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MICROCRUSTACEAN (CLADOCERA, COPEPODA) COMMUNITIES IN ARTIFICIAL LAKES IN THE REGION OF THE NORTH HUNGARIAN MOUNTAINS, WITH SPECIAL REFERENCE TO THE ADVENTIVE SPECIES

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Artificial lakes like reservoirs and pit lakes are among the most frequent representatives of Hungarian standing waters. Although these habitats maintain high biodiversity, investigations of them are sparse worldwide. We studied the crustacean zooplankton of 23 artificial lakes in the North Hungarian Mountains, which are mainly used as recreational fish ponds and therefore highly affected by intensive fish stocking. Our main aims were to investigate their species richness and composition, together with the potential occurrence of adventive microcrustaceans. 53 microcrustacean species were found altogether, which proved to be relatively high compared to studies from other regions. Moreover, the species accumulation curves were not saturated, suggesting even higher total regional species richness. One of our most important results was the first finding of *Hemidiaptomus hungaricus* in the territory of modern-day Hungary. Three adventive species were found: *Eurytemora velox*, *Daphnia ambigua* and *Pleuroxus denticulatus*, of which *E. velox* may be regarded as invasive, as it was always the dominant zooplankter once it occurred in a lake, while the two cladocerans were never found in high abundances. Our results draw attention to the high biodiversity of these artificial habitats, as well as to their role as stepping stones for adventive microcrustacean species.

Key words: species richness, beta diversity, recreational fish pond, pit lake, reservoir, *Hemidiaptomus hungaricus*

INTRODUCTION

Pit lakes (mainly gravel, sand or peat excavation pits) and reservoirs are among the most frequent representatives of Hungarian standing waters. Many of them are used as recreational fish ponds, which cover 31,000 ha in Hungary. This represents approx. 20% of the area of all natural and artificial habitats where fishing or angling is allowed in the country (including all large rivers and lakes e.g. Lake Balaton; JÁMBORNÉ & BARDÓCZ 2010). Despite of the fact that most of them are man-made (or at least affected by human impact), artificial lakes maintain high biodiversity, offering living and feeding habitats for several vulnerable species among amphibians (KOVÁCS & BRANDON 2005), waterbirds (MILINKI *et al*. 2008) and mammals (LANSZKI *et al*. 2008). Nevertheless, biodiversity investigations of these artificial habitats are sparse worldwide. In Hungary, there are only a few former faunistic data concerning their zooplankton (e.g., GULYÁS & FORRÓ 1999, 2001) and some detailed studies on the plankton communities of single lakes (e.g., MILINKI 1996), with no large-scale investigations on several artificial lakes for a general overview.

Biological invasions have come to represent an increasing threat for global biodiversity in the last decades. Thousands of non-indigenous species have invaded several regions of the planet (VITOUSEK *et al*. 1997). This phenomenon is particularly true for freshwater ecosystems (MOYLE & LIGHT 1996, RICCIARDI 2006, ROMAN & DARLING 2007). For example, the invasion rate of freshwater Cladocera is now estimated to be 50,000 times higher than historical levels, before humans played a dominant role in species transport (HEBERT & CRISTESCU 2002). Artificial freshwater habitats appear to facilitate the access of alien species to inland waters, acting as "stepping stones" (HAVEL *et al*. 2005). Recently, BORZA *et al*. (2011) reported the occurrence of the invasive mysid shrimp *Limnomysis benedeni* in some of the recreational fish ponds of northern Hungary which were also the target of the present study. Their findings are especially noteworthy, as most of those lakes are more or less isolated systems, far away from large rivers, which are the main corridors of invasions.

