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THE COLONIZATION OF NEWLY BUILT FISHPONDS BY THE MACROINVERTEBRATE ASSEMBLAGES

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Abstract

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The succession of standing waters by aquatic macroinvertebrates is a present and insufficiently surveyed topic. This study is addressed to the issue of colonisation of newly created small standing waters. Two fishponds situated in the north of Moravia (Czech Republic) were studied. The aim of this study was to determine the character and colonisation rate of these ponds by macroinvertebrates, to evaluate the abundance, taxonomic composition and changes in composition of freshwater assemblages as a result of the fish stock influence. Basic abiotic parameters were also measured within the sampling occasions (e.g. water temperature, dissolved oxygen, conductivity, pH, total nitrogen and phosphorus concentrations). Samples of aquatic macroinvertebrates were taken monthly during the years 2012 and 2013, by kick sampling method using the hand net. The character of sampled fishponds was very similar, environmental parameters (e.g. area, substrate, depth etc.) were comparable. The colonisation of both fishponds was very fast. The pioneer colonists were mainly insect larvae (e.g. chironomids). Very low numbers of macroinvertebrates as a result of fish stock influence were recorded on both sites during the observation with the highest abundances in summer season.

Keywords: fishpond, macroinvertebrates, colonization, temporary fauna

INTRODUCTION

The creation of new aquatic habitats is an omitted and less surveyed topic (Barnes, 1983; Gee *et al.*, 1997; Fairchild *et al.*, 2000; Oertli *et al.*, 2005; Ruhí *et al.*, 2009; Cañedo-Argüelles and Rieradevall, 2011). Aquatic macroinvertebrates were used as model organisms because they belong in general to the first colonizers of newly created aquatic biotopes (Milner, 1994). The colonization of aquatic biotope can be expected even during the first year of the existence of habitat unless there are barriers and obstacles on the locality which is providing sufficient amount of usable sources (Barnes, 1983; Wrublenski, 1999). According to Bilton *et al.*, (2001) the initial phase of colonization depends mainly on the dispersion ability of particular species. Subsequent changes in the assemblage structure are based on the changes within the local conditions of the biotope, e.g. transition from the dominance of aquatic macrophytes to dominance of phytoplanktonic assemblages (Scheffer *et al.*, 1993; Jeppenes *et al.*, 1999; Jones and Sayer, 2003). New habitats are quickly colonized by the organisms with high reproduction potential which are able to effectively utilize available sources. Typical aquatic representatives of such strategy are organisms which occupy ephemeral or periodical waters (pools, spring ponds, etc.) or the organisms which come as first after natural disturbances. Life strategy of these species must be adapted for adverse conditions. Usually, they produce high number of offspring, their reproduction comes most likely at the beginning of adulthood and the most of energy from available sources is invested rather into the reproduction than into the growth and life span. Such species are called r-strategists.

The colonization rate and the structure of created assemblage are influenced by local factors, mainly the physicochemical parameters of water, fish stock composition, type of the fishpond, water level fluctuation, melioration, intensifying interventions etc. (Della Bella *et al.*, 2005). Local abiotic conditions can be limiting factor for the settlement of newly created aquatic biotope (Cottenie *et al.*, 2003), so the taxonomic composition and abundance can be considered as indicators of environmental and food conditions of biotope (Johnson *et al.*, 1995). Colonization can be realized by a few ways which are species-specific (Williams and Hynes, 1976). The first of them is the colonization by air when insect imagoes land on the specified locality and lay eggs. In our conditions, this is possible only during the warm seasons of the year so the complete colonization of new habitats might be much slower. In running waters there is important aquatic phase of colonization when organisms are drifting from the upper parts of the stream or by upstream migration from the lower parts of the stream. In the case of standing waters, organisms can reach the basin mainly by the water inflow.

Aquatic invertebrates which colonize new biotopes among the firsts are the representatives of orders Odonata, Ephemeroptera, Diptera, Hemiptera and Coleoptera and family Chironomidae (Voshell and Simmons, 1984; Layton and Voshlel, 1991; Batzer and Wissinger, 1996; Wrubleski, 1999, 2005).

