	+	L
Lecane cornuta (Müller, 1786)	+	+		L
Lecane curvicornis (Murray, 1913)		+	+	L
Lecane elsa (Hauer, 1931)*		+	+	
Lecane flexilis (Gosse, 1886)	+	+		
Lecane furcata (Murray, 1913)*		+		
Lecane hamata (Stokes, 1896)	+	+	+	
Lecane inermis (Bryce, 1892)		+		
Lecane ludwigii (Eckstein, 1883)	+	+	+	L
Lecane luna (Müller, 1776)		+	+	L
Lecane lunaris (Ehrenberg, 1832)	+	+		
Lecane nana (Murray, 1913)*		+		L
Lecane opias (Harring & Myers, 1926)*			+	L
Lecane perpusilla (Hauer, 1929)*	+			L
Lecane pyriformis (Daday, 1905)*		+		L
Lecane scutata (Harring & Myers, 1926)		+		
Lecane signifera (Jennings, 1896)		+		L
Lecane stenroosi (Meissner, 1908)*		+		
Lecane tryphema (Harring & Myers, 1926)		+		
Proalidae (Bartos, 1959)				
Proales decipiens (Ehrenberg, 1832)	+	+	+	L
Proales fallaciosa (Wulfert, 1937)		+		L
Synchaetidae (Hudson & Gosse, 1886)				
Polyarthra longiremis (Carlin, 1943)		+	+	P
Polyarthra remata (Skorikov, 1896)	+	+	+	P
Polyarthra vulgaris (Carlin, 1943)	+	+	+	P
Synchaeta kitina (Rousselet, 1902)		+	+	P
Synchaeta lakowitziana (Lucks, 1930)	+			P
Synchaeta oblonga (Ehrenberg, 1831)	+	+		P
Synchaeta pectinata (Ehrenberg, 1832)	+	+	+	P
Synchaeta tremula (Müller, 1786)			+	P
Testudinellidae (Harring, 1913)				
Pompholyx complanata (Gosse, 1851)	+	+	+	P
Pompholyx sulcata (Hudson, 1885)		+	+	P
Testudinella elliptica (Ehrenberg, 1834)		+	+	L
Testudinella parva (Ternetz, 1892)			+	
Testudinella patina (Hermann, 1783)	+	+	+	
Trichocercidae (Remane, 1933)				
Trichocerca brachyura (Gosse, 1851)			+	
Trichocerca cylindrica (Imhof, 1891)		+		
Trichocerca dixon-nuttalli (Jennings, 1903)		+	+	
Trichocerca elongata (Gosse, 1886)	+	+		L
Trichocerca intermedia (Stenroos, 1898)		+	+	
Trichocerca pusilla (Jennings, 1903)	+	+		
Trichocerca rattus (Müller, 1776)	+	+		L
Trichocerca similis (Wierzejski, 1893)		+		
Trichocerca stylata (Gosse, 1851)*		+		
Trichocerca uncinata (Voigt, 1902)*		+		L
Trichocerca weberi (Jennings, 1903)	+	+	+	
Trichotriidae (Harring, 1913)				
Trichotria pocillum (Müller, 1776)		+		
Cladocera				
Bosminidae (Baird, 1845)				
Bosmina longirostris (O.F. Müller, 1776)	+	+	+	
Eubosmina coregoni (Baird, 1857)	+	+	+	P
Chydoridae (Stebbing, 1902)				
Acroperus harpae (Baird, 1835)			+	L
Alonella excisa (Fischer, 1854)	+	+	+	L
Alonella exigua (Lilljeborg, 1853)	+	+	+	L
Chydorus gibbus (Sars, 1891)*	+	+		L
Chydorus ovalis (Kurz, 1874)*	+	+		L
Chydorus sphaericus (O.F. Müller, 1785)	+	+	+	
Tretocephala ambigua (Lilljeborg, 1900)*	+	+	+	L
Daphniidae (Straus, 1820)				
Ceriodaphnia laticaudata (P.E. Müller, 1867)	+	+	+	L
Daphnia cucullata (Sars, 1862)	+	+	+	
Daphnia curvirostris (Eylmann, 1887)	+	+	+	L
Daphnia longispina (O.F. Müller, 1776)	+			
Daphnia pulex (Leydig, 1860)	+	+	+	P
Scapholeberis mucronata (O.F. Müller, 1776)	+	+	+	L
Simocephalus exspinosus (De Geer, 1778)	+	+	+	L
Simocephalus vetulus (O.F. Müller, 1776)	+	+	+	L
Sididae (Baird, 1850)				
Diaphanosoma brachyurum (Liévin, 1848)	+		+	L
Copepoda				
Cyclopoida (Burmeister, 1834)				
Acanthocyclops vernalis (Fischer, 1853)	+	+		L
Cyclops furcifer (Claus, 1857)	+	+		
Cyclops insignis (Claus, 1857)	+			
Cyclops kolensis (Lilljeborg, 1901)	+	+		
Cyclops lacustris (G.O. Sars, 1863)	+	+		P
Cyclops scutifer (G.O. Sars, 1863)	+	+		P
Cyclops strennus (Fischer, 1851)		+		

