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Periphyton nematode assemblages in association with *Myriophyllum spicatum* L. in Lake Sakadaš, Croatia

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Summary. This survey reports on periphyton nematode assemblages associated with the submersed macrophyte *Myriophyllum spicatum* L. sampled in Lake Sakadaš (Croatia) at three stations. Nematode abundance and species diversity were examined during one vegetation season (July – September 2004). The measured environmental parameters within macrophyte stands were in the same range at all stations, but changed from the beginning to the end of the season. A significantly lower nematode abundance was recorded for stations I and II compared to station III. A low number of nematode species (maximum of twelve per station) was recorded, with no differences in diversity between stations. The variation in abiotic and biotic parameters allowed us to subdivide the period of investigation as the beginning of nematode colonization (July samples), stabilization (August samples) and stagnation (September samples). Statistically significant differences in chlorophyll A, dissolved oxygen concentration, depth and fresh macrophyte biomass occurred between all three months. Non-metric MDS based on square root transformed nematode abundance data separate the July and August nematode assemblages from the September assemblage. Nematode abundance increased from the beginning to the end of the vegetation season, coupled with a decrease in species number. Epistrate feeders as primary consumers dominated in nematode assemblages in all samples, increasing from July to September, followed by 'chewers' (predators and omnivores) as tertiary consumers. Environmental parameters affect the life span of *Myriophyllum spicatum* L., and could have both direct and indirect effects on nematode abundance and species diversity.

Key words: colonization, nematofauna, *Myriophyllum spicatum*, periphyton.

Periphyton on submerged macrophytes is a complex habitat. According to Gressens (1995), it provides more nutritious substrates than sediments or vascular plant tissues and, consequently, it is an important energy source for both detritus and grazing food chains. Factors that control qualitative composition of periphyton and population abundances of associated fauna include the duration of flooding, life span of macrophytes and trophic conditions (Dvořák & Imhof, 1998). According to Death (1995), habitat variability influences the presence and relative abundances of species and has a strong effect in structuring communities. A wide range of invertebrate fauna is associated with periphyton, including nematodes. Previous studies revealed significant differences in nematode abundance, species composition and distribution of functional feeding groups among different types of substrate and lakes with different trophic status for periphyton development (Pieczyńska, 1960, 1961; Pieczyńska & Spondiewska, 1963; Croll & Zullini, 1972; Prejs & Wiktorzak, 1976; Prejs, 1987; Prejs & Prejs, 1992; Peters & Traunspurger, 2005). Macrophytes with dense epiphytic cover are important for the structuring of nematode assemblages (Pieczyńska, 1960; Pieczyńska & Spondiewska, 1963; Jensen, 1984; Linhart *et al.*, 1998).

The purpose of this investigation was to point out the effects of habitat stability on nematode abundances and species composition, and their functional role in the periphyton found on the submerged aquatic macrophyte *Myriophyllum spicatum* L. (Eurasian water milfoil).

MATERIAL AND METHODS

Studied area. The study was carried out at three stations (I, II, III) in Lake Sakadaš (Kopački rit Nature Park), a floodplain in the north-east of

Fig. 1. A: Map of Lake Sakadaš in the Kopački rit Nature Park, Croatia. Roman numbers (I, II and III) indicate the sampling stations in lake; black colour indicates water surface, dark gray – forest and groves, and white – reeds. B: Submerged macrophyte species *Myriophyllum spicatum* L. with fine dissected leaves. Drawing according to Jávorka & Csapody (1991).

Croatia at the confluence of the Rivers Drava and Danube (Mihaljević *et al.*, 1999). Lake Sakadaš is the deepest water depression in the area with an average water depth of 7 m, oval in shape and with relatively steep shore slopes. The total surface area of the lake is estimated at up to 6 ha (Mikuska, pers. com.). Water level fluctuation of Lake Sakadaš is determined by fluctuation of the Danube and, to a lesser extent, by fluctuation of the Drava, as well as by the amount of precipitation and changes of the groundwater level. Long-term investigations established that Lake Sakadaš has shifted from meso- to hypereutrophic conditions (Bogut *et al.*, 2003). In the lake, high concentrations of nutritionally rich organic matter were recorded, and hypoxic/anoxic conditions occur during summer and early autumn months (Vidaković *et al.*, 2001, 2005). According to the granulometric analysis, the eulittoral zone and the deepest central part of Lake Sakadaš are characterized as sandy sediment sites (Bogut & Vidaković, 2002; Vidaković & Bogut, 2004).