Comparing to the terrestrial ecosystems, the topic of succession was not very frequent subject of studies and colonization of aquatic ecosystems is relatively unsurveyed. Only a few studies are involved in aquatic ecosystems colonization and furthermore, most of them are just short-time research which can be limiting for evaluation of ecological function of these ecosystems (Zedler and Callaway, 1999) in spite of newly created aquatic biotopes seem to be optimal systems for studying and monitoring the colonization dynamics (Oertli *et al.*, 2005).

Till nowadays, studies of aquatic biotopes were mostly based on the observation of species diversity of aquatic invertebrates. It is also important to take into consideration other aspects of taxonomic affinity (Warwick and Clarke, 1995). The colonization of newly created fishpond is more fast the more close it is to another aquatic biotope. This generally applies to aquatic plants, aquatic invertebrates and other animals (Gee *et al.*, 1997; Fairchild *et al.*, 2000). According to Fisher (1983) process of settlement includes a quick initial phase of colonization and following changes in the structure and organization of created assemblage.

The aim of this study is to monitor the initial phase of succession and speed of colonization of newly created aquatic habitats with the focus on the aquatic invertebrates and taxonomical and functional structures of the assemblage. The next aim was to compare the progress of colonization in two fishponds with different fish stock.

MATERIALS AND METHODS

Study Area

The area of interest is situated in the Northern Moravia near the city Třinec at the altitude of 325 m. The area belongs to the foothills of Moravskoslezské Beskydy. The climate is cold, moist and harsh. The total annual precipitation was 755 mm in 2012 and 764 mm in 2013. Monitored fishponds belong to the system of six newly built fishponds. Within this study, the results of two of these fishponds are presented. The fishpond system is surrounded by forest from one side and by the roadway on the other. In the vicinity there are pastures for cattle. Two streams flow around the fishponds. One of them supplies the fishponds. The inflow from this stream is secured by the net against the entrance of undesirable organisms from the surroundings. All of the fishponds are used for rearing fish.

Fishpond No. 1

The fishpond was built and flooded in the autumn 2011. Intensification measures were carried out after flooding, including fertilization by manure and liming by ground limestone. The area of this fishpond is 0.098 ha, an average depth is 1.3 m and maximal depth is 1.9 m. The undersoils consist mostly of clays. The fluctuation of water level is about 10 cm during the year. The littoral zone slopes steeply to the centre of the fishpond. There was no vegetation in the fishpond at the beginning of the season, but at the end of sampling period the littoral zone was partly overgrown by aquatic macrophytes (*Typha latifolia, Carex acuta, Phragmites australis*).

The fish stock was polycultural in 2012, composed by benthophagous tench (*Tinca tinca*) broodstocks (715 ind/ha), carnivorous largemouth bass (*Micropterus salmoides*) broodstocks and two years old fish (350 ind/ha, 1020 ind/ha), and fodder white fish (*Rutilus rutilus* and *Scardinius erythrophthalmus*).

Fishpond No. 2

The second monitored fishpond was built as the last within the fishpond system. It was created and flooded in September 2012. The intensification measures including fertilization by manure and liming by ground limestone were applied. The area of fishpond is 0.5 ha, average depth is 1.2 m and maximal depth is 2.1 m. The undersoils consist mostly of clays. The fluctuation of water level is about 40 cm during the year. The littoral zone slopes gently to the midpoint of the fishpond. Littoral zone was planted by marsh and aquatic plants. The fishpond was stocked in the autumn 2012 by tench (*Tinca tinca*) broodstocks (140 ind/ha), largemouth bass (*Micropterus salmoides*) broodstocks and two years old fish (50 ind/ha, 74 ind/ha), common carp (*Cyprinus carpio*) four years old fish (8 ind/ha) and zander (*Sander lucioperca*) fingerlings (360 ind/ha) and supplemented by fodder white fish. This fishpond was stocked in the spring 2013 by more zander fingerlings (760 ind/ha).

