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Interactions of weed-bed invertebrates and *Ceratophyllum demersum* stands in a floodplain lake

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Abstract: This investigation reports on weed-bed invertebrate abundance associated with the submersed macrophyte *Ceratophyllum demersum* L. in Lake Sakadaš within Kopački rit Nature Park (Croatia). Twenty five taxonomic groups, with the dominance of chironomids (79%), were recorded at three stations during the investigation from July 14 to September 8, 2004. Nematodes and large predatory larvae of Zygoptera with 6% were second in dominance, followed by oligochaetes with 5%. Weed-bed invertebrates on *C. demersum* were more abundant than on *Myriophyllum spicatum* L. due to different morphology of the host plants. Environmental parameters within *C. demersum* stands were found in the same range at all stations, but they changed during the season. They indicated eutrophy with the tendency to hypertrophy which is reflected by the composition of the weed-bed invertebrate community.

Key words: submerged macrophytes; weed-bed invertebrates; environmental parameters

Introduction

Submersed macrophytes provide a complex habitat and periphyton growing on stems and leaves supplies more nutritious substrate than sediments or vascular plant tissues themselves (Gressens 1995). According to Kuczyńska-Kippen & Nagengast (2006) and Kuczyńska-Kippen (2007), each particular macrophyte species has a specific spatial structure, different length, width and surface area of stem. The biomass of different aquatic plants may depend on nutrient concentration, prevailing turbidity and light condition, their species-specific ability to grow towards the water surface, and the particular growing season which directly influence macrophyte development (Pieczyńska 1988). In relatively small and shallow lakes, the littoral flora plays an important role in productivity and can regulate and dominate the metabolism of entire lake ecosystem (Wetzel 2001).

Aquatic plants in shallow waters are an important habitat for weed-bed invertebrate fauna since the invertebrates utilize macrophytes for shelter from predators and disturbance (Dvořák & Best 1982; Gregg & Rose 1985; Tessier et al. 2004), food source – plant tissue and colonized surface by periphyton (Dvořák & Best 1982; Rooke 1986; Monahan & Caffrey 1996; Zirk & Goldsborough 1996) and spawning sites (Keast 1984). Many authors (e.g., Soszka 1975; Hann 1995; Cheruvelil et al. 2002; Balci & Kennedy 2003) state that macrophytes with different architecture of leaves support different biomass, taxonomic composition as well as size structure of weed-bed invertebrate fauna. While Bogut et al. (2007b) found that higher leaf complexity provides better shelter and support for weed-bed invertebrate fauna, Cyr & Downing (1988) found no differences.

The goal of this study was to document and explain the changes in weed-bed invertebrate diversity and abundance in macrophyte stands, particularly in *Ceratophyllum demersum* colonized at peak development in July 2004. This paper provides information on community structure and abundance of weed-bed invertebrates as a function of changes of environmental parameters, such as different water parameters, and plant morphology, in Lake Sakadaš within the Kopački rit floodplain.

Study area

Lake Sakadaš (geographic location 18°48′ E, 45°36′ N, altitude 80.5 m a.s.l., surface area about 9 ha) is situated in the Kopački rit Nature Park (north-eastern part of the Republic of Croatia, called Baranja). The lake is the deepest water depression in Kopački rit with a maximum depth between 9 m and 11 m, and a mean depth of about 6 m. The Danube River hydrology directly influences the composition of flora and fauna and the state of water-bodies of the entire Kopački rit as well as Lake Sakadaš since it is an open floodplain system, with a water inflow to the lake through

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the Čonakut Channel in the east. The lake is connected to the Novi Channel in the south, and in the west there is a constant exchange of water through a dam (Fig. 1). During the years, the trophic state of Lake Sakadaš shifted from meso-eutrophy to hypertrophy (Vidaković et al. 2002; Bogut et al. 2003). In spite of its relatively small surface area, Lake Sakadaš can significantly contribute to the regional biodiversity, supporting heterogeneous communities of aquatic weed-bed invertebrates and, hence, to the ecological functioning of natural floodplain system such as Kopački rit Nature Park.

According to the monitoring data (Project – Protection of the Kopački rit water-bodies; Ministry of Science, Education and Sports), between November 1997 and June 2004, there were no macrophytes recorded in Lake Sakadaš (Vidaković & Bogut 2007). However, since 2004 different macrophyte types formed microhabitat patches. Peršić & Horvatić (unpublished data) recorded highest heterogeneity of nitrates after the overbank flooding in April and in June in 2004 with gradual decrease in nitrogen concentrations towards the edge of floodplain. This decrease in N concentrations could be explained with an uptake of nitrogen by macrophytes (Hamilton & Lewis 1987; Unrein 2002; Olde Venterink et al. 2003). Considerable amounts of nitrogen brought by the floodwaters or sediment resuspension related to the inflow of floodwaters during the inundation period, could be the cause of substantial macrophyte development.

