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Ecological dynamics between Lake Sucutardul Mare and its temporary fry pond (the Fizeş Valley, Transylvania, Romania): the case of aquatic invertebrates

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SUMMARY. Temporary water bodies, connected or not to permanent wetlands, have a major importance for the regional biodiversity, acting as source of individuals for recolonization, refuge habitats or foraging sites. Colonization of zoobenthos and zooplankton from Lake Sucutardul Mare into its temporary fry pond was investigated in summer and autumn 2015. The instability of the temporary water pool, which dried out in autumn, together with its lower habitat heterogeneity led to decreased numbers of zoobenthic colonizers, that failed to survive in this "sink" habitat. No true colonization occurred in case of zooplankton, since the permanent connection between the two ponds led to similar animal communities in the water column. A rapid shift between the dominant zooplankton groups, rotifers and copepods, was observed.

Keywords: colonization, dynamics, temporary pond, zoobenthos, zooplankton

Introduction

Wetlands, man-made or natural, represent an important part of the landscape, due to their multiple values: not only hydrological and physico - chemical (water supply for different purposes, nutrient sinks or sources, flood control etc.) but also biological (maintaining species and genetic diversity, passage habitat for birds etc.) and socio - economic (supporting fisheries and agriculture, recreation or spiritual values) (Haslam, 2007).

Aquatic invertebrates characteristic to wetlands develop in benthic habitats, as well as in the water column (O'Sullivan and Reynolds (eds.), 2004). Zoobenthos comprises a high variety of taxa, from herbivores to carnivores, having different adaptations to the

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lentic environment. Zooplankton inhabits the pelagic habitats and includes mainly rotifers and microcrustaceans (cladocerans and copepods). It represents an important link in the food web, connecting the primary producers to the higher consumers (Cole, 1983).

The present study considered the aquatic invertebrate communities from a fish pond located in the Fizeș River Valley, Lake Sucutardul Mare, and the temporary pond connected to it, used to farm newly hatched fish. Together with 16 other wetland habitats, Lake Sucutardul Mare is included in a complex of aquatic and terrestrial ecosystems, Natura 2000 Special Protection Area ROSPA 0104 "The Fizeş Valley catchment area [Bazinul Fizeşului]", important as reproduction habitats and stopover sites for bird species.

Previous literature from the area focused on lake chemistry (Mihăiescu *et al.*, 2008; Mihăescu *et al.,* 2010) or wetland protection and management (Maloş *et al.*, 2008; Mihăiescu and Mihăiescu, 2010). Biotic communities were analyzed in relation with waterfowl ecology (Stermin *et al.*, 2011) or algae (Momeu *et al.,* 1979). Fish productivity of several ponds from the Fizeș Valley was examined in an unpublished rapport following a three-year research grant, which also included physico-chemical, phytoplankton and invertebrate data (Rapport for research grant no. 2, 1986).

The present paper aimed to investigate the dynamics between a fish pond (Lake Sucutardul Mare) and its connected temporary fry pond. The latter should have been a promising habitat for aquatic invertebrates to colonize, due to its proximity and permanent connection to the fish pond. However, only zoobenthic groups colonized the temporary pond, which finally acted as a sink habitat, since it dried out completely. The present study represents the first attempt to characterize colonization of aquatic invertebrates in wetlands from the Fizeș Valley catchment area.

Materials and methods

Lake Sucutardul Mare (Sucutard II) (**L1**) is located in the Fizeș River catchment area, a tributary of the Someșul Mic River, in the center of the Transylvanian Plain, north-west Romania (N: 46º54'1.51"; E: 24º4'1.87") (Fig. 1). It is a fish pond, created in 1966 by damming the Fizeș River at the junction with the Puini Valley. The present surface of the lake is 46 ha, with a depth ranging from 4 m in 1966 to 2.5 m in 1997 (Sorocovschi, 2005). The fry pond (**L2**) (N: 46º54'17.94"; E: 24º4'11.16") represents a small water body where reproductive fish are isolated, to assure the best start in life for the newly hatched alevins. It is permanently connected to Lake Sucutardul Mare through a subterranean pipe system, where water moves gravitationally from the main lake to lower grounds. The fry pond often dries out in late summer.