Sampling Methods

Sampling was realized monthly during the years 2012 and 2013 immediately after the flooding of fishponds. Macroinvertebrates were sampled from the bottom by hand net of a size of 25×25 cm with mesh size of 0.5 mm, regularly in the same time (8–10 AM). Particular types of habitats in fishponds were not distinguished due the undifferentiated character of the fishpond and undeveloped littoral zone. Samples were taken by semiquantitative method, then partially sorted and conserved by 4% formaldehyde *in situ*. Final processing was realized in the laboratory. Particular individuals were identified to the lowest possible taxonomical level i.e. genus or species. Consequently with the biota samples, physicochemical parameters of water (temperature, dissolved oxygen saturation, pH, conductivity, total nitrogen, total phosphorus, chlorophyll a) were measured.

Data Analysis

Based on the reached data, taxonomical composition, abundance and functional structure of macroinvertebrates assemblage were evaluated in particular samples.

From the functional structure point of view, particular taxa were sorted according to the species traits: substrate preferences, zonation preferences, saprobity, feeding type and life strategy. In this respect, family Chironomidae is problematic and was singled out from the order Diptera because of the lack of autecological information about some species.

RESULTS AND DISCUSSION

Physicochemical Parameters of Water

Within this study, basic physicochemical parameters of water in particular fishponds were measured during the whole sampling period. Minimum, maximum and mean values of the main abiotic parameters are summarized in Tab. I. Key role in aquatic ecosystems plays water temperature. In the first fishpond an average temperature was 17.0 ± 0.5 °C, in the second was 18 °C. Maximum values were measured in the summer season. Both fishponds are shallow and unshaded by littoral vegetation which is missing surrounding fishponds. As a consequence of this water column in both fishponds is quickly warmed up during the sunny days and water temperature can exceed 26 °C.

Dissolved oxygen amount is closely connected to the water temperature. Average values of dissolved oxygen were fluctuating around 100% during the most of the year in both fishponds. But in summer season was situation different in each fishpond. There was significant dissolved oxygen depression in the beginning of July in the fishpond 1, minimum reached 23.6% saturation. This decrease could be caused by several environmental factors. One of the main reasons is usually water temperature and quantity of the fish stock. Last but not least participation on dissolved oxygen decrease has qualitative and quantitative composition of phytoplankton and zooplankton. Subsequently, phytoplankton decrease is attended by decreasing of photosynthesis and low oxygen assimilation in aquatic environment. This fact was confirmed because the lowest chlorophyll a value was measured at the same time. Subsequently the next month the chlorophyll a value and phytoplankton increased. Simultaneously higher values of dissolved oxygen were measured.

There was recorded no lack of dissolved oxygen in the summer season in the fishpond 2 with smaller amount of fish.

Other monitored parameter was conductivity of water. The conductivity influences primarily the amount of dissolved substances. Both fishponds differ in conductivity considerably. Fishpond 1 showed significant fluctuations, minimum conductivity was 232 $\mu S.cm^{-1}$ and maximum 519 $\mu S.cm^{-1}$. Fishpond 2 showed relatively constant values with minimal fluctuations during the growing season. Also pH did not show significant fluctuations during the growing season in both fishponds, no extreme values were measured.