The shoreline was colonized by emerged (mainly *Typha* sp. and *Carex* sp.), submerged (*Myriophyllum spicatum* and *Ceratophyllum demersum*) and free-floating macrophyte species [*Spirodella* sp. and *Nymphoides peltata* (S. G. Gmel.) O. Kuntze]. The amphibious species *Polygonum amphibium* All. was recorded sporadically, as well as free-floating *Lemna* sp.*, Trapa natans* L. and *Potamageton gramineus* L.. In summer 2004, large stands of *M. spicatum* and *C. demersum* at three different shallower parts of the lake were formed. These two species created adjacent but clearly separated beds with a maximum distance of half a meter. The data concerning *M. spicatum* – invertebrate and nematofauna relation were published in Čerba et al. (2009) and Vidaković & Bogut (2007).

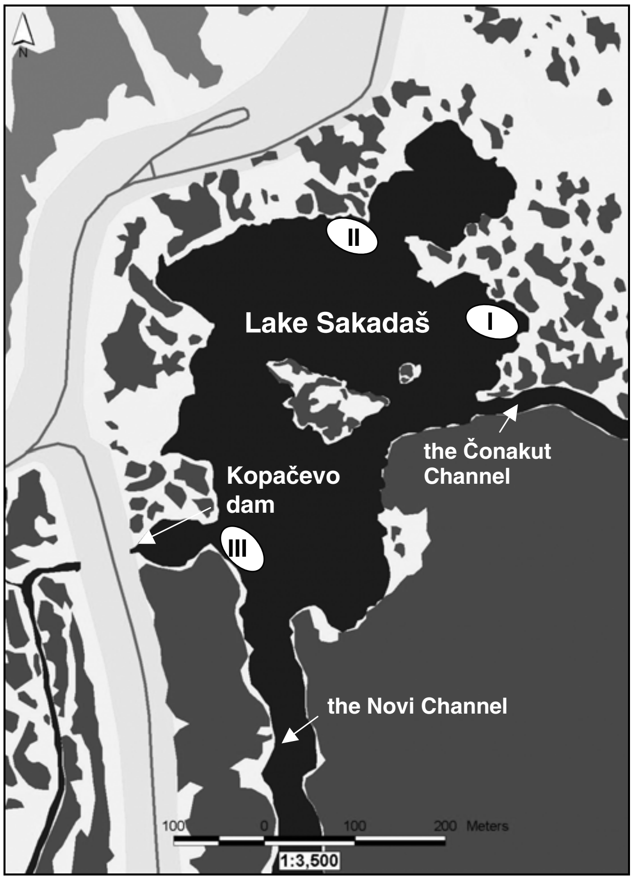

Fig. 1. Position of research stations I, II and III in Lake Sakadaš.

Material and methods

For the purpose of sampling the invertebrates associated with *C. demersum*, three stations were selected (Fig. 1):

Station I – littoral site near the mouth of the Čonakut Channel flowing into Lake Sakadaš, in the east part of the lake; the stand was constant throughout the vegetation season (July 14 | September 8, 2004);

Station II – littoral site near pier, in the north-east part of the lake; the stand was constant throughout the vegetation season (July 14 | September 8, 2004);

Station III – in front of Kopačevo dam, in the south-western part of the lake; the stand was present from August 4 till September 8, 2004.

Environmental parameters

Chemical and physical water parameters were measured weekly *in situ* within macrophyte stands: water depth and transparency, water temperature, dissolved oxygen concentration (10 cm below water surface) and O_2 – saturation (using a Multi 340i / set, Wissenschaftlich-Technische Werkstätten, WTW) total phosphorus (TP) and chlorophyll-*a*. Methods according to APHA (1985) were used for chlorophyll-*a* and TP analysis. Trophic state indices (TSI) were determined according to Carlson & Simpson (1996).

Vegetation and invertebrates

Triplicate samples of *Ceratophyllum demersum* (each replicate included a single plant) within every macrophyte stand, were taken from a boat with a plastic hand cylinder (43 cm high, covered surface area of 78.5 cm^2) in weekly intervals during July 14 – September 8, 2004. Before July 14, macrophyte stands were not sufficiently developed and were too deep under the water surface and therefore could not be sampled by means of the cylinder. After September 8, with the end of the vegetation season, the stands sank to the bottom and therefore sampling could not be carried out. In the laboratory, the invertebrates were rinsed off the plants and collected on a sieve with 60 μm mesh-size. Animals were preserved in a solution made of 585 ml 96% ethanol, 310 ml H_2O, 100 ml 4% formaldehyde and 5 ml glycerine. Macrophytes fresh biomass was determined with a weighing scale EK120i (A&D Co, Tokyo, Japan) and dry weight was determined after drying in a thermostat at 60 °C for 24 hours (Hann 1995; Cattaneo et al. 1998).