Zoobenthos and zooplankton samples were taken in 2015, as follows: on June the 14th (6/14/15), June the 28th (6/28/15), July the 14th (7/14/15), July the 28th (7/28/15), August the 15th (8/15/15), September the 5th (9/5/15) and October the 3rd (10/3/15).

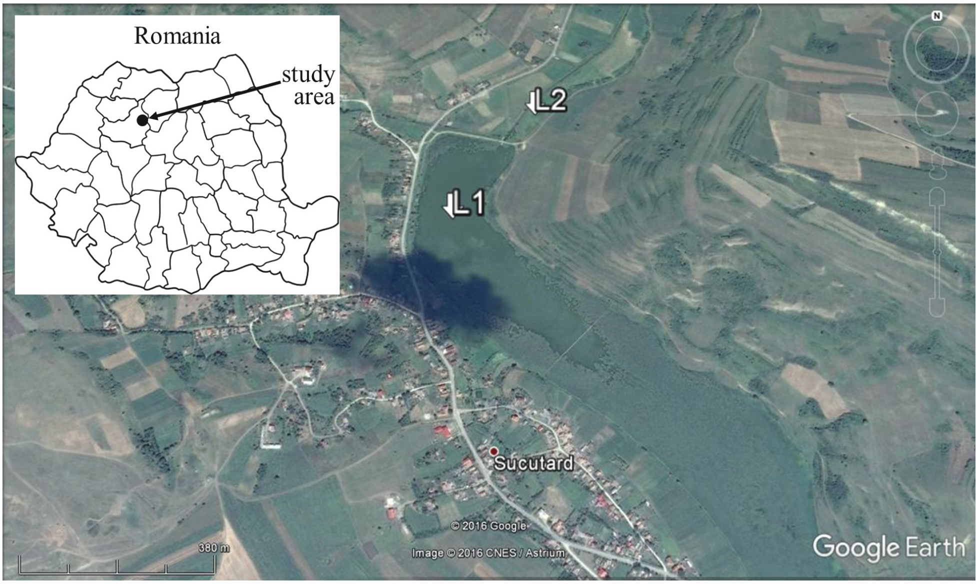

Figure 1. Location of Lake Sucutardul Mare (**L1**) and the temporary fry pond (**L2**)

Due to its shallow depth, the fry pond often dries out in summer or autumn. This was also the case in 2015, when sampling was impossible in October for both zooplankton and zoobenthos. In fact, periods of low water levels are common in the ponds of the Fizeș Valley area. Lake Sucutardul Mare was completely emptied in 2007, during a prolonged period of low rainfall, in order to maintain a higher water level in Lake Țaga Mare, a fish pond located downstream (David, 2008).

Qualitative multihabitat samples were collected with a 250 µm mesh net for zoobenthos and a 55 µm mesh net for zooplankton; they were preserved in 4% formaldehyde. Physico-chemical parameters were measured in the laboratory using a Hanna multiparameter H198130. Benthic invertebrate identifications were made to the genus level for Ephemeroptera and Hemiptera (Heteroptera) and to various taxonomic levels for the other groups, using Sansoni (2001) and Bouchard (2004). Total length was measured for Ephemeroptera individuals (antennae and cerci excluded) (according to Petrovici, 2009), and the following size classes were considered: 1 (1 – 1.99 mm); 2 (2 – 2.99 mm); 3 (3 – 3.99 mm); 4 (4 – 4.99 mm); 5 (5 – 5.99 mm); 6 (6 - 6.99 mm); 7 (7 – 7.99 mm) and 8 (8 – 8.99 mm). In case of zooplankton, microcrustaceans were identified to the species level using Negrea (1983) for cladocerans and Damian-Georgescu (1963) and Einsle (1993) for cyclopoid copepods, while rotifers larger than 55 µm were considered as a group. The validity of all taxa was checked using de Jong *et al*. (2004). Relative abundance, frequency and the Shannon-Wiener diversity index were calculated for both zoobenthic and zooplankton communities.