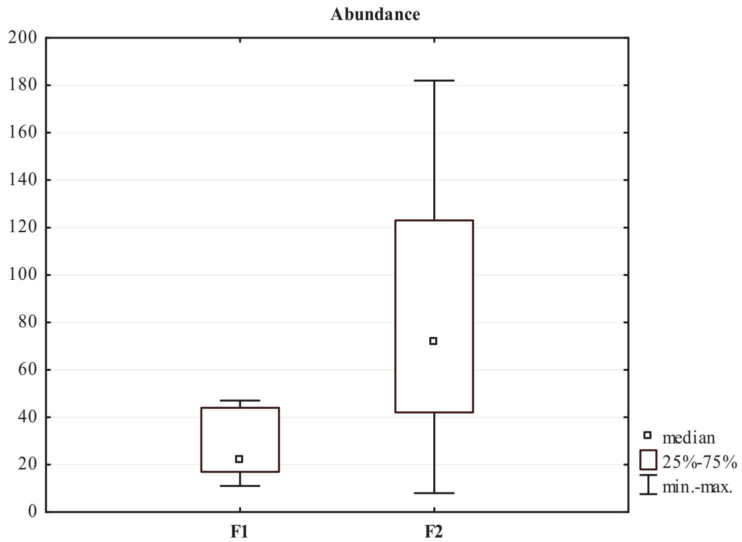
From nutrient content point of view, total phosphorus (TotP) and total nitrogen (TotN) were monitored during the whole season. Sufficient amount of nutrients has influence on fishpond productivity; nevertheless, nutrient surplus means risks for aquatic ecosystems and can influence a whole range of negative impacts. In fishpond 1 there was a constant increase of TotP and TotN during the whole season. The highest values were measured in summer. The nutrient surplus in aquatic ecosystems often causes development of algae and cyanobacteria, which was confirmed in our case by large amount of chlorophyll a in August and September. In fishpond 2 there was no significant increase of nutrients during the season. Also phytoplankton community did not show massive growth.

Macroinvertebrate Assemblages

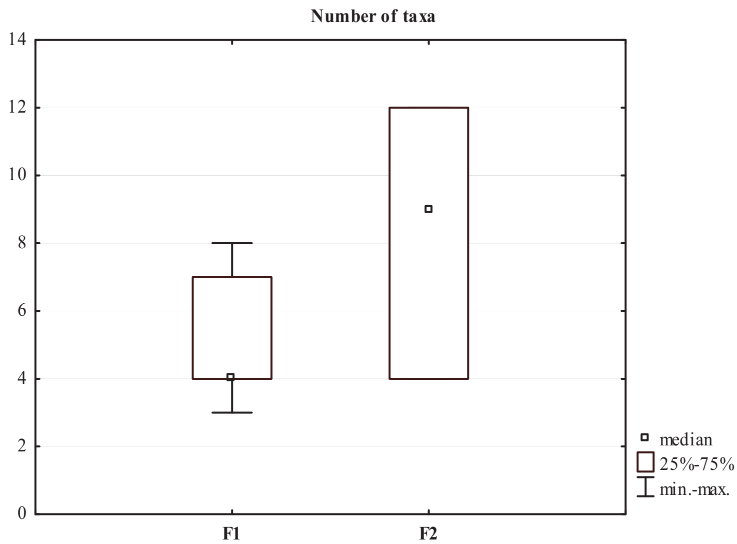
Both fishponds were flooded in the autumn (of the prior year). The survey of aquatic biota started immediately in the spring of following year. The initial colonization of newly created fishponds was very quick. In the first spring samplings there were invertebrates identified, mainly larvae of aquatic insect with terrestrial adults. In general, there are three possible ways for aquatic invertebrates how to colonize new habitats. In running waters, they

I: *Minimum, maximum and mean values of the main abiotic parameters at each site, computed for the whole sampling period*

	Fishpond 1			Fishpond 2		
	min	**max**	**mean**	**min**	**max**	**mean**
oxygen saturation [%]	23.6	179.4	103.1	90.0	210.4	120.3
pH	7.6	9.7	8.5	8.4	9.3	8.9
temperature [°C]	7.3	24.9	16.7	6.9	26.8	17,8
conductivity [µS/cm]	232.0	519.0	402.3	247.0	371.0	291.9
N_{total} [mg/l]	1.0	2.9	2.0	0.7	3.4	1.2
P_{total} [mg/l]	0.1	0.4	0.2	0.0	0.1	0.1
Chlorophyl a [µg/l]	32.6	375.9	153.9	2.7	54.9	23.4