In June 2004, different macrophyte stands were established for the first time since 1997 (*Ceratophyllum demersum*, *Myriophyllum spicatum*, *Trapa natans*, *Spirodela polyrrhiza*, *Potamogeton* spp., *Lemna* sp., *Nuphar luteum*, *Polygonum amphibium*, *Nymphoides peltata*). Three stations (Fig. 1A) with *Myriophyllum spicatum* and *Ceratophyllum demersum* were chosen for studies of associated fauna.

Sampling strategy. Macrophytes (*Myriophyllum spicatum* L., Fig. 1B) and periphytic invertebrates were collected by boat on plastic cylinders 43 cm

high and 10 cm diameter, covering an area of 78.5 cm^2. Triplicate samples (each sample including a single plant) within each macrophyte stand were taken on a weekly basis from 14th July to 8th September 2004. Before the middle of July the stands were not sufficiently developed and were too deep under the water surface for sampling by means of the cylinder. After the middle of September, with the end of the vegetation season, the stands had sunk towards the bottom and, therefore, sampling could not be carried out. Macrophyte species were identified according to Jávorka & Csapody (1991), and fresh biomass was determined with a weighing scale EK120i (A&D Co, Tokyo, Japan). Dry weight was determined after the macrophytes were placed in a thermostatically controlled oven and dried at 60°C for 24 hours (Hann, 1995; Cattaneo *et al.*, 1998).

Physical and chemical measurements. Within macrophyte stands water depth (cm), transparency or Secchi depth (cm), water temperature, and dissolved oxygen concentration (mg O_2l^{-1}) were measured *in situ* with a Multi 340i/set, Wissenschaftlich-Technische Werkstätten (WTW). Water was sampled weekly for chlorophyll A concentration (μgl^{-1}), and total phosphorus content (mgl^{-1}) (Murphy & Riley, 1962; Scheiner, 1976; APHA, 1985).

Nematode measurements. In the laboratory, samples were put into a plastic tray with tap water. Remaining material and fauna were sieved through a 63 μm mesh screen, transferred to plastic bottles and preserved in a solution of 585 ml 96% ethanol, 310 ml H_2O, 100 ml 4% formaldehyde and 5 ml glycerine with Rose Bengal. Nematodes were counted and isolated under a stereoscopic microscope (x 100). In samples with low nematode abundances (less than 100 individuals) all individuals were separated, while in samples with higher nematode abundances 100 individuals were randomly picked out. Permanent slides for qualitative analysis of nematodes were prepared according to Seinhorst (1959). Nematodes were identified to species or genus level under the microscope Carl Zeiss, Jena (oil immersion, x 1000). Nematodes were classified according to Traunspurger (1997) into feeding groups.

Statistical analysis. Non-metric multi-dimensional scaling (MDS) was applied to the square root transformed environmental parameters data in order to detect differences present between surveyed stations and during three months (Clarke & Warwick, 2001).

Nematode assemblages for each station and each month were quantified as abundance (expressed as the number of individuals per 100 g of macrophyte dry weight) and the following diversity measures: species richness, evenness and diversity (Shannon's H', Margalef's d, Pielou's J). Nematofauna composition was determined based on 100 randomly picked individuals per sample. One-way ANOVA followed by Tukey HSD ($p < 0.05$) was used to compare nematode abundance between three different stations and months. All data were $\log_{10}(x+1)$ transformed prior to the variance analysis in order to achieve normality and homogeneity of variance. To test differences in nematode abundance, non-metric MDS (Bray-Curtis similarity measure was applied to square root transformed data) and the ANOSIM test ($p < 0.05$) (Clarke & Warwick, 2001). Where ANOSIM detected significant differences between groups, the SIMPER routine in PRIMER (version 5.2.9. software) was performed to determine the relative contribution of each nematode species to those differences. The graphical distributional method k-dominance curves were conducted to reveal the differences in nematode diversity using the same software. The coefficient of variation (CV = standard deviation/mean) was used to quantify the overall variability of the invertebrate habitat (Kaenel *et al.*, 1998).

RESULTS

Environmental parameters. Results of the measured environmental parameters (depth, chlorophyll A concentration, dissolved oxygen concentration and total phosphorus) as well as macrophyte fresh and dry biomass were similar within each stand (Table 1), albeit with high values of CV (Table 2). There were no statistically significant differences between stands in the measured parameters.