Results and discussion

Physical and chemical parameters

Lake Sucutardul Mare belongs to bicarbonate - sulphate mixed class as concens the dominant anions, and to magnesium class for cations (Mihăiescu *et al*. 2010). Water temperature recorded normal values for the sampled months, ranging from 10 to 30°C, with slightly higher values in **L2**, probably due to the lower depth of the fry pond. pH values were alkaline: 8.37 in **L1** and 8.2 in **L2**, while conductivity recorded relatively high values, reaching 2.24 mS/cm in **L1** and 1.46 mS/cm in **L2** (all values recorded in August 2015).

Physical and chemical values of Lake Sucutardul Mare measured in 2015 were similar to those recorded in previous studies (Rapport for research grant no. 2, 1986; Mihăiescu *et al*., 2008), showing constant conditions over time.

Water level fluctuations caused by the drying periods can cause faster degradation of organic matter in the system (Wetzel, 2001). This could explain the moderate amount of organic matter measured in Lake Sucutardul Mare: 30 – 70 mg $KMnO4$/L (Rapport for research grant no. 2, 1986). The nutrients released by these oxidation processes could be, in turn, used by algal communities, since the nutrient load of the lake was low: nitrate values below 1 mg/L and total phosphorus lower than 0.2 mg/L (Rapport for research grant no. 2, 1986, Mihăiescu *et al*., 2008).

Zoobenthos and zooplankton abundances

A total of 24 zoobenthic taxa were identified in Lake Sucutardul Mare (**L1**) and only half in its temporary fry pond (**L2**) (Table 1). Several benthic groups were transported from **L1** in **L2**, through the pipe system connecting the two water pools. Most taxa that colonized **L2** were identified in the first months of the study, and only *Corixa* sp. was present in **L2** after August 2015.

A diverse zoobenthic community was present in **L1** in the sampling dates. No dominant group stood out, even if chironomids increased their percentage in autumn, while oligochaetes decreased (Fig. 2). By contrast, zoobenthos taxa depicted a well-balanced percentage distribution only in the first sampling date in **L2**, since chironomids clearly dominated the benthic communities in all other dates, with percentages exceeding 60% (Fig. 2). In fact, the Shannon-Wiener diversity index, calculated for insect orders alone, ranged between 0.4785 and 1.289 in **L1**, and only between 0.1906 and 0.8839 in **L2**.

Three zooplanktonic groups were present in the samples (Table 1): rotifers (*Asplanchna* sp., *Brachionus* sp., *Filinia* sp., *Keratella* sp., *Lecane* sp., *Polyarthra* sp.); cladocerans and cyclopoid copepods (immature and adult individuals). Cladoceran species recorded low frequencies and they were represented by few individuals, all parthenogenetic females. Only *Chydorus sphaericus* (O. F. Muller 1776) and *Moina micrura* Kurz 1875 were present in more than 50% of all samples (Fig. 3).

Table 1

List of taxa identified at the sampling dates in Lake Sucutardul Mare (**L1**) and the temporary fry pond (**L2**) (*- planktonic taxa; crustaceans and insect in phylogenetic order according to Martin and Davis 2001; Wheeler *et al.,* 2001; see text for sampling date abbreviations)