Among the native species, members of the *Acanthocyclops robustus* species complex are common species in the waterbodies of continental Europe. In the last decade, MIRABDULLAYEV and DEFAYE (2002, 2004) re-examined species of *A. robustus* of Europe, Asia, America and North Africa and came to the conclusion that this species occurs only in Scandinavia and North America. Additionally, they described *A. trajani* and *A. einslei* which are the only representatives of the species complex that occur in Central Europe. They are both common species of fish ponds, lakes and reservoirs, as well as pools and ditches. The taxonomic status of these two new species was also confirmed recently by molecular investigations (BLÁHA *et al*. 2010). Taking this into account, we decided to use this new classification in our survey for the first time in Hungary. As the species previously designated as *A. robustus* is common in Hungary, inhabiting almost all types of waters, including fish ponds, lakes and reservoirs (GULYÁS & FORRÓ 2001), we expected the occurrence of *A. trajani* and/or *A. einslei* in our study area.

Our aims were to investigate microcrustacean species richness and community composition in artificial lakes covering a relatively large area (approx. 5,000 km^2).

Table 1. List of the investigated artificial lakes in the North Hungarian Mountains.

No.	Latitude	Longitude	Settlement	Sampling date	Type	Area (ha)
1	47.810564	19.595275	Palotás	24.04	reservoir	73
2	47.761975	19.766289	Ecséd	24.04	lignit pit lake	35
3	47.772978	19.774575	Rózsaszentmárton	24.04	lignit pit lake, later reservoir	29.6
4	47.788178	19.768392	Szücsi	24.04	lignit pit lake, later reservoir	15
5	47.798336	19.803122	Gyöngyöspata	24.04	reservoir	17
6	47.796733	19.825319	Gyöngyöstarján	24.04	reservoir	17
7	47.770089	19.897147	Gyöngyös	24.04	reservoir	54
8	47.929722	20.082417	Parádfürdő	26.04	mineral mine pit lake	13.8
9	47.939144	20.138439	Recsk	26.04	reservoir	54
10	48.034225	19.947883	Mátraterenye	26.04	coal pit lake	13
11	47.810044	20.080894	Markaz	26.04	reservoir	154
12	47.814428	20.108131	Domoszló	26.04	reservoir	54
13	47.889408	20.318917	Egerszalók	27.04	reservoir	120
14	47.878394	20.424064	Ostoros	27.04	reservoir	30
15	47.914258	20.669044	Sály	27.04	reservoir	23
16	47.969303	20.733519	Harsány	27.04	reservoir	20
17	48.118075	20.826125	Miskolc	27.04	pit lake	94
18	48.105594	20.621208	Lillafüred	27.04	reservoir	10
19	48.157728	20.612708	Varbó	27.04	reservoir	13.6
20	48.272567	20.546403	Vadna	27.04	pit lake	19
21	48.178033	21.300222	Mád	27.04	reservoir	4.5
22	48.339603	21.571614	Sárospatak	27.04	pit pond	0.4
23	48.343989	21.524242	Hercegkút	27.04	artificial fish pond	0.15

Particular attention was paid to alien species. Their occurrence was expected since the presence of an invasive mysid had previously been proved in some of the investigated lakes.

MATERIALS AND METHODS

Twenty-three artificial lakes of the North Hungarian Mountains region were involved in our study (Table 1). Most of them are reservoirs fed by streams and located in foothills or valleys; the others are pit lakes originated mainly from coal or lignite mining. 20 of the 23 lakes are affected by regular fish stocking (mainly whitefish from natural waters or carps from fish farms) and used for recreational purposes, according to the information collected from their managers. In the present paper, we will use the term 'artificial lakes' for all habitats and 'fish ponds' for these 20 locations as generic terms. The common characteristics of these habitats are a large, open area of water without macrophytes, the reed belt of variable size and the scarce submerged macrophytes. Regarding the three habitats that were not intensively stocked, No. 8 is a shallow, abandoned mineral pit lake, almost fully covered by reed, while the remaining two were rather ponds regarding their sizes: No. 22 is a pit pond in agricultural landscape and No. 23 is a fish pond, only occasionally used for recreational fishing.