Invertebrates were identified according to keys Nilsson (1996, 1997), Streble & Krauter (2002) and Engelhardt (2003). For counting of the fauna, different magnifications of stereoscopic microscope Olympus SZX9 were used. Weed-bed invertebrate assemblages for each station and each month were quantified as abundance and were expressed as the number of individuals per 100 g of macrophyte dry weight.

Table 1. Environmental parameters measured weekly from July till September 2004 at three stations in Lake Sakadaš.

Environmental parameters	Station I	Station II	Station III	July	August	September
	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)
Water temperature (℃)	23.83 (18–29)	23.94 (16.5–29)	24 (17–31)	24.83 (23–27)	24.29 (23–25.5)	21.83 (21–22.5)
Secchi depth (m)	0.74 (0.53–1.21)	0.62 (0.23–1.17)	0.68 (0.36–1.32)	1.01 (0.7–1.32)	0.51 (0.23–0.74)	0.53 (0.38–0.63)
Depth (m)	1.44 (0.73–3)	1.19 (0.23–3.74)	1.26 (0.36–3.22)	2.31 (1.13–3.74)	0.81 (0.23–1.67)	0.74 (0.38–1.02)
Dissolved oxygen concentration (mg L^{-1})	7.78 (3.77–12.55)	8.24 (3.6–12.03)	7.59 (3.95–12.08)	4.09 (3.6–5.27)	9.49 (7.28–12.55)	9.61 (8.39–11.62)
Chlorophyll-*a* (μg L^{-1})	36.77 (14.26–57.83)	36.59 (13.05–50.45)	40.55 (8.63–56.82)	26.4 (8.63–40.32)	40.27 (24.53–50.45)	50.72 (43.04–57.83)
Total phosphorus (mg L^{-1})	0.22 (0.04–1.16)	0.11 (0.07–0.15)	0.10 (0.01–0.16)	0.13 (0.08–0.16)	0.09 (0.05–0.13)	0.27 (0.01–1.16)
Dry biomass of *C. demersum* * (g)	1.368 (0.567–2.35)	1.902 (0.63–3.317)	1.302 (0.333–1.54)	0.92 (0.567–1.587)	1.632 (0.333–3.317)	2.023 (0.83–2.65)
TSI-Chl-*a*	65.3 (56.7–70.4)	65.3 (55.8–69.1)	65.9 (51.7–70.2)	61.6 (51.7–66.9)	66.7 (61.9–69.1)	69.1 (67.5–70.4)
TSI-TP	73.79 (58.1–105.8)	70.86 (65.4–76.3)	68.25 (35.8–77.3)	73.88 (68.1–77.2)	69.24 (61.7–74.2)	70.06 (35.8–105.8)

* three replicates

Statistical analysis

To test the spatial and temporal differences in invertebrate abundance and environmental parameters we applied the non-metric multidimensional scaling (NMDS) based on Bray-Curtis similarity applied to square root transformed data, and analysis of similarity (ANOSIM test) (PRIMER-e v5.2.9 software, Clarke & Warwick 2001). Data of seven (two biotic and five abiotic) parameters: number of individuals per 100 g d.w., chlorophyll-*a* concentration, water temperature, Secchi depth, lake depth, dissolved oxygen and total phosphorous have been used for statistical analysis.

In this study, the Principal Component Analysis (PCA) was performed to identify the similarity of biotic and abiotic parameters between two stations (those that supported macrophyte stands during entire sampling period) and for revealing the relationships between samples and parameters. The lack of data for biotic parameter invertebrate abundace for the first three sampling dates at station III, due to the no epearance of the macrophyte, it was not possible to compare it with the first two stations. Before computation, the data were standardized to avoid misclassifications arising from different orders of magnitude of measured variables. The data were mean (average) centered and divided by the respecting standard deviations. The principal factor loadings were calculated without rotation. PCA and other statistical calculations were performed by the software packages STATISTICA 8.

Recently, PCA has been successfully applied in combination with other methods to model the biological and ecological process (Pairnet et al. 2004; Palijan et al. 2007). More details on these methods can be found elsewhere (Jolliffe 1986; Malinowski 1991).