Taxa	**Sampling dates** 6/14/15	**6/28/15**	**7/14/15**	**7/28/15**	**8/15/15**	**9/5/15**	**10/3/15**
Annelida							
Hirudinea	L1	L1	L1	L1, L2	L1	L1	L1
Oligochaeta	L1, L2	L1, L2	L1, L2	L1, L2	L1	L1	L1
Rotifera*	L1, L2	L1, L2	L1, L2	L1, L2	L1, L2	L1	L1
Mollusca							
Gastropoda	L1	L1, L2	L1	L1	L1	L1	L1
Arthropoda, Crustacea							
Branchiopoda, Cladocera*							
Bosmina longirostris	—	*L1*	—	—	*L1*	—	—
Ceriodaphnia reticulata	—	*L1*	—	—	—	—	—
Chydorus sphaericus	*L1, L2*	*L1, L2*	*L1*	*L1*	—	—	—
Moina micrura	*L1, L2*	*L1, L2*	*L1*	*L1*	*L1*	*L1*	—
Simocephalus vetulus	*L1*	—	—	—	—	—	—
Maxillopoda, Copepoda*							
Acanthocyclops robustus	—	*L1*	—	—	—	—	—
Mesocyclops leukarti	*L1, L2*	*L1*	*L1*	*L1*	*L1*	—	—
Thermocyclops oithonoides	*L1, L2*	*L1, L2*	*L1, L2*	*L1, L2*	*L1, L2*	*L1*	*L1*
Malacostraca, Isopoda	L1	L1	L1	L1	—	—	—
Arthropoda, Hexapoda, Insecta							
Ephemeroptera							
Caenis sp.	*L1*	*L1*	*L1*	*L1*	—	*L1*	*L1*
Cloëon sp.	*L1, L2*	*L1, L2*	*L1, L2*	*L1*	*L1*	*L1*	*L1*
Odonata	L1, L2	L1	L1, L2	L1, L2	L1	L1	L1
Hemiptera (Heteroptera)							
Corixa sp.	—	—	*L1*	*L1, L2*	—	*L1, L2*	*L1*
Cymatia sp.	—	—	—	—	—	*L1*	—
Gerris sp.	*L1*	—	*L1*	—	*L1*	—	—
Micronecta sp.	*L1*	*L1, L2*	*L1*	*L1*	*L1*	*L1*	—
Naucoris sp.	*L1*	*L1*	*L1*	*L1*	*L1*	—	—
Plea sp.	*L1*	*L1*	*L1*	*L1*	*L1*	*L1*	—
Ranatra sp.	—	*L1*	—	—	—	—	—
Megaloptera	L1	—	L1	—	—	—	—
Coleoptera	L2	L1, L2	L1, L2	L1, L2	L1	L1	—
Trichoptera	—	—	L1	—	—	—	—
Diptera, Culicidae	L1	L1	L1	L1	—	L1	—
Diptera, Chironomidae	L1, L2	L1, L2	L1, L2	L1, L2	L1	L1, L2	L1
Diptera, Ceratopogonidae	L1	L2	L1	—	—	—	—
Diptera, Ptycopteridae	—	L1	—	—	—	—	—
Diptera, Simuliidae	L2	L2	L1, L2	—	—	—	—
Diptera, Stratiomyidae	—	—	L2	—	—	—	—
Diptera, Syrphidae	—	L1, L2	—	—	—	—	—

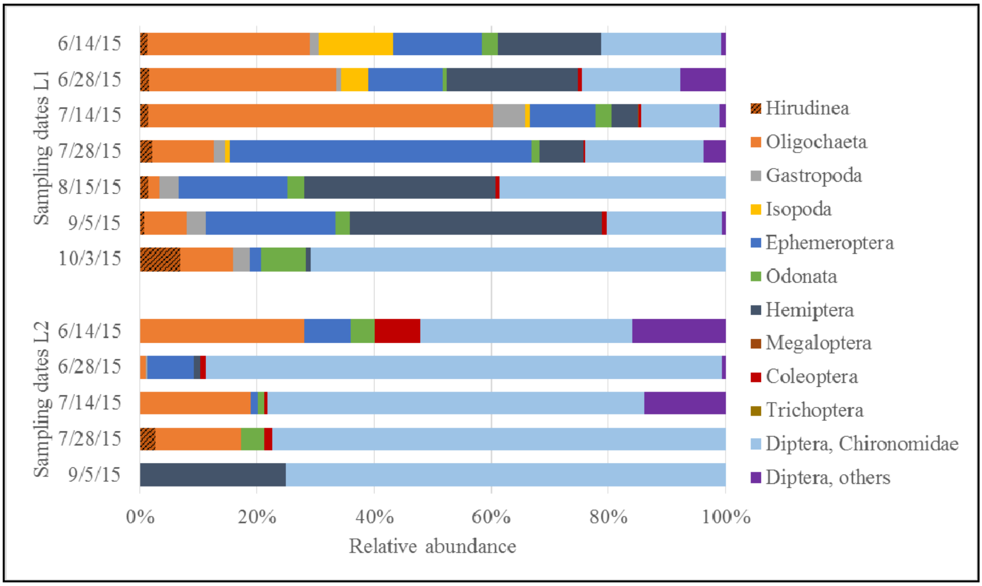

Figure 2. Relative abundance of benthic invertebrate groups in Lake Sucutardul Mare (**L1**) and its temporary fry pond (**L2**) (see text for sampling date abbreviations)