Sampling was carried out on the 24th and 26–27th April 2010. A hand net (mesh size: 45 µm) was used to collect microcrustaceans from the littoral zone of the lakes, by exhaustively sampling all the microhabitats (e.g., rip-raps, submerged macrophytes, emerged macrophytes) that were present. Samples were preserved in 70% ethanol solution. We counted the first 300 specimens in the samples to assess the relative abundances of species and afterwards, the whole sample was checked for additional rare species. Species were identified following the keys from GULYÁS and FORRÓ (1999) for cladocerans, EINSLE (1993) and GULYÁS and FORRÓ (2001) for cyclopoid and calanoid copepods as well as DAMIAN-GEORGESCU (1970) and JANETZKY *et al*. (1996) for harpacticoid copepods. *Acanthocyclops* species were identified according to MIRABDULLAYEV and DEFAYE (2002, 2004).

Only fish ponds (n = 20) were used in the statistical analyses and comparisons of species richness and frequency of occurrence among lakes, while the other three sites were only included in the faunistic investigations. Species accumulation curves were constructed in R (R Development Core Team 2009) by resampling the number of species with bootstrapping and plotting the mean species numbers±SD against the number of samples. SDR-simplex analysis was carried out on binary data with SDRSimplex software according to PODANI & SCHMERA (2011). This method evaluates relativized similarity (S), richness difference (D), species replacement (R), beta diversity (R+D), nestedness (S+D) and species richness agreement (S+R). Ternary (SDR) plot was drawn with SYN-TAX 2000 software (PODANI 2001).

RESULTS

Twenty-four Cladocera, 20 Cyclopoida, 5 Harpacticoida and 4 Calanoida species were found altogether (Table 2). Mean local species richness was 10.5±2.4. The lowest species set was 2, while the highest was 16. The species accumulation curves for copepod, cladoceran and entire species sets were similar: all of them were only slightly saturated. It was clearly visible that there were a few more copepod species per fish pond than cladocerans (Fig. 1).

The SDR-simplex analysis revealed high beta diversity and species replacement in the data set (Fig. 2). Relativized species replacement (R) was 50.9%, while similarity (S) and richness difference (D) were much lower (23.4 and 25.8%, respectively). Relativized beta diversity (R+D) was very high (76.6%), and richness agreement (S+R) was also similar (74.2%), while nestedness (S+D) was only 49.2%.

The most frequently occurring species in the lakes were *Chydorus sphaericus* (present in 85% of the fish ponds), *Bosmina longirostris* (75%), *Daphnia cucullata* (55%) among cladocerans, *Cyclops vicinus* (65%), *Eucyclops serrulatus*

Table 2. List of the microcrustacean species found in the artificial lakes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CLADOCERA																							
Acroperus harpae (Baird, 1834)																	+						
Alona affinis (Leydig, 1860)																		+					
Alona guttata Sars, 1862											+			+									
Alona quadrangularis (O. F. Müller, 1776)					+																+		
Alona rectangula Sars, 1862							+		+	+			+						+				+
Bosmina coregoni Baird, 1857															+								
Bosmina longirostris (O. F. Müller, 1776)	+		+	+	+		+			+	+	+	+	+		+	+	+	+		+		
Camptocercus rectirostris Schoedler, 1862																		+					
Ceriodaphnia laticaudata P.E. Müller, 1867			+		+		+	+						+	+			+					
Ceriodaphnia rotunda Sars, 1862													+										
Ceriodaphnia sp. juv.										+													
Chydorus sphaericus (O. F. Müller, 1776)	+	+	+	+	+			+	+	+	+	+	+	+		+	+	+	+	+	+		+
Daphnia ambigua Scourfield, 1946																+							
Daphnia cucullata Sars, 1862	+		+	+	+				+		+		+	+	+	+		+					
Daphnia sp. juv.												+											
Daphnia pulex Leydig, 1860																				+		+	
Diaphanosoma mongolianum Ueno, 1938												+											
Macrothrix laticornis (Jurine, 1820)	+			+	+		+						+						+		+		
Megafenestra aurita (Fischer, 1849)													+										
Moina macrocopa (Straus, 1819)												+											
Pleuroxus aduncus (Jurine, 1820)		+	+	+					+	+							+		+		+		
Pleuroxus denticulatus Birge, 1879				+															+				
Scapholeberis mucronata (O. F. Müller, 1776)	+		+	+			+												+				
Sida crystallina (O. F. Müller, 1776)																	+		+				
Simocephalus exspinosus (Koch, 1841)								+				+											
Simocephalus vetulus (O. F. Müller, 1776)	+		+	+				+	+	+								+	+				+