Results

Environmental data

Environmental parameters are given in Table 1. No significant difference was present among the stations but ANOSIM showed statistically significant temporal differences between July and August ($R = 0.647$, $P < 0.001$), and July and September ($R = 0.739$, $P < 0.001$). Chlorophyll-*a* ($F = 19.549$), lake depth ($F = 14.995$), Secchi depth ($F = 18.744$) and concentration of oxygen ($F = 36.894$) showed significant differences between months at $P < 0.0001$ (df = 8.18; $F_{\text{crit.}} = 2.510$). Trophic state indices values ranged from 35.8 to 105.8 when based on the amount of total phosphorus (TSI-TP) and from 51.7 to 70.4 when based on the concentration of chlorophyll-*a* (TSI-Chl-*a*) indicating eutrophy and hypertrophy during the research period.

Weed-bed invertebrates

In total, 25 taxonomic units were found which belonged to the following main groups: insect larvae (Chironomidae, Ceratopogonidae, Ephemeroptera, Ephydridae, Heteroptera, Odonata (Zygoptera, Anisoptera), Plecoptera, Trichoptera, Muscidae, Dytiscidae, Notonecta, Curculionadae), Crustacea (Cladocera, Ostracoda, Copepoda including nauplii, Mysidae), Hirudinea, Oligochaeta (Naididae), Nematoda, Turbellaria, Gastropoda, Hydracarina, Hydrozoa and Aranea (*Argyroneta aquatica*). Taxonomic groups are presented in Table 2 by their abundance, those with <0.5% are compiled to "others". Chironomids had the highest abundance (79%), while Nematodes and large predatory larvae of Zygoptera made each 6%, and oligochaetes 5%. Nematodes were recorded at station III in higher percentage (18%) than at stations I and II (1.3%). In contrast, chironomid abundance decreased from 85% (stations I and II) to 63% at station III. In *C. demersum* zooplankton was represented by cladocerans (1397 ind. 100 g^{-1} d.w.) and copepodes (incl. nauplii) (562 ind. 100 g^{-1} d.w.) with a relative abundance of 3%. Clado-

Table 2. Abundance of weed-bed invertebrate fauna (number of individuals per 100 g dry weight) associated with *C. demersum* in Lake Sakadaš.

Invertebrates	Station I	Station II	Station III	July	August	September
	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)	Mean (min – max)
Diptera, Chironomidae	66400 (10861–210877)	52937 (11887–116479)	49157 (15908–133735)	72296 (11887–10877)	24178 (10861–41803)	107510 (60219–207565)
Oligochaeta, Naididae	3742 (579–20974)	2032 (142–5040)	6005 (226–14515)	1106 (265–2393)	3237 (142–14515)	7085 (2458–20974)
Odonata, Zygoptera	3117 (641–7183)	4447 (63–20732)	4916 (888–14414)	1179 (63–4795)	6305 (1121–20732)	1875 (805–3172)
Crustacea, Cladocera	1032 (184–4358)	1576 (41–7581)	1678 (216–5457)	1041 (106–4358)	357 (41–1019)	3834 (1011–7581)
Copepoda incl. nauplii	676 (30–1819)	391 (20–1111)	646 (43–1802)	603 (256–1111)	418 (20–1819)	808 (269–1526)
Nematoda	979 (36–5337)	869 (0–4818)	13963 (407–76104)	293 (0–726)	579 (61–2324)	15285 (645–76104)
Others	1303 (356–3507)	519 (211–1363)	1168 (228–2706)	1537 (357–3507)	954 (211–2706)	458 (314–682)
Number of individuals	77249 (20760–237172)	62771 (15178–134462)	77534 (19303–222129)	78654 (15178–108511)	36027 (19303–72171)	136855 (73205–237172)

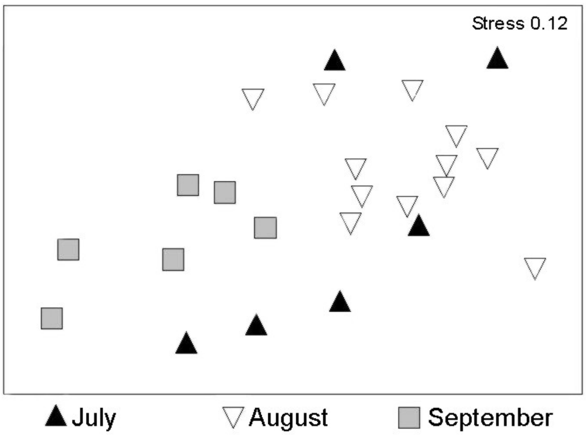

Fig. 2. Non-metric multidimensional scaling (NMDS) of invertebrate abundances, with regard to research months, during the entire research period in Lake Sakadaš.
Stress in MDS plots indicates the distortion between the similarity rankings in the ordination plot. Stress of <0.1 corresponds to a good ordination with no real prospect of misleading interpretation while as stress of < 0.2 still gives a potentaly useful 2–dimensional picture, though for values at upper end of this range too much reliance should not be placed on the detail of the plot.