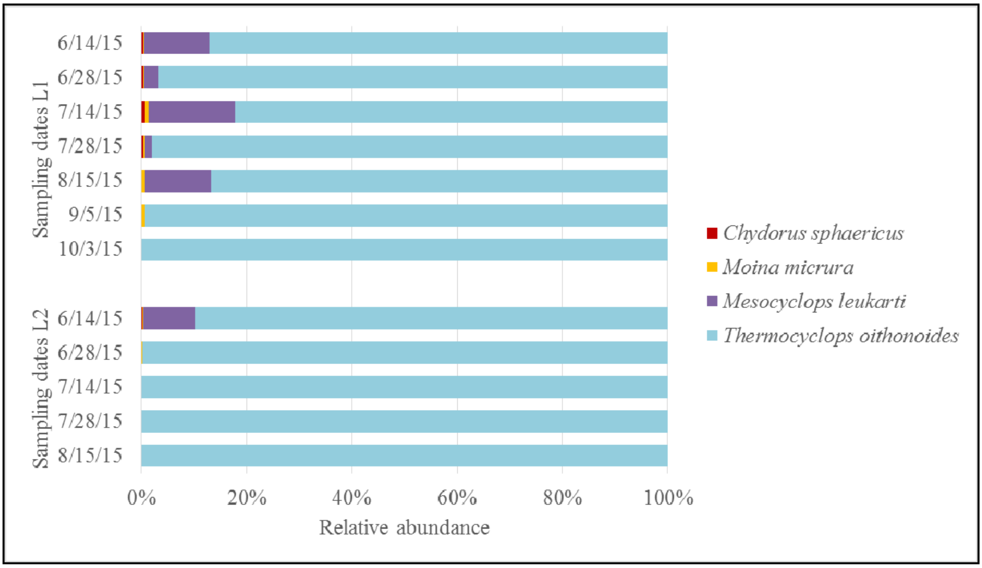

Figure 3. Relative abundance of planktonic microcrustacean species (cladocerans and copepods) in Lake Sucutardul Mare (**L1**) and its temporary fry pond (**L2**) (species with frequencies ≤ 30% excluded; see text for sampling date abbreviations)

Copepods and rotifers clearly dominated both water bodies. *Thermocyclops oithonoides* (Sars 1863) was the dominant copepod species: adults and immature individuals (copepodites and nauplii) reached high abundances in all sampling dates (Fig. 3). This was the reason why the Shannon-Wiener diversity index recorded low values for microcrustaceans: slightly higher in **L1**, ranging between 0 and 0.5238; and very low in **L2**, not exceeding 0.3448, with 0 for three sampling dates, from July to August 2015. Significant differences were recorded between the averaged diversity indices for microcrustaceans in **L1** compared to **L2** (t test = 3.211; p = 0.0014).

Zoobenthos dynamics between the two water bodies

During the sampling period, the temporary fry pond (**L2**) was colonized by zoobenthic groups coming from **L1**. In most cases, the number of individuals in **L2** was much lower than in **L1**, and they did not survive the whole sampling period (Fig. 4: A, B, C). Dipterans belonging to Chironomidae and Simuliidae represented an exception, since they were present in higher numbers in **L2** in June and July 2015 (Fig. 4: D, F). Some groups, like Culicidae, were unable to colonize **L2** (Fig. 4, E).