Table 2 (continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
COPEPODA																							
Cyclopoida																							
Acanthocyclops trajani Mirabdullayev & Defaye, 2004	+			+	+					+	+		+	+			+		+		+		
Acanthocyclops vernalis (Fischer, 1853)												+											
Cyclops strenuus Fischer, 1851												+				+						+	
Cyclops vicinus Ulianine, 1875			+	+	+	+			+	+	+		+	+	+	+			+		+		
Diacyclops bicuspidatus (Claus, 1857)																						+	
Diacyclops bisetosus (Rehberg, 1880)														+									
Ectocyclops phaleratus (Koch, 1838)									+														
Eucyclops sp. juv.														+									
Eucyclops macruroides (Lilljeborg, 1901)		+	+					+									+		+				
Eucyclops macrurus (Sars 1863)																	+						
Eucyclops serrulatus (Fischer, 1851)	+			+	+		+	+	+	+			+				+	+		+			+
Eucyclops speratus (Lilljeborg, 1901)	+	+	+					+	+						+	+	+						
Macrocyclops albidus (Jurine, 1820)	+		+	+					+	+					+				+	+	+		+
Macrocyclops fuscus (Jurine, 1820)								+															
Megacyclops gigas (Claus, 1857)																						+	
Megacyclops viridis (Jurine, 1820)								+				+			+								
Mesocyclops leuckarti (Claus, 1857)			+							+				+				+		+			
Microcyclops rubellus (Lilljeborg, 1901)								+															
Paracyclops poppei (Rehberg, 1880)									+										+				
Paracyclops fimbriatus (Fischer, 1853)													+							+			
Thermocyclops crassus (Fischer, 1853)				+				+			+						+	+					
Thermocyclops oithonoides (Sars 1863)	+		+			+	+		+							+					+		
Calanoida																							
Eudiaptomus gracilis (Sars, 1863)			+	+	+					+	+	+	+	+						+	+		+
Eurytemora velox (Lilljeborg, 1853)										+										+			
Hemidiaptomus hungaricus Kiefer, 1933																						+	
Mixodiaptomus kupelwieseri (Brehm, 1907)																						+	

Table 2 (continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Harpacticoida																							
Attheyella crassa (G. O. Sars, 1863)					+																		
Bryocamptus minutus (Claus, 1863)					+																		
Canthocamptus staphylinus (Jurine, 1820)	+		+					+						+	+								
Elaphoidella gracilis (Sars 1863)									+														
Nitocra hibernica (Brady, 1880)		+	+	+						+							+		+				

(50%), *Acanthocyclops trajani* (50%) among cyclopoids and the calanoid *Eudiaptomus gracilis* (50%; Fig. 3).

The most important faunistic result was the finding of the calanoid copepod *Hemidiaptomus hungaricus*, which is new to the fauna of Hungary. It was found in an approx. 0.4 ha covering pit pond in the territory of Sárospatak (No. 23), surrounded by agricultural (mainly rapeseed) fields.

From the recently described new *Acanthocyclops* species, we only found *A. trajani*. However, it was quite frequent, as its occurrence was detected in 10 fish ponds.

Three alien species were recorded from the investigated artificial lakes. The calanoid copepod, *Eurytemora velox* and the chydorid cladoceran, *Pleuroxus denticulatus* each occurred at two (Nos. 10 and 20 and Nos. 4 and 19, respectively), while the daphniid cladoceran, *Daphnia ambigua* at one (No. 16) site. No overlap was found in the presence of the three species, thus five lakes were inhabited by non-indigenous microcrustacean species in total (Fig. 4). The two cladocerans occurred only with low relative abundances (<1% in all cases), while *E. velox* was the most frequent microcrustacean once it occurred in a lake. It co-occurred with the native calanoid copepod, *Eudiaptomus gracilis* in both cases, but was 1.5 and 189 times more frequent (Fig. 5).