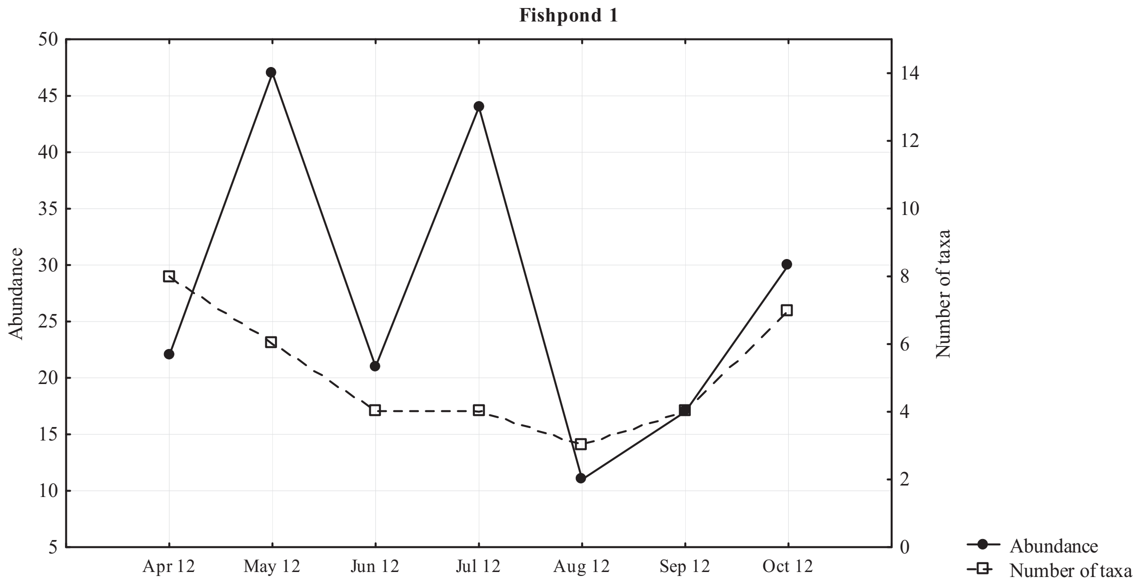
1: *The comparison of total abundance between fishpond 1 (F1) and fishpond 2 (F2)*



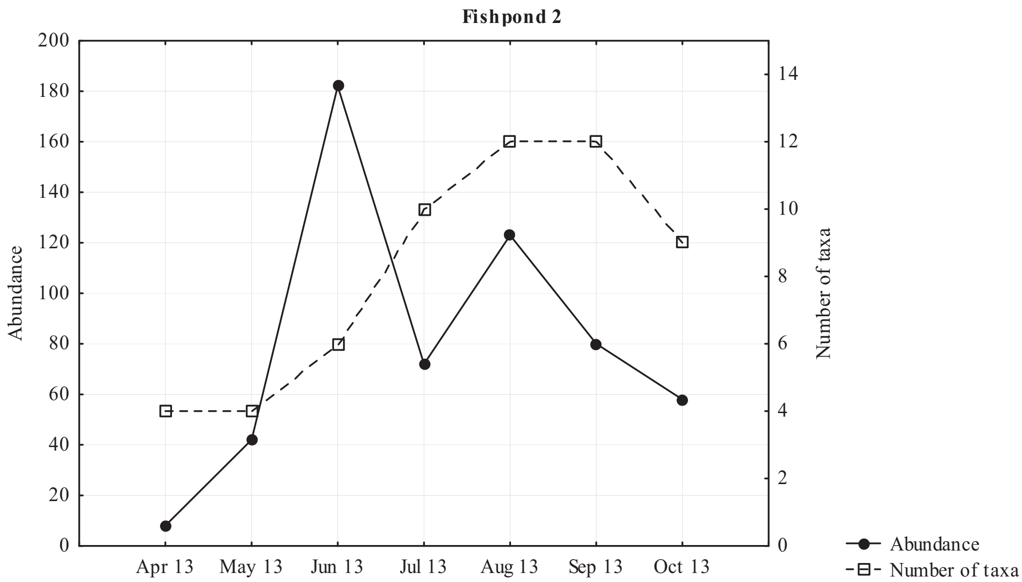
2: *The number of taxa on fishpond 1 (F1) and fishpond 2 (F2)*