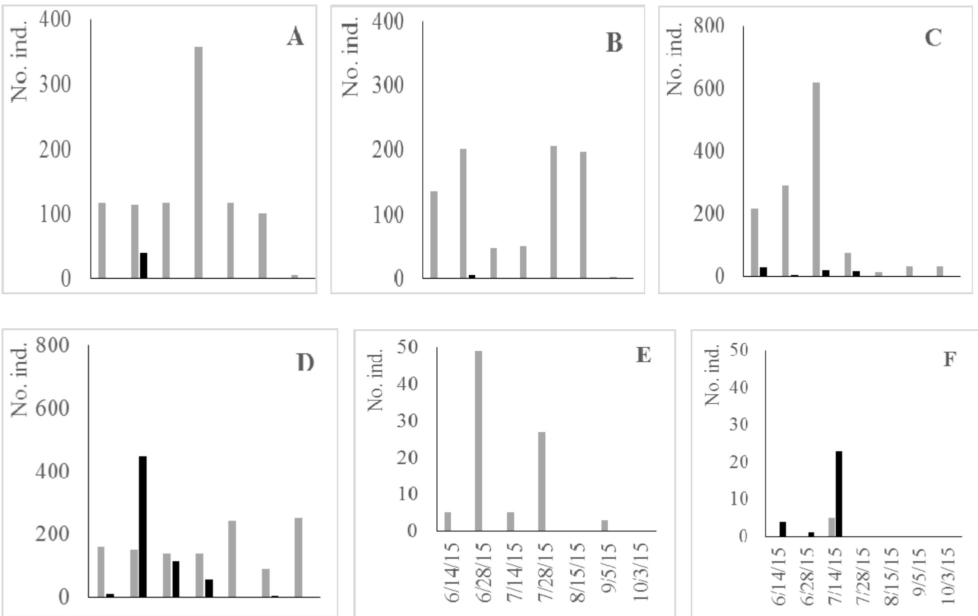

Figure 4. The number of individuals from Lake Sucutardul Mare (**L1**, gray columns) and its temporary fry pond (**L2**, black columns) for: A –Ephemeroptera; B – Hemiptera (Heteroptera); C – Oligochaeta; D – Chironomidae; E – Culicidae; F - Simuliidae (No. ind. – number of individuals; see text for sampling date abbreviations)

In case of Ephemeroptera, *Cloëon* sp. was represented in both water bodies by individuals differing in size (Fig. 5). Mayflies are known to be multivoltine, depending on local habitat conditions; development can take from several months up to a year (Bauernfeind and Soldán, 2012).

Two cohorts were visible in *Cloëon* population in **L1**: the first one with large, older individulas in late June (size classes 7 and 8), that probably colonized **L2**. The second one, characterized by larger individuals in August - September was unable to disperse in **L2**, due to the lack of favorable habitats in the fry pond, which eventually dried out.

Larger *Cloëon* individuals were present in **L2** in late June (Fig. 5), probably due to lower fish pressure, since fish fry usually feed on zooplankton and not on larger benthic invertebrates (Froese and Pauly (eds.), 2016).

Most of the *Cloëon* individuals emerging from **L2** in late June probably layed their eggs back in **L1**, since fewer individuals were found in **L2** afterwards. This could be explained by the decrease in suitable habitats for benthic invertebrates in **L2**, once the pond dried out.

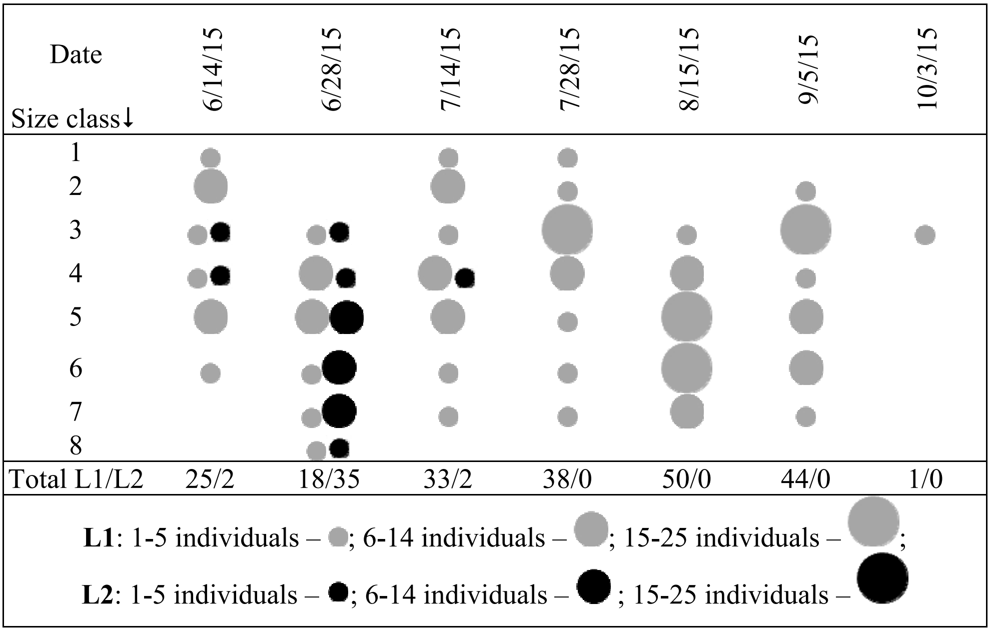

Figure 5. Dynamics of *Cloëon* sp. (Ephemeroptera) belonging to different size classes in Lake Sucutardul Mare (**L1**) and in its temporary fry pond (**L2**) (see text for sampling date abbreviations)