DISCUSSION

The total regional (53) and mean local species richness (10.5) of the 23 investigated artificial lakes both proved to be very high: if we only include fish ponds and pelagic groups (excluding Harpacticoida) for comparability, regional richness (43) is still much higher than those in other similar scaled studies dealing with 28–45 freshwater lakes in a region, resulting

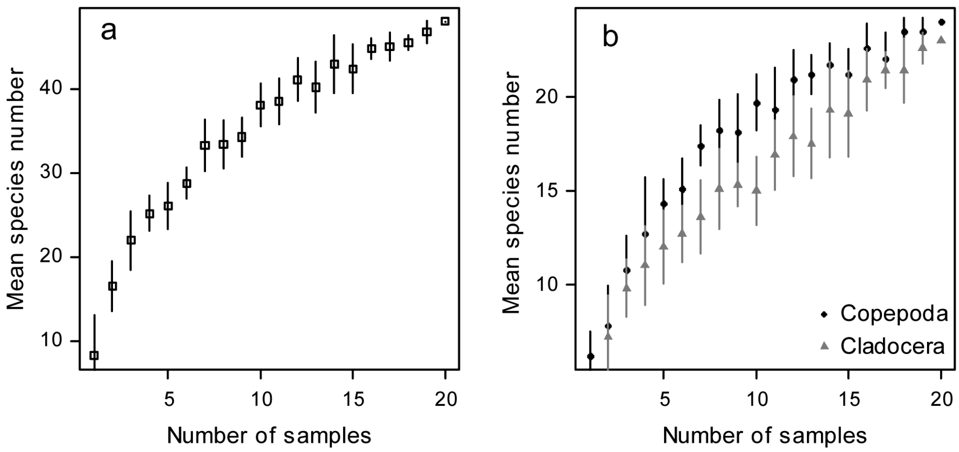

Fig. 1. Species accumulation curves of the fish ponds for total microcrustaceans (a) and for cladocerans and copepods separately (b)

in 6–28 species (SHURIN *et al.* 2000). According to the species accumulation curves that were not saturated, regional species richness can be even higher in our case. Additionally, beta diversity of the microcrustaceans was also high among the 20 fish ponds, which was attributable to the high species replacement between sites rather than differences between their species numbers. Our results highlight the

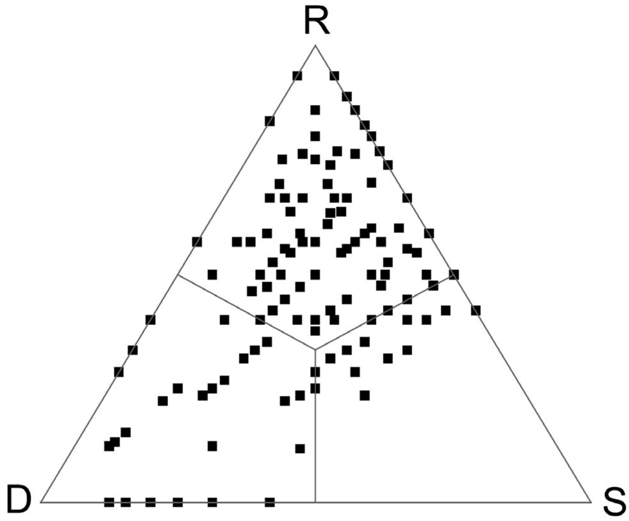

Fig. 2. SDR-simplex of the microcrustacean communities of the 20 fish ponds. S, D and R refer to relativized similarity (S), richness difference (D) and species replacement (R)