Comparison of environmental parameters for the July, August and September samples revealed some differences between the beginning of the vegetation season and the end of the season (Table 1). Water depth was significantly higher in July compared with August and September, while the concentration of dissolved oxygen was significantly lower in the July samples compared with August and September samples (Table 1.). The highest chlorophyll A concentration was recorded for September samples compared with the July and August samples, and macrophyte fresh biomass was also significantly higher at the end of the season (September samples) compared with July and August biomass. Coefficient of variations for environmental parameters and macrophyte biomass were lowest for September samples (Table 2) except for T-P (CV = 125%). The overall trend

was a decrease in variations within macrophyte stands from the beginning to the end of the vegetation season.

Nematode abundance and species composition. At stations I and II, a very low nematode abundance was recorded (number of individuals = 587 ± 761 per 100 g d.w. and 694 ± 366 per 100 g d.w., respectively) with only five to ten nematode species of which the 'chewer', *Eutobrilus notus*, was dominant. At station III, the nematode mean number was 12086 ± 9972 per 100 g d.w. and twelve nematode species were recorded with the epistrate feeder, *Chromadorina bioculata*, as the dominant species (Table 3). There were no significant differences in nematode abundance and species number between stations I and II. However, significant differences existed between station III and the other two stations in nematode abundance, but not in species diversity (Table 3). *Chromadorina bioculata* was recorded in associations with *Myriophyllum spicatum* at all stations but with different abundances. This species abundance was significantly higher at station III compared with stations I and II (Table 3). *Eutobrilus notus* was also recorded for all stations but differences in abundance were not statistically significant. *Ethmolaimus* sp. was recorded only at stations II and III with highest abundances at station III ($p < 0.001$).

MDS of square root transformed data of nematode abundances, differentiated nematodes associated with *M. spicatum* at station III (Fig. 2). ANOSIM detected significant differences between groups (stations I, II and III) with $R = 0.623$, $p < 0.05$. SIMPER indicated that one species, *Chromadorina bioculata*, accounted for 28% of the overall average dissimilarity (36.5%) in nematode assemblages between stations I and II. Two species, *Eutobrilus notus* and *Chromadorina bioculata*, accounted for 51.0% of the overall average dissimilarity (52.9%) in nematode assemblages between stations I and III. Between stations II and III the same species accounted for 53.0% of the overall average dissimilarity (54.9%).

Nematode abundances recorded for September samples were significantly higher in relation to July samples (Table 3), but in the same range between August samples. Six species were recorded in all sampling months but with different abundances (*Chromadorina bioculata*, *C. viridis*, *Eutobrilus notus*, *Eumonhystera dispar*, *Ethmolaimus* sp. and *E. filiformis vulgaris* group). *Prochromadorella* sp. and *Plectus* sp. were recorded only in one sample in July (Table 4). *Mesodorylaimus* sp. and *Brevitobrilus stefanskii* were recorded only in August and September samples. *Monhystera* sp. and *Dorylaimus helveticus* were recorded only in September samples. According to k-dominance curves, the lowest species diversity was significant for September samples (Fig. 3) in relation to July and August diversity. NMDS calculated on square root transformed data discriminate September samples from July and August samples (Fig. 4). ANOSIM detected significant differences between groups (July and August, July and September) with $R=0.592$, $p \geq 0.05$. By comparing nematode assemblages among months, SIMPER indicated that two species, *Chromadorina bioculata* and *Eutobrilus notus*, accounted for 42.0% of the overall average dissimilarity (43.4%) between July and August samples. Between July and September, and between August and September, only one species, *Eutobrilus notus*, accounted for 34% and 32%, respectively, of the overall average dissimilarity (54% and 39.1%, respectively). In both cases, greater abundance of these species was recorded during the vegetation season. The abundances of *Chromadorina bioculata* and *C. viridis* were different between investigated months (Table 3).

Table 1A. Water parameters and *Myriophyllum spicatum* biomass from three stations.