A high taxonomic richness was recorded in **L1** in case of true bugs, Hemiptera (Heteroptera): seven genera present, compared to only 2 in **L2** (Fig. 6). Several habitat characteristics influence true bug community structure in lakes: the presence of aquatic vegetation, accumulation of organic matter and water chemistry (Savage, 1989). Moreover, true bugs occupy different ecological regions in aquatic ecosystems, including not only benthic but also nektonic and neustonic communities. Thus, the low diversity of genera in **L2** showed the absence of suitable habitats in the temporary fry pond, compared to the main lake (Fig. 6).

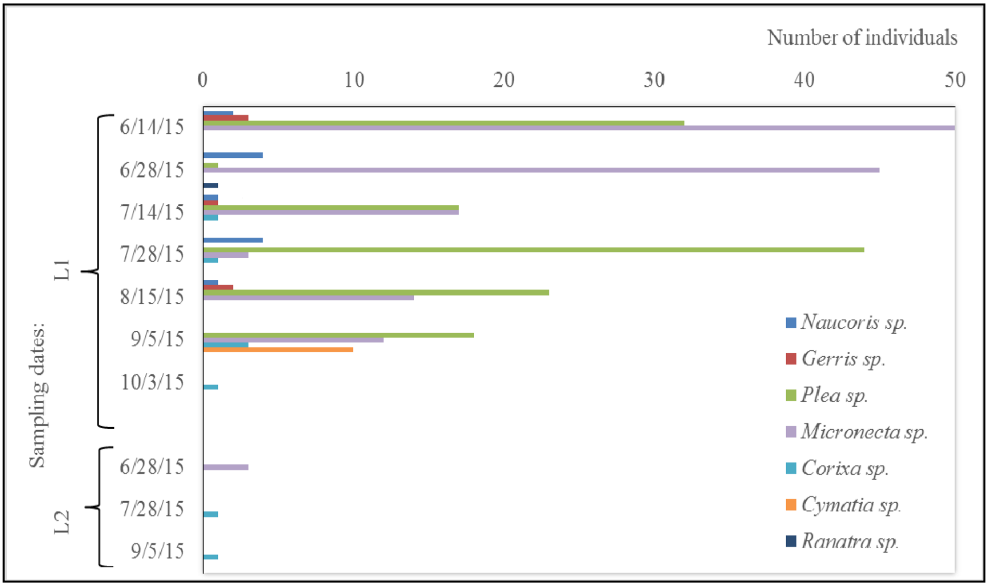

Figure 6. Number of individuals belonging to different Hemiptera (Heteroptera) individuals from Lake Sucutardul Mare (**L1**) and its temporary fry pond (**L2**) (see text for sampling date abbreviations)

Zooplankton dyamics between the two water bodies

The dominating groups of the animal plankton community changed rapidly in a short time, showing a dynamic community (Fig. 7). Rotifers, characterized by parthenogenetic reproduction under favorable conditions, were able to dominate the water column during the first sampling dates in both water bodies, outcompeting the cladocerans. However, *T. oithonoides* reached the dominant position in the water column, sometimes in only two weeks, as for the temporary fry pond (**L2**) (Fig. 7).