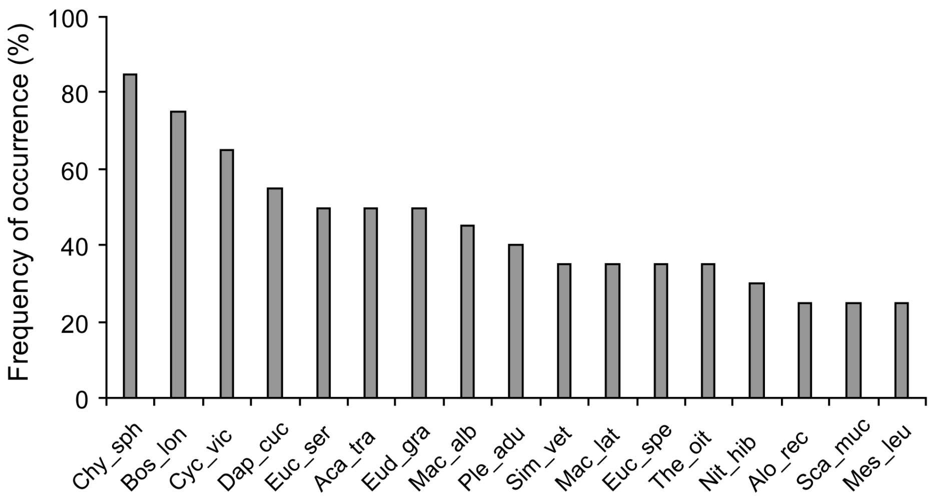

Fig. 3. Frequency of occurrence (incl. species occurring in at least 5 fish ponds). Abbrev.: Chy_sph – *Chydorus sphaericus*, Bos_lon – *Bosmina longirostris*, Cyc_vic – *Cyclops vicinus*, Dap_cuc – *Daphnia cucullata*, Euc_ser – *Eucyclops serrulatus*, Aca_tra – *Acanthocyclops trajani*, Eud_gra – *Eudiaptomus gracilis*, Mac_alb – *Macrocyclops albidus*, Ple_adu – *Pleuroxus aduncus*, Sim_vet – *Simocephalus vetulus*, Mac_lat – *Macrothrix laticornis*, Euc_spe – *Eucyclops speratus*, The_oit – *Thermocyclops oithonoides*, Nit_hib – *Nitocra hibernica*, Alo_rec – *Alona rectangula*, Sca_muc – *Scapholeberis mucronata*, Mes_leu – *Mesocyclops leuckarti*

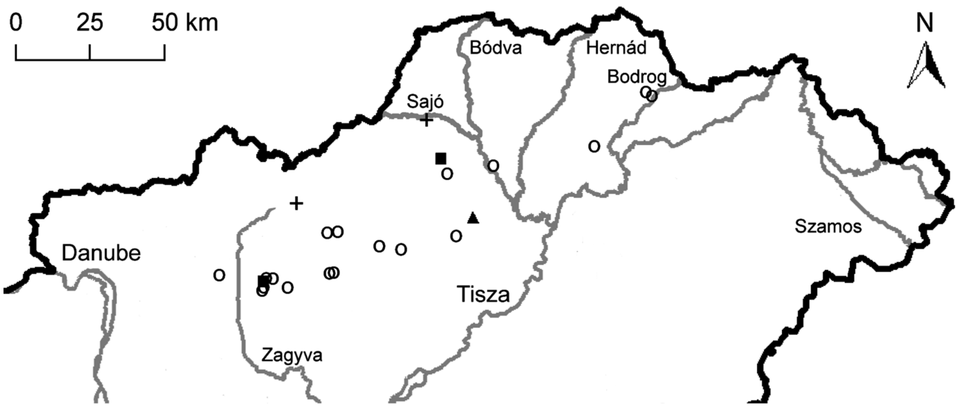

Fig. 4. Occurrences of the non-indigenous microcrustacean species in the investigated artificial lakes of north-eastern Hungary. Abbrev.: *Eurytemora velox*: +, *Daphnia ambigua*: ▲, *Pleuroxus denticulatus*: ■, other lakes: ❍.

high biodiversity of these often neglected artificial habitats also from the standpoint of zooplankton.

Most of the collected microcrustacean species are widespread and characteristic examples of the fauna of fish ponds in Central Europe, such as *Bosmina longirostris*, *Chydorus sphaericus* or *Cyclops vicinus* (KOMÁRKOVÁ 1998, MAIER 1998).