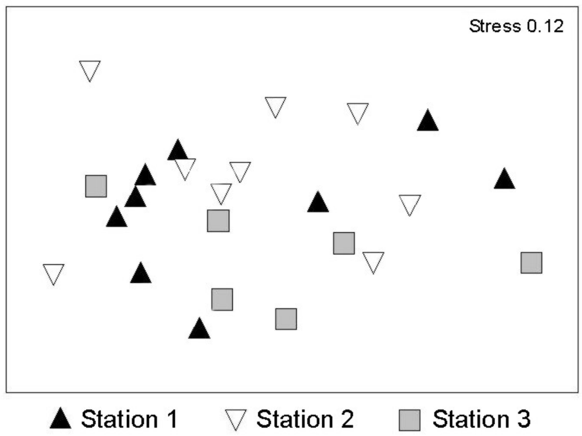

Fig. 3. Non-metric multidimensional scaling (NMDS) of invertebrate abundances, with regard to research stations, during the entire research period in Lake Sakadaš. For explanations see Fig. 1.

cerans were numerous in September with 3834 individuals per 100 g d.w. (Table 2).

Abundances of invertebrate taxa compared by ANOSIM showed differences between July and August ($R = 0.417$, $P < 0.002$), July and September ($R = 0.287$, $P < 0.02$), and August and September ($R = 0.817$, $P < 0.001$), as presented in the NMDS plot (Fig. 2). However, no statistically significant difference between all three stations was found (Fig. 3).

Principal component analysis (PCA)
Interpretation of PCA results is usually carried out by visualization of the component scores and loadings. In this study only components with eigenvalues greater than 1 are considered important (Jolliffe criterion). According to this criterion the eigenvalues of all measured data reveal two significant principal components (PC1 and PC2), which in both stations account for approximately 80% of the total variation and, hence, adequately represent the measured data.

The loading and score plots for PC1 and PC2 in station I are given in Figs. 4a and 4b, respectively. Different samples can be characterized by corresponding groups of parameters. Whereas samples J2, J3 and A1 are typical in terms of their higher values of water temperature and phosphorus concentrations, sample J1 is typical in terms of its higher values of Secchi depth, lake depth (high scores on PC1) and number of in-

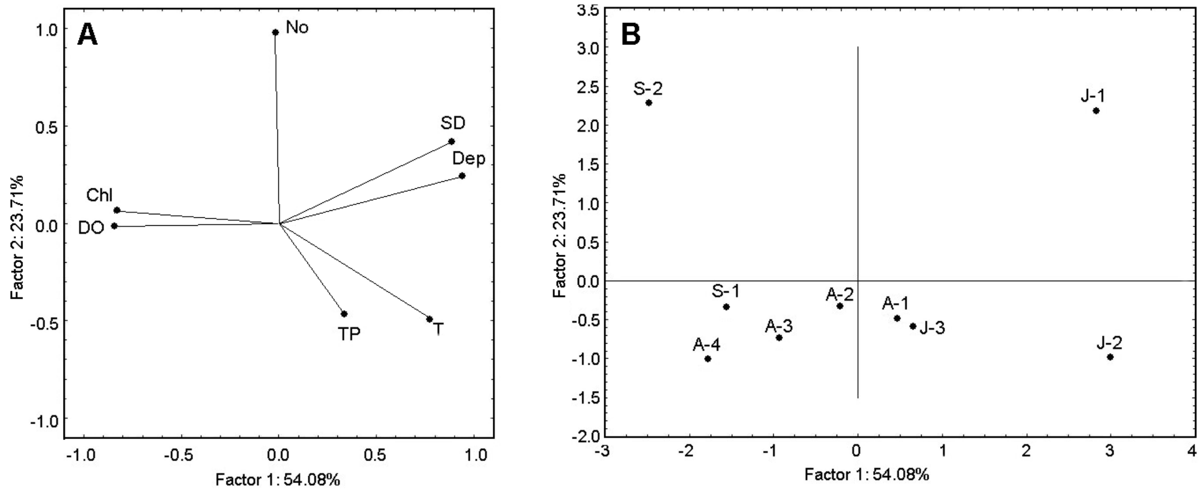

Fig. 4. Principal component analysis (PCA) for station I in Lake Sakadaš. Factor loadings L1 vs. L2 (A) and factor scores S1 vs. S2 (B). No – number of individuals per 100 g d.w., Chl – chlorophyll-*a* concentration (μg L^{-1}), T – water temperature (°C), SD – Secchi depth (m), Dep – lake depth (m), DO – dissolved oxygen (mg L^{-1}), TP – Total phosphorus (mg L^{-1}). J1 – 14 July; J2 – 21 July; J3 – 28 July; A1 – 4 August; A2 – 12 August; A3 – 18 August; A4 – 25 August; S1 – 1 September; S2 – 8 September.

