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PHYTOPHILOUS FAUNA OF A SMALL AND ARTIFICIAL URBAN LAKE

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ABSTRACT

Phytophilous community on *Myriophyllum spicatum* was studied in a small artificial urban lake in the city of Osijek (eastern Croatia), during the spring and summer season in 2010. In the eutrophic conditions, macrophyte stands were well developed and in the formed periphyton representatives of the following invertebrate taxa were found: Hydrozoa, Nematoda, Gastropoda, Cladocera, Copepoda, Insecta larvae - including families Chironomidae and Coleoptera. They displayed differences in temporal abundance patterns. Two separate phases in macrophyte colonization with differences in invertebrate composition and abundance were recorded. Insect larvae, particularly Chironomidae, were most abundant in the first phase, through the spring period, and *Hydra oligactis* (brown hydra) was most abundant in the second phase, i.e. summer period. Concurrently, microcrustacean abundance declined towards the end of the summer. Results of the analyses indicated that water temperature and perihyton biomass were the variables exerting the main influence on the invertebrate assemblage, while interestingly, macrophyte size and biomass were negatively correlated with most of the fauna abundance. On the other hand, brown hydra was negatively correlated with all other invertebrate taxa, except gastropods. Larger surface of submersed macrophytes is the main parameter supporting the increase of invertebrate abundance due to providing protection from predators and growth for periphyton, an important food source for these phytophilous organisms. Macrophyte length was positively correlated with *Hydra* abundance, while Chironomids were more influenced by periphyton biomass. These organisms can indicate water quality conditions and a potential increase in primary and secondary production.

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INTRODUCTION

Urban and artificial lakes are usually small in size, created for recreational purposes, or have been formed as a consequence of building materials extraction. Over 200 million smaller lakes worldwide have an area of less than 1 ha, but their total area extends over a larger area than big lakes (Downing et al., 2006; Downing and Duarte, 2009). Small water bodies are usually rather shallow (depth < 3 m), have specific interactions of water column and the sediment, support the development of macrophyte communities (Scheffer, 1998) and play important role in maintaining biodiversity and hydrological buffering (Blindow et al., 1998; Downing and Duarte, 2009). Nevertheless, when considering interactions within invertebrate communities of lentic ecosystems, small water bodies have often been omitted, regardless of their significance or fauna diversity. The continental part of Croatia is rich in such specific aquatic biotopes - small artificial lakes created by excavation in gravel or clay, i.e. by removing such substrates and leaving depressions in the ground eventually filled with water, and whose hydrological regime depends on the fluctuations of groundwater and precipitation (Mihaljević et al., 1996a).

Littoral zone of shallow lakes is often covered with macrophytes, where submersed macrophytes significantly impact environmental conditions, i.e. stabilize the sediment, provide refuge and food source for invertebrates, and influence the nutrient cycle (Meerhoff et al., 2007; Bogut et al., 2010; Čerba et al., 2010; Špoljar et al., 2012; Basińska et al., 2014). Watermilfoil *Myriophyllum spicatum* is a submerged plant with dissected, thin leaves which create particularly favourable microhabitat conditions for aquatic invertebrates (Čerba et al., 2009, 2010; Kuczyńska-Kippen and Basińska, 2014). Besides shelter from predators, macrophyte stands are suitable habitats with plenty of food resources, i.e. periphyton, for many phytophilous groups of invertebrates (Liboriussen et al., 2005; Špoljar et al., 2017). Brown hydra *Hydra oligactis* (Pallas, 1776), various insect larvae and fish represent main predators in such communities (Armitage et al., 1995; Casatti et al., 2003). Brown hydra is an important predator in the lake communities (Kovačević et al., 2007) and is not selective regarding the size or other characteristics of its prey (Schwartz et al., 1983). The presence or absence of hydra in a water body could have a significant impact on the composition and abundance of invertebrate communities (Schwartz et al., 1983; Walsh, 1995, Cortez and Abrams, 2016), where *H. oligactis* can be a more successful predator than other *Hydra* species (Kaliszewicz, 2013). This species has often been neglected in ecological research regarding trophic interactions, but has usually been a model organism for toxicology, regeneration and genetic studies (Quinn et al., 2012; Kovačević et al., 2016).