Water parameters	Mean ± SD (range)		
	I	II	III
Depth (cm)	144 ± 83.5 (73-300)	119 ± 112.8 (23-374)	126 ± 95.1 (36-322)
Chl. A (μgl^{-1})	36.7 ± 13.3 (14.2-57.8)	36.5 ± 11.3 (13-50)	40.5 ± 14.4 (8.6-56.8)
Dissolved oxygen (mg $O_2 l^{-1}$)	7.7 ± 3.1 (3.8-12.6)	8.2 ± 2.9 (3.6-12)	7.5 ± 2.9 (3.9-12.1)
T-P (mgl^{-1})	0.2 ± 0.3 (0.04-1.2)	0.1 ± 0.02 (0.07-0.2)	0.1 ± 0.04 (0.009-0.2)
Fresh biomass (gm^{-2})	3.9 ± 1.29 (1.4-6.4)	5.1 ± 2.0 (2.7-9.4)	6.3 ± 4.4 (2.3-26.1)
Dry biomass (gm^{-2})	0.6 ± 0.3 (0.2-1.3)	1.0 ± 0.4 (0.4-2.2)	0.9 ± 0.4 (0.3-2.6)

Table 1B. The range of water parameters and *Myriophyllum spicatum* biomass at three stations in July, August and September (B) in Lake Sakadaš.

	Mean ± SD (range)					
Water parameters	**July**	**August**	**September**	**J vs. A**	**J vs. S**	**A vs. S**
Depth (cm)	231 ± 91 (113-374)	89 ± 54 (36-167)	67± 2 (65-68)	$p < 0.002$ $t = 3.953$, $df = 13$	$p < 0.001$ $t = 5.439$, $df = 8$	–
Chl. A (μgl^{-1})	26.4 ± 11.7 (8.6-40.3)	37.9 ± 8.7 (24.5-48.8)	55.3 ± 2.2 (53.7-56.8)	–	$p < 0.001$ $t = 6.872$, $df = 9$	$p < 0.002$ $t = 4.780$, $df = 7$
Dissolved oxygen (mg $O_2 l^{-1}$)	4.1 ± 0.5 (3.6-5.2)	9.3 ± 1.7 (7.3-12.1)	8.7 ± 0.4 (8.3-8.9)	$p < 0.001$ $t = 7.688$, $df = 7$	$p < 0.01$ $t = 13.254$, $df = 2$	–
T-P (mgl^{-1})	0.1 ± 0.02 (0.1-0.1)	0.1 ± 0.01 (0.1-0.1)	0.1 ± 0.1 (0.1-0.2)	–	–	–
Fresh biomass (gm^{-2})	4.6 ± 1.3 (2.3-7.5)	4.8 ± 2.2 (1.4-9.4)	6.7 ± 1.3 (5.2-8.2)	–	$p < 0.01$ $t = 3.651$, $df = 8$	$p < 0.02$ $t = 2.708$, $df = 14$
Dry biomass (gm^{-2})	0.8 ± 0.3 (0.2-1.5)	0.9 ± 0.5 (0.2-2.2)	1.1 ± 0.2 (0.8-1.4)	–	–	–

Table 2. Coefficient of variations for environmental parameters for three stations and three investigated months (CV = SD/Mean x 100).

Environmental parameters	**I**	**II**	**III**	**July**	**August**	**September**
Depth (cm)	58	95	58	39	61	3
Chlor. A (μgl^{-1})	36	31	38	45	23	4
Dissolved oxygen (mg $O_2 l^{-1}$)	40	36	39	13	19	5
T-P (mg l^{-1})	161	27	44	18	15	125
Fresh biomass (gm^{-2})	33	39	70	28	45	1
Dry biomass (gm^{-2})	54	48	45	44	45	21

Table 3. Qualitative and quantitative (ind. 100 g^{-1} d.w.) nematofauna composition associated with macrophyte species *Myriophyllum spicatum*. Three replicates weekly per station (I, II, III).