can migrate to current locality from upper or lower parts of the stream (Soderstrom, 1987; Elliott, 2003). In our study, the stream could be the source of colonization regardless of the water filtration by mesh at the inflow. The mesh size was sufficiently sparse for the entry of small macroinvertebrates. Other possibility how to colonize new habitats is by adult aerial inmigration (Tronstad *et al.*, 2007). This colonization is based on oviposition of eggs by adults and following spread or on the passive transportation by aquatic vertebrates. Potential aerial colonizers come originally from the current habitat or they migrate from their original locality (Tronstad *et al.,* 2007). Adult aerial inmigration, reproduction and settlement of aquatic environment are dependent on the life cycle of invertebrates, local conditions and season (Smock, 1999). Monitored fishponds were colonized mostly by air thanks to the local conditions. Sources of colonization could be two creeks on the locality or two fishponds from near surroundings, just 320 m far from the studied locality.

In spite the fact that studied fishponds were very similar and differs only in the fish stock, the colonization was proceeding differently. In fishpond 1 the fish stock was denser and much lower numbers of macroinvertebrate individuals (Fig. 1) as well as numbers of taxa (Fig. 2) were present in all samples. The tench and largemouth bass fingerlings feed mainly on macroinvertebrates. The highest abundances were noted in May and July (Fig. 3) and the decrease of individuals was recorded in June. The worsening of abiotic factors as rapid growth of water temperature and dissolved oxygen saturation decrease could have an influence. Other factor is natural life cycle of insect. Most of the aquatic insects can finish their larvae development at the end of the spring. This is the reason of lower abundances in summer season in our climate. The highest number of taxa was observed in spring season. Paradoxically, the lowest number of individuals was found out in this time.



3: *The course of the abundance and the number of taxa on the fishpond 1 in year 2012*



4: *The course of the abundance and the number of taxa on the fishpond 2 in year 2013*

In the fishpond 2 there was significantly higher abundance and number of taxa found out (Fig. 4). As mentioned above, main difference between the fishponds was the predatory pressure of fish stock on the macroinvertebrates. During the spring both individual abundance and number of taxa increased. Significant changes in abundance occurred in the half of July when rapid decrease occurred. This was probably caused by the same factors as in the fishpond 1and by stocking more fish into the fishpond. Nevertheless, number of taxa in fishpond 2 kept increasing till the autumn. Rapid increase of individual abundances was observed in the autumn.

Taxonomic composition of assemblages of both fishponds was diverse. Together with abundance it can be considered as indicator of physical, chemical and food conditions of biotope (Johnson *et al.*, 1995). Just 10 of 30 taxa were found in both observed fishponds (Tab. II). Orders Diptera and Ephemeroptera were present in both fishponds but in higher abundances in fishpond 2. Chironomids belong to the first colonists of newly created aquatic habitats (Barnes, 1983; Ruhí *et al.*, 2009; Cañedo-Argüelles and Rieradevall, 2011). This group was clearly most abundant group of macroinvertebrates in both fishponds. The genus *Tanytarsus* sp. and species *Polypedilum* gr. *nubeculosum* were recorded first of all on both localities. At the turn of spring and summer the species *Chironomus plumosus/balatonicus* was added and then was dominant taxon for the rest of season. Found genera and species are common for the Czech Republic. There was only one mayfly species found *Cloeon dipterum*, which is a common representative of standing waters and can be found all over the area of Czech Republic. The orders Odonata, Trichoptera and Heteroptera were absent obviously in fishpond 1; there were recorder in low numbers only in fishpond 2. In summer there were found few individuals of dragonflies (*Cordula aenea*, *Coenagrion* sp. and *Somatochlora* sp.). Caddisflies were represented in very low abundance by two species namely *Mystacides longicornis* and *Oecetis lacustris*. All these mentioned insect groups belong to temporal fauna and they are able to colonize new habitats by adult aerial inmigration (Tronstad *et al.*, 2007).