Sampling dates:		6/14/15	6/28/15	7/14/15	7/28/15	8/15/15	9/5/15	10/3/15
L1:	dominant group	R	R	R, *To*	*To*	*To*	*To*	*To*
	common group	*To*(i)	*To*		*Osc.*		R	R
L2:	dominant group	R	*To*(i)	*To*	*To*	-		
	common group	*To*(i)	R	R	R	*Osc.*		

Figure 7. Zooplanktonic dominant and common groups in Lake Sucutardul Mare (**L1**) and its temporary fry pond (**L2**): R – rotifers; *To* – *Thermocyclops oithonoides*; i – immature stages (nauplii and copepodites); *Osc.* – *Oscillatoria* sp. (see text for sampling date abbreviations)

Lake Sucutardul Mare had a higher zooplankton species richness compared to the fry pond: from a total of 8 microcrustacean species, 4 were found only in **L1**. However, the same dominating groups were characteristic to both **L1** and **L2** (Fig. 7), with monospecific microcrustacean communities in July and August in **L2**, when only *T. oithonoides* was identified (next to rotifers). This showed that the source of zooplanktonic individuals in **L2** was undoutably Lake Sucutardul Mare, since they could pass freely from **L1** to **L2** with the water. A two-week delay was observed in **L2** in case of a strong phenomenon of water blooming with Cyanobacteria *Oscillatoria* sp., confirming the clear connection between the two water bodies.

Colonization or seasonal dynamics?

Colonization of temporary habitats by aquatic invertebrates is mainly controlled by environmental pressures (Schneider and Frost, 1996; Incagnone *et al.,* 2015). Pond duration represents the most important factor influencing the community structure of the colonizing taxa (Schneider and Frost, 1996). Other environmental factors include habitat heterogeneity, water depth, connectivity, surface area (Studinski and Grubbs, 2007; Frisch *et al.,* 2012). Biotic interactions play an important role too, but their effect increases with increasing habitat duration (Schneider and Frost, 1996). In some cases though, some taxa cannot survive and reproduce because of short hydroperiods; these temporary ponds become "sink habitats" for those taxa (Pulliam, 1988; Schneider and Frost, 1996).

During the sampling months, zoobenthic individuals colonized the temporary fry pond (**L2**), but for a short time and in small numbers for most groups. In case of Ephemeroptera for example, more larger individuals were found in **L2** in late June than in **L1**, showing better environmental conditions in the temporary pond, probably due to lower fish predator pressure. However, decreased numbers of mayfly individuals were found in subsequent months in **L2**, as for Heteroptera, Oligochaeta, Chironomidae etc. Thus, a short hydroperiod in **L2**, together with low habitat heterogeneity, led to decreased numbers of zoobenthic colonizers from the main lake into its fry pond. **L2** would probably be a more interesting environment to colonize for benthic invertebrates if longer wet periods created more diverse habitats, like regions with macrophytes, accumultation of organic matter etc.

In case of microcrustaceans (Cladocera and Copepoda), they are considered to be well adapted to colonize and survive in temporary environments, where hydroperiod represents the main stressor, since they have short life spans, they can reproduce asexually through parthenogenesis, and they can produce resting eggs. In fact, copepod assemblages were suggested as candidates for biological indicators for environments with different wet period durations (Seminara *et al.,* 2016).

Zooplankton was more diverse in **L1** compared to the temporary fry pond. Similar results were reported in the literature, and they were explained by physical factors, like suspended solids, conductivity or pH, that made the temporary habitats unsuitable for colonizers (Simões *et al*., 2011).

However, no true colonization for zooplankton occured in the study area during the sampling dates, since the constant connection between **L1** and **L2** assured the presence of similar communities in both pools. Thus, the heterogeneity of the new habitats was less important than the constant connectivity for zooplankton, as shown also in the literature (Frisch *et al.,* 2012).

Nevertheless, the temporary ponds play an important role in preserving regional invertebrate diversity in wetlands, acting as place of refuge, source of individuals etc., provided that the hydroperiod allows taxa to survive and reproduce.

Conclusions

Zoobenthos and zooplankton communities from Lake Sucutardul Mare and its temporary fry pond were analyzed during summer and autumn 2015

A higher diversity for both communites was recorded in the main water body, due to more constant ecological conditions and a higher heterogeneity of habitats.

Colonization of the temporary fry pond with benthic invertebrates was observed, but low in intensity and duration. The temporary pond acted as “sink” for most benthic groups, when the water pool went completely dry.

No true colonization occurred in case of zooplankton, since the permanent connection of the two water bodies led to similar communities in the water column. However, rapid shifts in the dominant groups, from rotifers to copepods were observed.

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