Nematode species	**I**	**II**	**III**	**July**	**August**	**September**
Chromadorina bioculata	145	116	4082	545	2468	7861
Eutobrilus notus	303	322	459	228	679	76
Eumonhystera dispar	29	10	19	19	20	14
Chromadorina viridis	10	10	585	91	476	601
Mesodorylaimus sp.	27	37	17	26	30	–
Prochromadorella sp.	–	18	–	10	–	–
Ethmolaimus sp.	–	29	377	29	312	548
Diplogaster sp.	–	5	7	–	12	–
Eumonhystera filiformis vulgaris group	–	5	20	12	4	46
Mononchus sp.	–	10	–	–	7	–
Plectus sp.	–	–	7	7	–	–
Brevitobrilus stefanskii	–	–	44	12	42	–
Monhystera sp.	–	–	10	–	10	11
Dorylaimus helveticus	–	–	15	–	15	14
Number of species **S**	5	10	12	10	12	8
Number of individuals **N**	514	562	5642	979	4075	9171
Margalef's **d**	0.64	1.42	1.27	1.30	1.32	0.76
Pielou's **J'**	0.66	0.60	0.39	0.58	0.49	0.27
Shannon's **H'** (log e)	1.06	1.38	0.99	1.35	1.23	0.57
Significant differences						
between all stations in nematode abundance	$F = 17.458$	$F_{crit.} = 3.682$	$df = 2,15$	$p < 0.001$	–	–
July vs. September in nematode abundance	$F = 9.978$	$F_{crit.} = 3.682$	$df = 2,15$	$p < 0.001$	–	–
between all stations in *C. bioculata* abundance	$F = 14.612$	$F_{crit.} = 3.402$	$df = 2,24$	$p < 0.0001$	–	–
between all months in *C. bioculata* abundance	$F = 10.762$	$F_{crit.} = 4.102$	$df = 2,10$	$p = 0.003$	–	–
between all months in *C. viridis* abundance	$F = 10.946$	$F_{crit.} = 4.102$	$df = 2,10$	$p = 0.003$	–	–

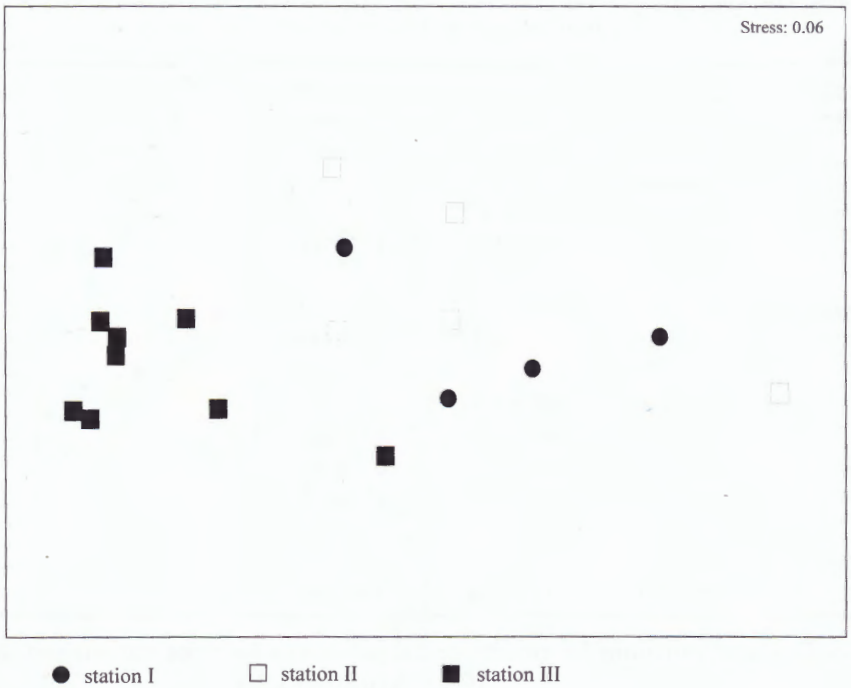

Fig. 2. Ordination plot from NMDS discriminates nematodes associated with *Myriophyllum spicatum* at station III in Lake Sakadaš.