II: *The list of recorded taxa on both studied sites*

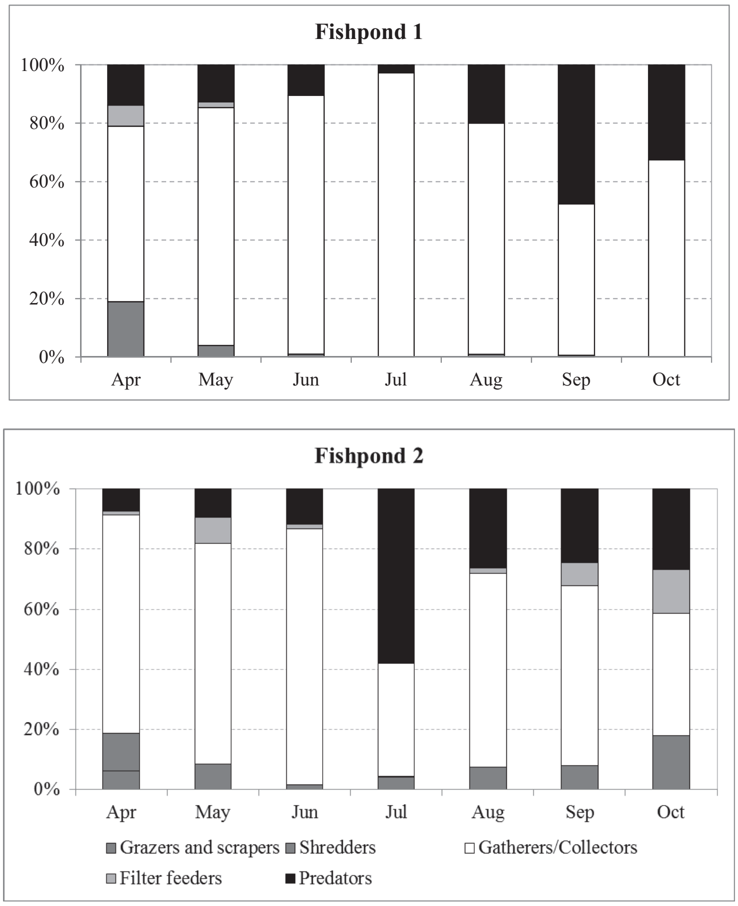
		F1	F2
Mollusca	*Lymnaea stagnalis*	+	
Ephemeroptera	*Cloeon dipterum*	+	+
Hemiptera	Corixidae		+
Odonata	*Cordula aenea*		+
	Coenagrion sp.		+
	Somatochlora sp.		+
Trichoptera	*Mystacides longicornis*		+
	Oecetis lacustris		+
Diptera	Diptera others	+	+
Chironomidae	*Cladopelma* gr. *laccophila*	+	+
	Cladotanytarsus sp.		+
	Cricotopus sp.		+
	Cryptochironomus sp.	+	
	Cryptochironomus sp.		+
	Dicrotendipes sp.	+	
	Endochironomus sp.		+
	Glyptotendipes sp.	+	+
	Holotanypus sp.	+	+
	Chironomus plumosus/balatonicus	+	+
	Chironomus sp. juv.		+
	Kiefferulus tendipediformis	+	
	Microtendipes gr. *chloris*	+	+
	Orthocladius sp.		+
	Paratanytarsus cf.		+
	Polypedilum gr. *nubeculosum*	+	+
	Polypedilum sp.		+
	Psectrocladius sordidellus		+
	Rheotanytarsus sp.	+	
	Tanypus sp.	+	+
	Tanytarsus sp.	+	+

Functional Structure of Assemblage

Also functional structure is developing during the succession besides the taxonomical composition and abundance of assemblage. This development and changes based mainly on the changes and character of the local conditions of the biotope. Second phase of the survey was focused on the selected species traits (substrate preferences, zonation preferences, saprobity, feeding type, life strategies).

On both localities gatherers and collectors were dominant (Fig. 5). Due the prevailing substrate on fishpond bottom which was mud and clay with organic matter, invertebrates preferred gathering food strategy (gatherers/collectors). In this group belong species which take in food by collecting or gathering the detritus, sediments or biofilm. Typical representatives are taxa *Chironomus plumosus*-Gr., *Polypedilum nubeculosum*-Gr., *Tanytarsus* sp. *a Cladopelma* sp. Predators, the species which consume the whole animals or their parts, had relatively high representation in samples. Primarily it was order Odonata (*Coenagrion* sp., *Cordulia aenea, Somatochlora* sp.), Trichoptera (*Oecetis lacustris*), or chironomids *Tanypus* sp. and *Cryptochironomus* sp.