Table 2. (continued)

	SP	MP	DP	Habitat		SP	MP	DP	Habitat
Mytilinidae (Harring, 1913)					*Cyclops vicinus* (Ulyanin, 1875)	+	+	+	P
Mytilina crassipes (Lucks, 1912)	+		+		*Diacyclops bicuspidatus* (Claus, 1857)	+	+	+	L
Mytilina mucronata (Müller, 1773)	+	+	+		*Diacyclops bisetosus* (Rehberg, 1880)	+		+	
Mytilina ventralis (Ehrenberg, 1830)	+	+	+		*Diacyclops languidoides* (Lilljeborg, 1901)		+	+	L
Notommatidae (Hudson & Gosse, 1886)					*Diacyclops languides* (G.O. Sars, 1863)	+	+	+	L
Cephalodella auriculata (Müller, 1773)	+	+	+	L	*Eucyclops macruroides* (G.O. Sars, 1918)	+		+	L
Cephalodella catellina (Müller, 1786)	+	+	+		*Eucyclops serrulatus* (Fischer, 1851	+		+	L
Cephalodella gibba (Ehrenberg, 1832)	+	+	+	L	*Eucyclops speratus* (Lilljeborg, 1901)			+	
Cephalodella gibboides (Wulfert, 1950)*	+	+		L	*Macrocyclops fuscus* (Jurine, 1820)			+	L
Cephalodella sterea (Gosse, 1887)	+			L	*Megacyclops viridis* (Jurine, 1820)	+	+	+	L
Cephalodella tenuior (Gosse, 1886)*	+			L	*Microcyclops varicans* (G.O. Sars, 1863)	+	+	+	L
Cephalodella tenuiseta (Burn, 1890)*	+	+		L	*Thermocyclops crassus* (Fischer, 1853)		+	+	P
Cephalodella ventripes (Dixon-Nuttall, 1901)	+				**Ostracoda**				
Notommata cyrtopus (Gosse, 1886)	+	+	+	L	**Candonidae** (Kaufmann, 1900)				
Taphrocampa annulosa (Gosse, 1851)		+	+	L	*Candoda* sp. (Baird 1845)			+	L/B
Taphrocampa selenura (Gosse, 1887)			+	L	*Cyclocypris* sp. (Brady & Norman, 1889)	+	+		L/B
Philodinidae (Ehrenberg, 1838)					*Cypria exsculpta* (Fischer, 1855)		+		L
Dissotrocha sp. (Bryce, 1910)	+	+			**Cyprididae** (Baird, 1845)				
Philodina sp. (Ehrenberg, 1830)	+	+	+		*Eucypris* sp. (Vávra, 1891)		+	+	L/B

Explanations: SP – the shallowest pond, MP – pond of medium depth, DP – the deepest pond with their habitat preferences (P – pelagial, L – littoral, B – benthic zone).