According to the previous, preliminary research of phytophilous community developed in this urban lake, *H. oligactis* has been recorded in the *Myriophyllum* periphyton and it is a eutrophic lake (Dakić et al., 2008). The objectives of this research were: (i) to determine the qualitative and quantitative composition of invertebrate community inhabiting stands of the submerged macrophyte species *M. spicatum*, with a special reference to the presence and abundance of *Hydra oligactis* and (ii) to assess the impact of environmental conditions on the qualitative and quantitative composition of phytophilous community.

MATERIALS AND METHODS

This research was conducted in Osijek, a city in the eastern part of Croatia at Gornjogradsko Lake (45°33'06.10 "N, 18°39' 57.71" E) which was formed towards the end of 1856, when excavation in clay had began, and lasted until the mid-1970s. After that period, lake formed into the shallow and narrower southern section (maximum depth was about 3 m), and the deeper northern section (the maximum depth was about 7 m). The surface area was 4 ha. A continuous pollution of this artificial lake caused its rapid degradation (southern part), which resulted in area reduction, now only 1.5 ha in its northern part.

The samples were taken in the 15 sampling occasions between 3 April and 24 July 2010 on a weekly basis, using 5 L plastic bags. Quantitative samples of macrophytes were taken at a depth of 1 m below the water surface, using a 0.5 m × 0.5 m wooden frame (Soszka, 1975; APHA, 1985). The remaining content of the bag was rinsed through sieve with a mash size of 60 μm and isolated in separate containers. After determining the number of brown hydra individuals on every plant, each stem was separately rinsed of the remaining periphyton on the sieve and examined. The total length of the branches of plants was measured as well. The fresh mass of the plant and the fresh biomass of the separated periphyton were weighted.

The qualitative and the quantitative composition of invertebrates was determined using a stereo microscope and a Carl Zeiss Jena microscope (100×), with identification keys by Streble and Krauter (1998) and Engelhardt (2003). Invertebrate abundance was calculated as a mean value of individuals recorded on 10 sampled plants, and the abundance is expressed as the number of individuals per fresh macrophyte biomass (ind. 10 g^{-1} FW). Dominance (%) and constancy (%) as population parameters were calculated according to Odum (1971).

During each sampling, the following parameters were measured in the accessible southern section of the lake: air and water temperature, water depth and transparency. At the same time, samples of water were collected for the analysis of dissolved oxygen concentration, chlorophyll *a* concentration and the amount of total nitrogen and total phosphorus, according to APHA (1985). Trophic state of Gornjogradsko Lake was determined, according to Carlson

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and Simpson (1996), based on chlorophyll *a* concentration and total phosphorus.

The Redundancy Analysis (RDA) was performed using Canoco 4.5 (Biometrics-Plant Research International, the Netherlands) to identify limnological and macrophyte parameters influencing brown hydra and other invertebrate abundance patterns. RDA analysis was selected since the initial detrended correspondence analysis (DCA) gradient length was < 3.0, which suggested a linear ordination model (Lepš and Šmilauer, 2003). Invertebrate abundance was log(x+1)-transformed to secure the normal distribution of the data. The significant subset of environmental parameters ($p < 0.05$) contributing to taxa variance was determined using the forward selection and Monte Carlo unrestricted permutation test (499 permutations).

RESULTS

During the investigation in 2010, water temperature values varied (in total 13°C) from the recorded 13.5°C at the beginning of the investigation to 26.5°C noted in the early summer. Maximum values for oxygen concentration were measured in the first phase of the research period and the general trend for this parameter was a decrease of the values towards the end of the research in the summer. The highest recorded chlorophyll *a* concentrations were recorded in the late spring, with the maximum values of 54.32 mg L^{-1}. The trophic state index values based on the concentration of chlorophyll *a* (TSI Chl) indicated a eutrophic state with a trend towards hypertrophy in the middle of the spring. Also, advanced eutrophication (hypertrophy) was indicated by trophic index based on total phosphorus concentration (TSI TP) with values over 85 during the investigated period (Table 1).

The middle of the research period was optimal for macrophyte development as the macrophyte biomass increased towards the late spring and early summer, with maximum values of 6.42 g FW recorded in June. This trend was evident for periphyton biomass as well.