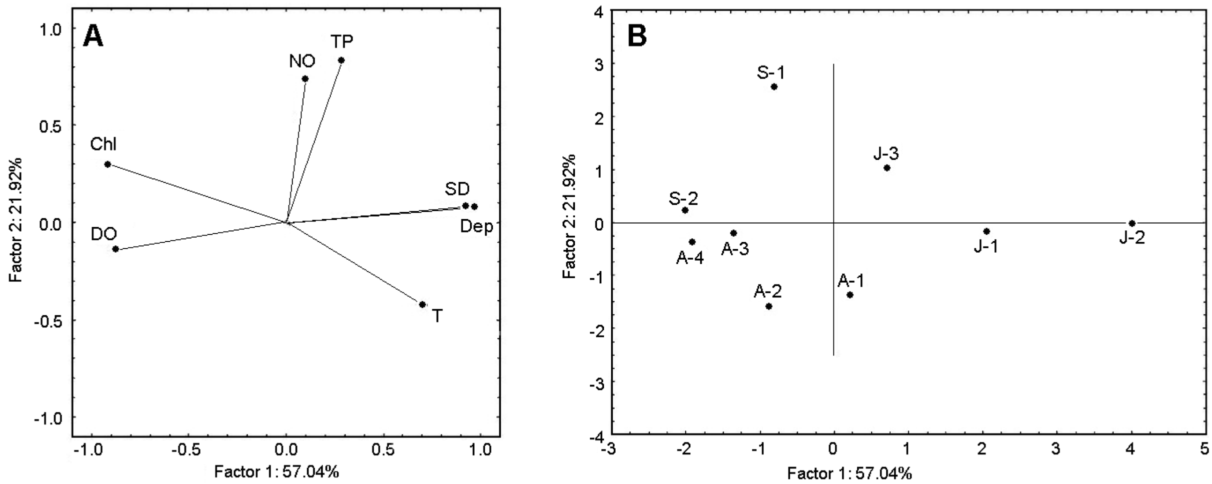

Fig. 5. Principal component analysis (PCA) for station II in Lake Sakadaš. Factor loadings L1 vs. L2 (A) and factor scores S1 vs. S2 (B). No – number of individuals per 100 g d.w., Chl – chlorophyll-*a* concentration (μg L^{-1}), T – water temperature (°C), SD – Secchi depth (m), Dep – lake depth (m), DO – dissolved oxygen (mg L^{-1}), TP – Total phosphorus (mg L^{-1}). J1 – 14 July; J2 – 21 July; J3 – 28 July; A1 – 4 August; A2 – 12 August; A3 – 18 August; A4 – 25 August; S1 – 1 September; S2 – 8 September.

vertebrates (high scores on PC2). High scores on PC2 are found for sample S2 which was additionally characterized by relatively high number of invertebrates. In general, the vector of variables (Fig. 4A) indicates the relation to respective samples (Fig. 4B). For instance, variable DO and chlorophyll-*a* are correlated, so that they must be most effective for samples A2, A3, A4, S1 and S2. Secchi depth, lake depth, water temperature and total phosphorus are negatively correlated to these samples. For station II, the situation was somewhat different (Figs 5A, B). Samples J1 and J2 were very similar; both were characterized by high lake depth and Secchi depth. Additionally, sample J3 is influenced by slightly elevated values of phosphorus concentrations and sample A1 by higher water temperature. However, dissolved oxygen and chlorophyll-*a* concentration were negatively correlated to these samples. Higher concentrations of dissolved oxygen and higher chlorophyll-*a* concentration are again typical for samples A2, A3, A4, S1 and S2. Additionally, sample S1 (high scores on PC2) is related to higher phosphorous concentrations and higher invertebrate abundance.

Discussion

Water temperature followed seasonal changes in air temperature peaking in summer. Accordingly, high temperatures and dry periods caused decreasing water depth. At the end of the vegetation season, greater macrophyte biomass was recorded as well as higher chlorophyll-*a* concentration. Increased primary production induced high concentrations of dissolved oxygen.