The finding of *Hemidiaptomus hungaricus* was the first occurrence of the species in the present territory of Hungary. This species was described by KIEFER (1933) in the vicinity of Nagysalló (now Tekovské Lužany in Slovakia) from some samples from E. DUDICH, who had collected it only at one location, although later on, he found the species there in several different years (DUDICH 1957). Apart from Slovakia, the species was also found in the lowlands of other countries in the Central and Eastern European region like Romania (DAMIAN-GEORGESCU 1966, DEMETER & MARRONE 2009), Ukraine (SAMCHYSHYNA 2008) and the Czech Republic (FOTT *et al.* 2005). However, it is always rare, therefore it was also included e.g., on the Czech Red List of invertebrates (FOTT *et al.* 2005). The Czech Republic is regarded as the westernmost occurrence of *H. hungaricus*, which may be an explanation for its rarity in the country. On the other hand, the species is quite frequent in some areas of Russian steppes (EVDOKIMOV & ERMOKHIN 2007, 2009) and generally considered as an Eastern European species (EVDOKIMOV & ERMOKHIN 2007, DEMETER & MARRONE 2009). This monocyclic, cold-stenotherm species inhabits lowland temporary ponds (EVDOKIMOV & ERMOKHIN 2007, SAMCHYSHYNA 2008). This habitat preference is also confirmed by our locality, as the species composition of the Hungarian pit pond in the foothills of the Zemplén Mountains composed of typical representatives of astatic waterbodies, with the

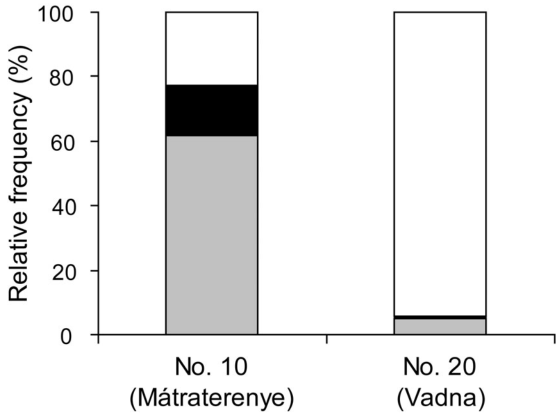

Fig. 5. The relative frequencies of *Eurytemora velox* (white), *Eudiaptomus gracilis* (black) and all other microcrustacean species (grey) in those fish ponds where the invasive *E. velox* was present

dominant species of *Mixodiaptomus kupelwieseri* and *Daphnia pulex* and other temporary water species such as *Cyclops strenuus* or *Megacyclops gigas*.

Of the recently described new *Acanthocyclops* species, we only found *A. trajani*, even though MIRABDULLAYEV and DEFAYE (2004) reported its co-occurrence with *A. einslei* in small waterbodies, such as fish ponds. We emphasize the importance of reviewing the previous *A. robustus* data in Hungary, because *A. robustus* is a valid species and does not occur in Central Europe according to MIRABDULLAYEV and DEFAYE (2002).

The euryhaline copepod *Eurytemora velox* originally inhabited Palearctic coastal waters but invaded many freshwater habitat types, like rivers, floodplains and reservoirs connected to rivers (GAVIRIA & FORRÓ 2000). The first Hungarian record of this species originates from 1991 from the Szigetköz, western Hungary (FORRÓ & GULYÁS 1992), and it was shortly after found in the Danube near Göd in Central Hungary (BOTHÁR & KISS 1995). Nowadays, it is presumably present in the whole Hungarian section of the Danube (VADADI-FÜLÖP *et al*. 2009, KISS & SCHÖLL 2009) and some of its tributaries (GULYÁS 2000). Moreover, it was even recorded from stagnant waterbodies connected to rivers or channels (GULYÁS 2000, HORVÁTH & BOROS 2010). However, no records are available from such isolated systems in Hungary like the lake No. 10. Lake No. 20, the other occurrence of *E. velox* is situated next to the River Sajó. However, the presence of this species has not yet been proved from the river itself yet.