Table 1. Environmental and macrophyte parameters of Gornjogradsko Lake, Osijek

PARAMETERS	MIN	MAX	**mean**	SD*
air temp (°C)	9	33.5	**22.93**	6.71
water temp (°C)	13.5	26.5	**20.40**	4.63
depth and transparency (cm)	119	140	**129.33**	5.99
dissolved oxygen (mgL^{-1})	10.4	14.7	**12.93**	1.33
oxygen saturation (%)	129	164	**146**	10
chlorophyll *a* (μgL^{-1})	17.66	54.32	**31.36**	10.67
total nitrogen (mgL^{-1})	0.19	0.44	**0.30**	0.06
total phosphorus (mgL^{-1})	0.30	0.73	**0.53**	0.12
TSI Chl *a*	58.77	69.79	**63.87**	3.34
TSI P	86.25	99.26	**94.29**	3.49
M. spicatum stem length (cm)	26.50	33.10	**28.83**	1.97
M. spicatum weight (g FW)	4.31	6.42	**5.56**	0.65
periphyton weight (g FW)	3.12	5.22	**4.04**	0.59

* SD - standard deviation

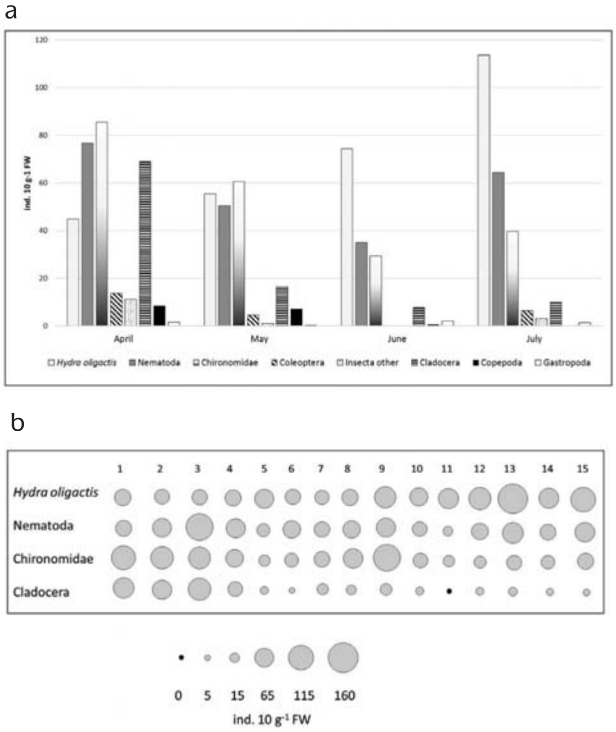

Fig 1. Mean values of macroinvertebrate abundances during the study period (a) and temporal oscillations in abundance of main groups (b) within phytophilous community in Gornjogradsko Lake (1-15 - sampling dates: 1-7 spring, 8-15 summer).

During the research period, six macroinvertebrate groups were determined in association with watermilfoil in Gornjogradsko Lake, according to the gradient of abundance: Hydrozoa (*Hydra oligactis* brown hydra), Nematoda, Insecta larvae, Cladocera, Copepoda and Gastropoda (juvenile stage). The highest abundance of invertebrates was 337 ind. 10 g^{-1} FW, and the lowest 116 ind. 10 g^{-1} FW. Abundance of the most abundant invertebrate group showed notable variation during the research period (Fig. 1).

Brown hydra individuals were the most abundant during the

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investigation period and contributed with 30% in the total fauna abundance, with an average of 68 ind. 10 g^{-1} FW. The highest density
of brown hydra (157 ind. 10 g^{-1} FW) was found in the early summer samples. Highly abundant populations also developed nematodes and chironomids with an average of 57 ind. 10 g^{-1} FW and share 25% in the total invertebrate abundance (Table 2). T Chironomidae larvae were most numerous in the late spring with recorded 132 ind. 10 g^{-1} FW, and through the studied period averaged around 57 ind. 10 g^{-1} FW. The presence of cladocerans was also significant (mean 28 ind. 10 g^{-1} FW), representing 12% of the total fauna. These four taxa were characterized as eudominant and euconstant groups during the study. Subdominant groups were Coleoptera larvae and Copepoda. Coleoptera larvae were observed in all samples and were characterized as euconstant, while other insect larvae, copepods and juvenile snails were constant in the samples (Table 2).