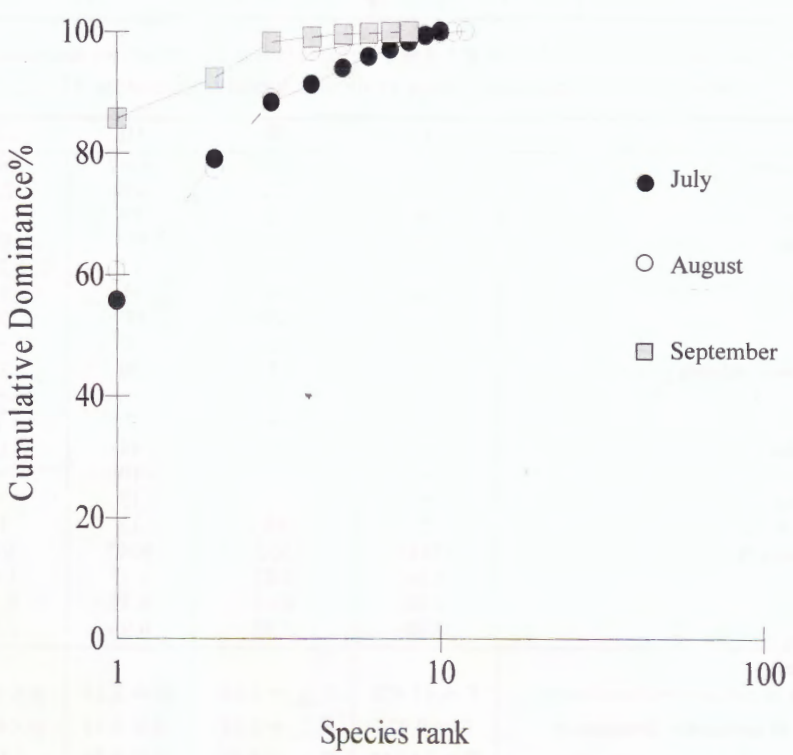

Fig. 3. k-dominance curve for nematode abundance: three months of investigation.

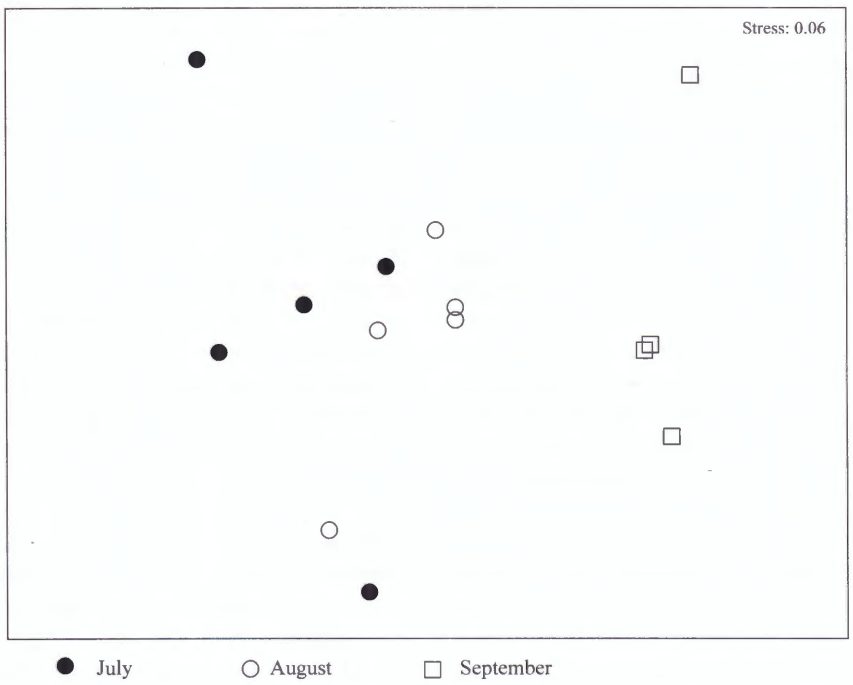

Fig. 4. Ordination plot from NMDS discriminates September nematode samples from July and August samples.

Table 4. Nematode feeding groups relative abundance according to Traunspurger (1997), recorded for *Myriophyllum spicatum* associated nematofauna at three stations and three months in Lake Sakadaš.

Feeding groups	I	II	III	July	August	September
Epistrate feeders	30	31	89	69	80	98
Detritus feeders	6	3	1	4	1	0.8
'Chewers'	59	60	9	25	18	0.8
Suction feeders	5	6	1	2	1	0.4

Nematode individuals were classified into four feeding groups and at stations I and II 'chewers' (CH) were dominant followed by epistrate feeders (EF). At station III, epistrate feeders were dominant (Table 4). Comparing the relative abundance of feeding groups among months, the dominance of epistrate feeders was evident, with their increase from July to September (Table 4).

DISCUSSION

Macrophytes are recognized as being very important in the structuring of meiofauna, including nematodes, in the littoral zone of lakes and shallow channels because they are continuously subject to colonisation by various inhabitants of the periphyton. Introduced in 1928 by Behning, the term periphyton is defined as the heterogeneus and complex microcommunity developing on natural as well as artificial submerged substrates (Wetzel, 1983). According to Peters (2005), because periphyton is both a resource and a habitat for meiofauna, factors that change the periphyton biomass indirectly influence meiofauna. The present knowledge on periphytic meiofauna is still limited, including nematodes as an important part.