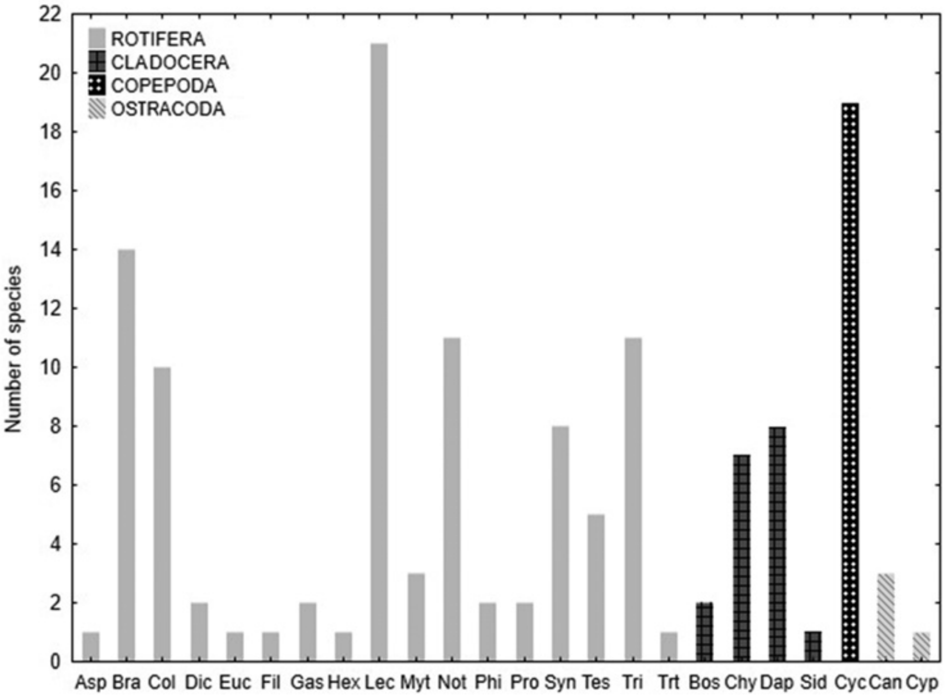

Fig. 2. The total species richness of rotifer and crustacean families observed in the meteorite water bodies. Rotifera: Asp – Asplanchnidae, Bra – Brachionidae, Col – Colurellidae, Dic – Dicranophoridae, Euc – Euchlanidae, Fil – Filiniidae, Gas – Gastropodidae, Hex – Hexarthidae, Lec – Lecanidae, Myt – Mytilinidae, Not – Notommatidae, Phi – Philodinidae, Pro – Proalidae, Syn – Synchaetidae, Tes – Testudinellidae, Tri – Trichocercidae, Trt – Trichotriidae Cladocera: Bos – Bosminidae, Chy – Chydoridae, Dap – Daphniidae, Sid – Sididae; Copepoda: Cyc – Cyclopoida; Ostracoda: Can – Candonidae, Cyp – Cyprididae; * – rare species.

3% of Polish ostracod fauna (Iglikowska & Namiotko 2012).

It is important to underline that such high values of zooplankton richness were attributed to only three water bodies. There are several reasons for obtaining such a great species variation in the investigated craters. Firstly, the intensive sampling covered a long period within the spring season, when environmental factors changed from almost winter conditions with ice cover until almost summer time with optimal conditions for development of aquatic organisms. Therefore, a variety of species adapted to different climate conditions (e.g., in reference to different temperature, water level changeability etc.) or different habitats (macrophyte-dominated zones) may have been recorded. At the beginning of the study we observed some species characteristic of cold seasons (winter and early spring) (e.g., *Notholca acuminata*, *Synchaeta lakowitziana*, *Cyclops insignis*), while thermophilic species (e.g., *Pompholyx sulcata*, *Diaphanosoma brachyurum*, *Microcyclops varicans*) were found at the end of the study (June). Moreover, zooplankton was not limited by vertebrate predators due to fishless character of the studied ponds and thus optimal conditions for rotifers and planktonic crustaceans development prevailed.

Another reason for obtaining considerably high values of zooplankton species richness was connected with high discrepancies referring to certain ponds. The number of zooplankton species differed between particular meteorite craters, especially in the case of rotifers. The highest species richness of Rotifera was observed in MP, which was characterised by a one-meter-wide belt of *Sium latifolium*, while statistically lower rotifer species richness was noted within the SP, without macrophytes during the whole study period. Moreover, MP was also characterised by the highest number of distinct species. Many authors (e.g., Declerck et al. 2006; Malekzadeh-Viayeh & Špoljar 2012; Špoljar et al. 2012; Chaparro et al. 2013) stated that macrophyte presence in water body increases biological and habitat diversity. The highest species richness of Ostracoda in MP also confirms the important role of macrophyte belts in structuring the diversity of invertebrate communities.

We found that cladocerans and copepods were the most diverse within the shallowest pond, where rotifers were represented at the lowest richness. Biotic interactions between particular zooplankton groups seemed to structure taxonomic composition in the case of SP. The crustacean community was most abundant within this water body compared to MP and DP. Additionally, large-bodied species dominated among cladocerans (60–98%), while within the copepod community larval stages constituted over 90% (Świdnicki et al. 2016). An effective competition (Cladocera and copepod larvae) and predation pressure (adult Copepoda) could have a negative effect on rotifer species richness within the shallowest pond.