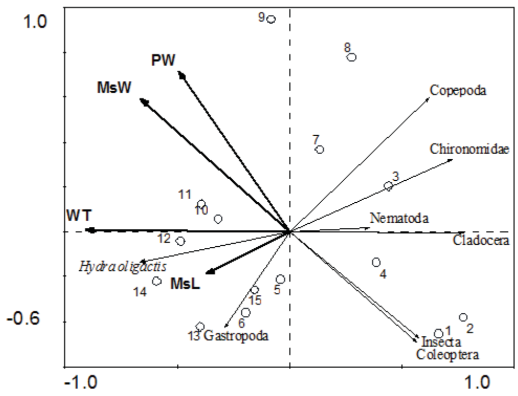

Fig 2. Relationship between environment variables and the abundance of phytophylous invertebrate taxa according to RDA analysis. WT – water temperature, MsL – *Myriophyllum spicatum* length, MsW - *Myriophyllum spicatum* weigth, PW – periphyton weight, 1-15 - sampling dates: 1-7 spring, 8-15 summer

Table 2. Qualitative and quantitative composition of invertebrate fauna in association with watermilfoil in Gornjogradsko Lake

INVERTEBRATES	MIN	MAX	**mean**	SD*	**D%**		C%	
Hydra oligactis Pallas, 1766	37	157	68	32.6	30.1	ED	100	EC
Nematoda	16	131	57	26.1	25.3	ED	100	EC
Chironomidae larvae	23	132	57	33.4	25.2	ED	100	EC
Coleoptera larvae	0	21	6.5	6.7	2.9	SD	100	EC
Insecta larvae (other)	0	23	4	6.3	1.7	R	73	C
Cladocera	0	93	27.5	28.6	12.2	ED	93.3	EC
Copepoda	0	19	5	6.7	2.1	SD	60	C
Gastropoda (juvenile)	0	4	1	1.4	0.5	SR	53.3	C
Total number of ind. 10^{-1} g fresh plant biomass	**116**	**388**	**222.5**	**81**	**100**			

SD* – standard deviation, D% - dominance, C% - constancy, ED – eudominant group, SD – subdominant group, R – recedent group, SR – subrecedent group, EC – euconstant group, C – constant group

RDA analysis indicated a significant relationship between environment variables and the abundance of phytophilous invertebrate taxa (Fig. 2). The eigenvalues for RDA axis 1 (0.388) and axis 2 (0.188) explained 61.4% of the variance in the species and the species-environment correlation of RDA (axis 1 0.828, axis 2 0.879). The forward selection of the analysis identified four significant environmental variables: water temperature, macrophyte biomass and length, and epiphyton biomass (Fig. 2). At the beginning of research, early spring was characterized with insect larvae of Chironomidae and Coleoptera. Second part of the research period, i.e. summer months, was characterized by an increase of *H. oligactis* and gastropod abundance, and positively correlated with macrophyte traits and periphyton as food resource (Fig. 2).

DISCUSSION

Recorded trophic and other environmental conditions of Gornjogradsko Lake present suitable conditions for the development of macrophyte stands and forming of a substantial epiphyton, since the water parameters such as temperature, nutrients or light availability can influence periphyton growth and composition (Kiffney and Bull, 2000; Moschini-Carlos, 2000; Vidaković et al., 2012; Stević et al., 2013). Due to the excavation in clay during seven decades, Gornjogradsko Lake revitalization was applied (Mihaljević et al., 1996a, 1996b). The lake was stocked with fish in 2006, which probably enhanced eutrofication due to bioturbation and nutrient loading. Hydrological studies conducted in 1995 indicated oscillations in the value of dissolved oxygen

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to the levels critical for the survival of living organisms (< 3 mgL^{-1}, Stevenson and Wyman, 1991), low transparency and densely developed macrophyte vegetation. The phytoplankton composition and the occurrence of water blooms indicated an eutrophication progress (Mihaljević, 1996).

Six invertebrate taxa groups (Hydrozoa, Nematoda, Gastropoda, Cladocera, Copepoda, insect larvae by Chironomidae and Coleoptera), characteristic for periphytic community in eutrophic waters, were recorded on *Myriophyllum* stems (Dvořák and Imhof, 1998; Dakić et al., 2008; Bogut et al., 2010). They displayed differences in temporal/seasonal abundance patterns, spring and summer, respectively. Dominance of Chironomidae larvae in the spring period was not unusual as they are known as successful pioneer colonizers (Čerba et al., 2012). A similar pattern was recorded for microcrustaceans. According to Peters et al. (2007), microcrustaceans are also among the first colonizers, due to their swimming abilities, often declining in abundance after spring. In this case, it could also be a consequence of a non-selective predator, increased abundance of *H. oligactis* (Schwartz et al., 1983) towards the end of the research period, i.e. in the summer. Some authors found that *Hydra* prefer smaller size prey, such as the representatives of *Bosmina* genus (Dodds and Cole, 2007) or *Cyclops* (Cuker and Mozley, 1981).