Daphnia ambigua is presumed to be North American in origin (MAIER 1996), which is in agreement with molecular investigations (HEBERT *et al*. 2003). Together with *Pleuroxus denticulatus*, they have been spreading from Western to Central Europe in the last few decades (VRANOVSKÝ & TEREK 1996, HUDEC & ILLIOVÁ 1998). According to some authors, *P. denticulatus* may also be a North American species (e.g., HUDEC & ILLIOVÁ 1998). The ecological implications of their arrival are still not clear, although there are some reports that e.g., *D. ambigua* is able to invade the niche of the native *D. galeata* in some cases (MAIER 1996). Their presence in Hungary was confirmed in the Danube, its floodplains (GULYÁS & FORRÓ 1999, KISS & SCHÖLL 2009, VADADI-FÜLÖP *et al*. 2009) and other recently created wetlands connected to rivers (KORPONAI 2002, HORVÁTH *et al*. 2012).

We found *Pleuroxus denticulatus* in both cases (lakes No. 4 and 20) together with the native *P. aduncus*. Moreover, in the lake No. 4, the native species was more than twice as abundant. Similarly, HUDEC and ILLIOVÁ (1998) found the species in pond-like habitats together with *P. aduncus*, where it was usually also subdominant. Relative abundances were similar in the case of *Daphnia ambigua* as well, as in the only lake where it was found (No. 16), it co-occurred with the more than three times more abundant *D. cucullata*. HUDEC and ILLIOVÁ (1998) note that these two adventive species may possibly spread with fish stocking and therefore, they often co-occur. They were also found together in another Hungarian wetland complex (HORVÁTH *et al*. 2012), although we found no co-occurrence of these two species in the region of the North Hungarian Mountains. Their low relative frequencies are parallel with the general opinion that they are always subdominant and cannot be regarded as real invasive species.

On the other hand, *Eurytemora velox* may be considered invasive in Hungary, as it appeared in high numbers in the Danube (FORRÓ & GULYÁS 1992) and it was the dominant calanoid (and at the same time, microcrustacean) species of the two artificial lakes in the region of the North Hungarian Mountains, similar to a soda pan in western Hungary (HORVÁTH & BOROS 2010) and a pit pond in south-eastern Hungary (GULYÁS 2000). Moreover, it was the only calanoid in the latter two cases. In the artificial lakes of the present study, it co-occurred with *Eudiaptomus gracilis*, but its abundance was higher than that of the native species. According to LOWNDES (1935), *E. velox* inhabits shoreline vegetation, while *E. gracilis* is a truly planktonic species. Taking this into account, their coexistence can be possible by spatial segregation. However, the co-occurrence of these two species was also observed in a small sand-pit lake, where they showed similar habitat preferences with more or less equal abundances (LACROIX & LESCHER-MOUTOUÉ 1995).

Species of zooplankton, especially cladocerans can easily spread with passive transport (i.a., via wind or water), mainly due to their ability to create resting eggs (HAVEL *et al*. 1995), although human mediated dispersal also exists, including aquarium trade or the ballast water of ships (HAVEL & HEBERT 1993, MACISAAC *et al*. 2001). BORZA *et al*. (2011) suggested that the presence of the invasive mysid shrimp *Limnomysis benedeni* in the isolated lakes of this region is attributable to fish stocking. This can also be possible in the case of the three adventive microcrustaceans of the present study, as HUDEC and ILLIOVÁ (1998) already noted it in the case of the two cladocerans (*P. denticulatus*, *D. ambigua*). Co-occurrence of alien mysids and microcrustaceans was observed in two lakes (No. 4 and 10), which also supports this theory.

Our results show that recreational fish ponds, which are often neglected in biodiversity surveys, can favour relatively high species richness of zooplankton. However, one quarter of them was inhabited by non-indigenous microcrustacean species. If we add this to the findings of BORZA *et al.* (2011), half of the fish ponds (10 out of 20) in this region are inhabited by alien species. This draws attention to their role as stepping stones for non-native aquatic species.

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