Most of the zooplankton taxa were common for all three examined crater ponds and they belonged to eurytopic, wide-spread species. However, the majority of species are classified as preferring littoral zone. Even though a small macrophyte belt was observed only in MP and the *Lemna minor* cover in DP, typically pelagic zone was not present within the studied water bodies, because of their shallowness. The small water volume of the studied meteorite craters can explain the strong domination of littoral species, which preferably chose vegetated areas or can also inhabit the bottom sediments (especially organic), which must have been the case in the studied ponds. Furthermore, the leaves accumulated at the bottom of craters may have created a suitable habitat for typically benthic or littoral ostracod taxa as has also been suggested by some other researches (e.g., Iglikowska & Namiotko 2012; Mori & Meisch 2012). Moreover, ostracod taxa, whose occurrence is mainly related to the spring season and to the littoral or benthic zone (Mori & Meisch 2012), were recorded. For example, the species *Cypria exculpta* is described as typical for astatic ponds and its occurrence indicates a low water level in lakes (Sohar & Meidla 2010). Therefore, it would have been possible to find it in the case of our meteorite craters.

Among rotifers Brachionidae occurred frequently within meteorite ponds. Members of the Brachionidae family have the malleate type of mastax, therefore, they can utilise a wide spectrum of available food source. They are able to feed through water filtrating, grasping and grinding as well as to feeding on detritus (Koste & Shiel 1987; Smith 2001; Radwan et al. 2004). According to Tavernini et al. (2005), the ability of feeding on various food sources is essential for fast colonisation of new niches by zooplankton within temporary water bodies and contributed to such a high frequency of brachionids. Families Daphnidae and Cyclopidae were represented by large-sized species, which are potentially a very attractive prey items to vertebrate predators (Gliwicz 1986; Havens & Beaver 2011; Iglesias et al. 2011; Vijverberg et al. 2014; Špoljar et al. 2016), while they are out of the interest of invertebrate planktivores. Therefore, the high frequency of families Daphnidae and Cyclopidae within the studied meteorite ponds was an indicator of lack of fish.

Moreover, the most frequently occurring taxa (bdelloids, *Lepadella ovalis* and *Megacyclops viridis*) are not only very common in Poland but also in other parts of the world. The presence of the rotifer *L. ovalis* has also been encountered in meteorite crater ponds located in Australia (Green 1981). All three taxa are known to inhabit a variety of ecosystems and due to their adaptations to resist the dry periods in diapause stages they can reach a very high abundance even in temporary waterbodies. Furthermore, after the dry period these rotifers can quickly re-colonise new habitats (Schröder 2001; Frish & Green 2007; Taylor & Duggan 2012). Even though the origin of the meteor crater ponds is very unique in general, the most frequent species remained similar to those inhabiting other temporary water bodies in Poland (Radwan et al. 2004; Rybak & Błędzki 2010).

We found 13 rare or infrequently noted species in Poland within the studied meteorite ponds. The relatively high number of such species increases the conservation value of the studied area. Among them most species belonged to representatives of littoral-benthic organisms or those which are typical of small and unstable aquatic ecosystems (e.g., *Lecane elsa*, *L. nana, L. opias*, *L. perpusilla*, *L. stenroosi*, *Cephalodella gibboides, C. tenuior* among rotifers and also *Chydorus gibbus*, *Ch. ovalis* and *Tretocephala ambigua* among cladocerans) (Flössner 1972; Radwan et al. 2004). Small water bodies are known to be a source for rare or infrequently occurring species. Literature data confirm that some rare species, such as *Ch. ovalis*, remain rare in many environments such as ditches, temporary pools, ponds, lakes, and canals (Louette et al. 2007). However, other species such as, e.g., *C. gibboides*, *Lecane* *furcata* or *L. pyriformis* may frequently be encountered in certain habitat. Thus, they have been reported from various types of small ponds (Ejsmont-Karabin & Kuczyńska-Kippen 2001; Basińska & Kuczyńska-Kippen 2009). This is why taxonomic studies, including thorough analyses of unique environments, are necessary to revise the level of species frequency in terms of common but also specific conditions. We can usually expect that rare species will be attributed to areas lacking human pressure. However, Declerck et al. (2006) observed that ponds located within areas of low anthropogenic impact will also contain new, rare or unique species in the country-wide scale. Therefore, even though the examined meteor craters are located at the borders of the city of Poznań, they may contribute to the enrichment of a local fauna, including valuable species of high conservation status. Additionally, the direct catchment area of craters is of a forest character and is also protected as nature reserve "Meteoryt Morasko". These two facts may also contribute to the fact that human impact becomes blurred.

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