Due to low habitat diversity of studied water bodies, microhabitat preferences of aquatic invertebrates did not differ. Representatives which prefer littoral zone were dominant in the assemblage mainly because of the shallow depth of fishponds. Littoral zone is the bottom of offshore zone which is determined by the light and the light intensity limits the presence of aquatic macrophytes. In this habitat were abundantly present chironomids *Chironomus plumosus/balatonicus, Tanytarsus* sp., *Endochironomus* sp., *Glyptotendipes* sp., *Tanypus* sp. and *Cladotanytarsus* sp.



5: *Relative abundance of macroinvertebrate feeding types on both fishponds*

which prefer light and shallow standing waters. The important substrate for benthic organisms is also macrovegetation which gradually developed in both fishponds. Mainly the chironomids representatives *Cricotopus* sp., *Orthocladius* sp. and *Glyptotendipes* sp. were there found out.

Most of the found taxa can be classified in beta- and alphamesosaprobic level from the saprobity point of view. This level shows less- or middle-heavy organic pollution. Intensive decomposition of some organic substances can occur in some cases. Due to this, decreasing of dissolved oxygen amount can be caused. Many species of original assemblage disappear, replaced by more resistant and adaptable species. This level of strain is tolerate by e.g. *Mystacides longicornis, Oecetis lacustris, Cricotopus* sp., *Cryptochironomus* sp., *Dicrotendipes* sp., *Endochironomus* sp., *Endochironomus* sp., *Glyptotendipes* sp., *Polypedilum* gr. *nubeculosum, Polypedilum* sp., *Tanypus* sp. Also some representatives which tolerate stronger organic strain and which are present also in polysabrobic level were found in both fishponds. This level represents considerable strain of aquatic environment by organic substances where oxygen can be totally depleted. Usually, it is quite impossible for aquatic biota to survive under this condition. The species diversity is in such waters poor. But some resistant species can reach high abundances anyway, e.g. *Chironomus plumosus/balatonicus* which was present in many samples from both fishponds.

Life strategy is a parameter which indicates the ability of either organism or the whole population to succeed when colonizing new environment (Wiliams and Feltmate, 1994). Organisms which colonize new habitats as first are called r-strategists. Their life strategy is focused mostly on the early reproduction with high number of offspring which makes them successful especially in the initial succession. The offspring are able to spread quickly on new localities thanks to high mobility; on the contrary they show low survival. These organisms are semelparous with reproduction occurring in early age because their life cycle is usually shorter than one year. They predominate in pioneering assemblages under the unstable conditions. Typical aquatic invertebrates with fast life cycle are chironomids which predominated in the most of the samples from both fishponds.

CONCLUSION

Within this study character and colonization rate in two newly built fishponds with different fish stock was evaluated. The environmental conditions in both fishponds were similar, only predatory pressure of fish on the macroinvertebrate assemblage was different. Both localities were colonized quickly by aquatic invertebrates, shortly after the initial flooding. Macroinvertebrates were present even in the first spring samples. During the whole season family Chironomidae was predominant, they can be considered as r-strategist which means that they are the first colonizers of newly created or disturbed habitats. The representatives of temporary fauna (larvae of aquatic invertebrates) were the only colonizers during the first year after flooding the fishponds. The colonization by permanent fauna is apparently much slower. Different abundances and numbers of macroinvertebrate taxa were identified in both studied fishponds. Both characteristics were significantly lower in the fishpond with higher fish stock. This was probably caused by the higher predatory pressure of fish. Significant fluctuations in benthic invertebrate abundances were observed in both fishponds during the season. The lowest values were observed in summer. It was probably caused by natural life cycles of insect larvae but also by increasing of fish stock during the year.

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