Hydra species are classified as valuable study organisms, especially as predatory invertebrates in trophic relations, studied also in matter and energy transport through various macrophyte species in the lake ecosystem which support a diverse composition and abundance of invertebrate fauna, depending on the morphology of leaves, production of allelopathic compounds and depending on whether they are submerged, floating or emerged plants (Cheruvelil et al., 2002; Mc Abendroth, 2005; Bogut et al., 2009). Representatives of *Hydra* genus appear in periphytic communities in Gornjogradsko Lake as in other shallow water bodies (Deserti et. al., 2011; Vidaković et el., 2016) in general.

Results of analysis indicated macrophyte characteristics as the main parameter influencing brown hydra abundance, as the increased size of the plants represented larger living surface for *Hydrae* as well as a potential food source, apart from some plankton species. Dakić et al. (2008) also found a significant correlation between the number of individuals of brown hydra and watermilfoil stem length, fresh macrophyte biomass and epiphyton biomass. Living and eating attached directly to the plant, it would be expected for them to be dependant and numerous on submerged macrophytes (Elliot et al., 1997; Dakić et al., 2008), whilst other invertebrates, although dependant on the substrate, are more motile, especially Cladocera and Copepoda which can easily detach and be part of the plankton community. Plants with dissected leaves, such as *Myriophyllum*, have a higher ratio of surface area and biomass and therefore provide a better shelter for representatives of invertebrate fauna than the macrophyte of simple architecture (Jackson, 1997; Cheruvelil et al., 2002; Vidaković and Bogut, 2006; Bogut et al., 2007, 2010; Čerba et al., 2009, 2010; Špoljar et al. 2011, 2012). In general, macrophyte appearance and invertebrate diversity and abundance can significantly alter the conditions within a small lake, influencing production, nutrient uptake and organic matter cycle (Scheffer, 1998).

Macrophytes with dissected leaves represent a suitable colonization substrate to predatory invertebrates as well. Although overgrowing of aquatic plants can have a negative impact on plankton and invertebrates, the presence of macrophytes is crucial for periphyton development and invertebrate abundance increase.

In conclusion, urban lakes notably increase the biodiversity and landscape heterogeneity of the local area. Small lakes, such as Gornjogradsko Lake, are vital for the social aspect of urban ecology, influencing health and the wellbeing of the people in the local community.

Sažetak

FITOFILNA FAUNA MALOG I UMJETNOG GRADSKOG JEZERA

Fitofilna zajednica na *Myriophyllum spicatum* proučavana je u malom umjetnom jezeru u gradu Osijeku (istočna Hrvatska) tijekom proljetne i ljetne sezone 2010. godine. U eutrofnim uvjetima makrofitni su bili dobro razvijeni, a na formiranom perifitonu zabilježeni su predstavnici slijedećih vrsta beskralješnjaka: Hidrozoa, Nematoda, Gastropoda, Cladocera, Copepoda, larve Insecta – uključujući i obitelji Chironomidae i Coleoptera. Pokazivali su razlike u vremenskim oblicima pojavljivanja. Zabilježili smo dvije zasebne faze u kolonizaciji makrofita s razlikama u sastavu i obilju beskralježnjaka. Larve insekata, osobito Chironomidae-a, bili su najrasprostranjeniji u prvoj fazi, tijekom proljetnog razdoblja, a *Hydra oligactis* (smeđa hidra) bila je u izobilju u drugoj fazi, tj. ljetnom razdoblju. Istodobno, obilje mikrorakušaca opadao je prema kraju ljeta. Rezultati analiza pokazali su da su temperatura vode i perifitonska biomasa bile varijable koje su imale glavni utjecaj na sastav beskralježnjaka, a zanimljivo je da su makrofitska veličina i biomasa negativno povezani s obiljem faune. S druge strane, smeđa hidra negativno je bila povezana sa svim ostalim beskralježnjačkim svojstvima, osim gastropoda. Veća površina uronjenih makrofita glavni je parametar koji pomaže povećanju obilja beskralješnjaka zbog osiguranja zaštite od grabežljivaca i rasta perifitona, važnog izvora hrane za ove fitofilne organizme. Duljina makrofita bila je pozitivno povezana s bogatstvom hidre, dok su Chironomidi bili više pod utjecajem perifitonske biomase. Ovi organizmi mogu ukazivati na kakvoću vode i potencijalno povećanje primarne i sekundarne proizvodnje.

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Ključne riječi: plitko jezero, *Myriophyllum spicatum*, perifiton, beskralježnjaci, smeđa hidra

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