According to Johnson et al. (2003), it is difficult to distinguish between the effects of habitat complexity and habitat area – they often co-vary in the field. In our study, PCA was performed to get an overall impression about assembling the samples in multidimensional space defined by the biotic and abiotic variables. The dominant pattern suggests that the samples collected in July and beginning of August are separated from those collected in middle August and September. The weed-bed invertebrates collected in the first period are mostly influenced by high values of Secchi depth, lake depth and temperature, whereas the fauna collected in the second period was greatly influenced by concentration of dissolved oxygen and chlorophyll-*a*. This indicates that at the beginning of the season growth of periphytic communities was stimulated mostly by light availability, lower growth rates of phytoplankton, available nutrients and suitable lake depth. As the season continued and the communitiy formed, available food for the periphytic invertebrates became more important. Parameters that influence diversity, abundance and community composition, besides macrophyte traits, are water quality, water-level and water-flow (Gregg & Rose 1985; Timms 1981; Strayer et al. 2003). Timms (1981) found correlation between invertebrate abundance, community composition and water-depth within three lakes.

Environmental data, including trophic state indices, as well as weed-bed invertebrate community composition were indicative for the eutrophic state, with a tendency to hypertrophy at all stations in Lake Sakadaš. This coincides with earlier research in waterbodies of Kopački rit (Vidaković et al. 2002). Pieczynska et al. (1999) state that Chironomidae abundance is more related to the trophy than to community composition and colonization. Lower values of Chironomidae densities were noted in lakes with low trophic status. Densities of Chironomidae were greatest in highly-eutrophic Lake Mikołajskie where they constituted more than 95% of all macroinvertebrates. According to Lindegaard (in Nilsson 1997), one of the main reasons for the high abundance of Chironomidae is that they exhibit all types of feeding behavior and food preference. Prejs et al. (1997) propose that predators such as Odonata and Heteroptera can regulate the density of chironomids larvae better than fish.

The majority of taxa recorded in association with *Ceratophyllum demersum* are fairly widespread and characteristic of eutrophic waters (Van der Berg 1999; Mackie 2001). When compared with previous research of the weed-bed fauna in Kopački rit, conducted in 2001 and 2002, some similarities can be found, since Čonakut Channel is slowly flowing and rather stagnant during low water-level in summer (Bogut et al. 2007b). Results for weed-bed invertebrate communities with *C. demersum* in that channel showed an eudominance of chironomids and oligochaetes as well as a dominance of insect larvae, cladocerans and nematodes at all investigation stations. The water level of Lake Sakadaš (depth at the stations) was directly dependent on the water levels of the Danube and the Drava rivers. The water from these rivers flows into Kopački rit floodplain and can rise the water level up to 3 m.

As a consequence of the strong eudominance (79%) of one group (Chironomidae), diversity was rather low at all stations and during all sampling dates. Chironomid larvae could profit from plenty food available as periphyton on *C. demersum*. Vermaat (2005) states that any submerged surface will rapidly be covered by a thin layer of bacteria (biofilm) and, if sufficient light is available, algae will subsequently attach and form the major structure of the developing periphyton. Chironomids associated with *C. demersum* had statistically higher abundance (at $P < 0.03$) than those recorded for *Myriophyllum spicatum* during the same research period in Lake Sakadaš (Čerba et al. 2009). Also, *C. demersum* supported higher invertebrate abundance ($P < 0.06$). Allthough *M. spicatum* and *C. demersum* do not differ much in their morphology, some differences have been found. *M. spicatum* has long stalks and most of its leaves are clustered near the surface, while *C. demersum* has denser dissected leaves organized along the entire length of the plant, thus, creating more surface for periphytic organisms (Fig. 6). Also, according to Kuczyńska-Kippen (2007), an important factor influencing habitat selectivity is the refuge effectiveness of macrophytes, which is higher in structurally more complex plants. A combination of various predators occurs in natural environments and their effectiveness in prey-capture depends on the increase of plant complexity (Van de Meutter et al. 2005). McAbendroth et al. (2005) state that a great number of small-bodied invertebrates was present in more complex macrophyte stands. Dense macrophytes serve as poor refuges for cladocerans (daphnids) because macoinvertebrates density, including odonates, often increases with increasing macrophyte density (Cattaneo et al. 1998). Mastrantuono & Mancinelli (2005) found in macrophyte communities qualitative dominance of chironomids, among few other groups, although quantitatively, microcrustaceans were dominant, indicating a good environmental status. Meiofauna is generally not considered phytophilous fauna according to Tessier et al. (2004), but it is found in the water column around marophytes and has an important role in the food web (Linhart et al. 1998). Macrophyte species *C. demersum* formed denser stands than *M. spicatum* in Lake Sakadaš. According to Sandilands & Hann (1996), denser stands of macrophytes harboured large numbers of invertebrates. Both macrophyte species, *C. demersum* and *M. spicatum*, are presently known to produce anti-algal compounds (allelochemicals or allelopathins, chemical inhibitors in the plant tissue) which may limit grazing by invertebrates (Papas 2007). Unfortunately, the composition of algal communities on the macrophyte species that we studied has not been investigated.

Most of the weed-bed invertebrates recorded during this research belonged to the feeding (trophic) classes of predators (Prus et al. 2002): Odonata representatives, Ceratopogonidae, Heteroptera, Plecoptera, Muscidae, Dytiscidae, Notonecta, Turbellaria, Hirudinea and Aranea. Plant-detritus feeders are Oligochaeta, Nematoda, Ephydridae and Trichoptera larvae and Gastropoda juveniles. Ephemeroptera can be predators or detritovores and Curculionida are plant eaters. Crustaceans and Bivalvia juveniles belonged to filter feeders. Odonata, sit-and-wait predators accord-

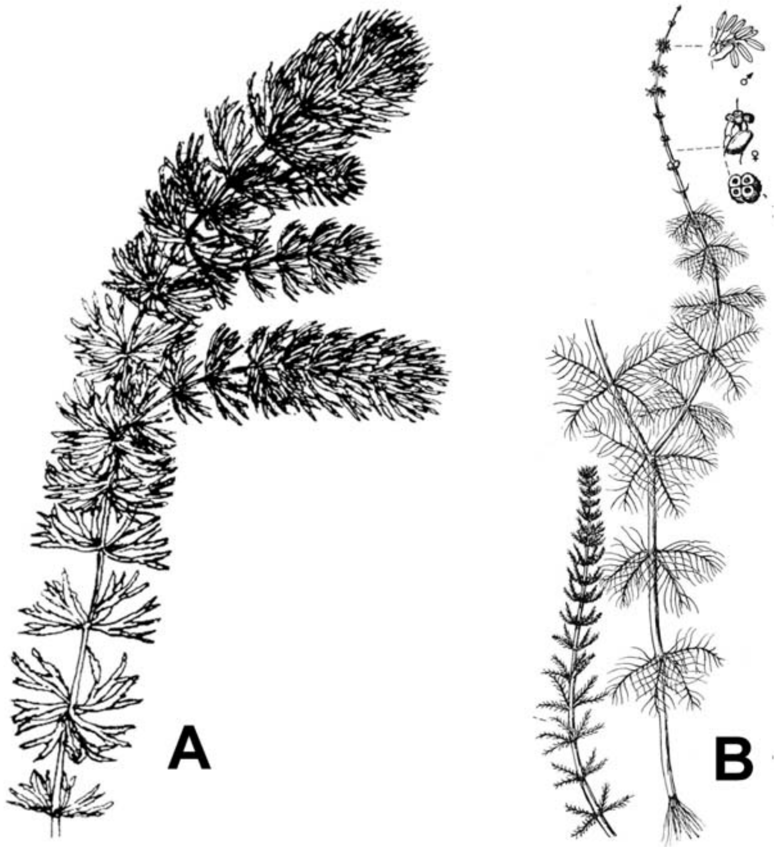

Fig. 6. Investigated macrophytes hosting weed-bed invertebrates in Lake Sakadaš. A – *Ceratophyllum demersum* L., B – *Myriophyllum spicatum* L. The different morphology influences periphyton growth and invertebrate colonization.

ing to Hann (1995), use the plant as a source of food by means of predation on invertebrates that find food and seek shelter, and at the same time avoid their own predators (Lombardo 1997; Prejs et al. 1997; Rennie & Jackson 2005).

So far, *Dreissena polymorpha* (Pallas, 1771) was the only Ponto-Caspian species recorded in Kopački rit (unpublished project report). During this research another neozoan, four specimens of *Limnomysis benedeni* Czerniavsky, 1882 (Crustacea: Mysidacea), were found in association with *C. demersum*, the first record of this species in Croatian inland waters; the influence of this species on Kopački rit ecosystem has not yet been perceived and remains unknown (Bogut et al. 2007a). We have not recorded an increase of their population but the survey continues. In contrast, a high number of *D. polymorpha* has been recorded during our research of periphyton communities on artificial substrates in Lake Sakadaš. Based on the currently available literature, Ponto-Caspian invaders have spread throughout the European water-bodies. These species can have a great ecological and economic influence on the native fauna and, therefore, it is of great importance to monitor their occurrence (Bij de Vaate 2003).

In conclusion, it is important to recognize the role that macrophyte stands play in supporting invertebrates as they indicate the trophic conditions in a lake and are an important habitat for a diverse invertebrate fauna. The present study implies that trophic state, water depth, nutrients, chlorophyll-*a* and the presence of macrophytes play a major role in floodplain ecosystems. The examined environmental indices mainly affected weed-bed invertebrate composition and abundance.

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