This paper gives a basic information on nematofauna community structure and abundance in periphyton on macrophytes as a function of changes of environmental parameters in the Lake Sakadaš within the Kopački rit floodplain. The goal of this study was to document the changes in nematofauna diversity and abundance in macrophyte stands as a result of the colonisation on *M. spicatum* when the stands of this macrophyte species developed in the littoral zone of the Lake Sakadaš in July 2004. The above-ground parts of this submersed species are composed of a long branched stem bearing many small leaves – a suitable substrate for epiphyton developing (Balci & Kennedy, 2003).

In *M. spicatum* stands at three stations in the Lake Sakadaš, nematodes represented between 10

and 28% of total phytophilous invertebrates. Nematodes associated with *M. spicatum* had greater abundance than those recorded for three different macrophyte species in the Čonakut Channel – 587 to 12086 ind. per 100 g dry weight of macrophytes versus 174.4 in association with *C. demersum* and 555.9 ind. per 100 g d.w. in *Carex* sp. stands (Vidaković & Bogut, 2006).

A total of 14 nematode species was recorded in association with *M. spicatum*, while in the previous studies on sediment nematodes in the eulittoral zone of the same lake, a total of 45 species was found (Bogut & Vidaković, 2002), and in the central part 23 nematode species were identified (Vidaković & Bogut, 2004). Only five species were found in both *M. spicatum* stands and the central part sediment (*Mesodorylaimus* sp., *Diplogaster* sp., *E. filiformis vulgaris*, *B. stefanskii* and *Monhystera* sp.) and eight species with the eulittoral sediment (*Chromadorina bioculata, Chromadorina viridis*, *Mesodorylaimus* sp., *Ethmolaimus* sp., *Mononchus* sp., *Plectus* sp., *E. filiformis vulgaris* and *B. stefanskii*). Four nematode species: *Eutobrilus notus*, *Eumonhystera dispar*, *Prochromadorella* sp. and *Dorylaimus helveticus* were found only in *M. spicatum* stands, without occurring in the sediments of Lake Sakadaš.

The first research on nematofauna in macrophyte stands (*Polygonum amphibium, Carex* sp. and *Ceratophyllum demersum*) in the Kopački rit began in 2001 in the slow-flowing Čonakut and abundance at stations throughout period of study, from the beginning of the vegetation season in July to the end of vegetation season in September. Throughout the present study, it was evident that environmental parameters affect the life span of *M. spicatum*, which had a direct influence on the periphyton development and, consequently, affected nematode abundance and species diversity. According to Cattaneo *et al.* (1998), plant architecture clearly affects the quantity of epiphyton, and this especially applies to submerged plants: the submerged stems and leaves trap detritus that could enrich the epiphyton. *Myriophyllum spicatum* with thin and finely dissected leaves provides a suitable surface for periphytic colonization.

The nematodes' diet varies – from periphyton (as a mixture of epiphytic algae, bacteria, protozoa and detritus according to Moss, 1998) to other invertebrates. In July, 'chewers' dominated in association with *M. spicatum*, but toward September epistrate feeders (feeding mainly on algae) outnumbered 'chewers' and became the dominant feeding group. Meiofauna studies in Channel, which connects the Lake Sakadaš with other water-bodies within the floodplain. Nineteen nematode species were recorded in the macrophyte stands in the Čonkaut Channel during two vegetation seasons (2001 and 2002): 10 species in association with amphibian species *Polygonum amphibium*, with undissected oval leaves, 16 species in association with *Carex* spp., emerged species, which has narrow undissected leaves and which was under the water surface during the investigated period, and 12 with submerged species with fine dissected leaves – *Ceratophyllum demersum* (Vidaković & Bogut, 2006). Five nematode species: *C. bioculata, C. viridis, B. stefanskii, E. notus* and *Ethmolaimus* sp. were common species for *M. spicatum* in the Lake Sakadaš and all three macrophyte species from the Čonakut Channel. Although having more similar leaf and stem morphology, *M. spicatum* and *C. demersum* had only seven species in common, while the nine common species were recorded in asociation with *Carex* sp.

Higher concentration of dissolved oxygen, as well as higher concentration of chlorophyll A, and greather macrophyte biomass were recorded at the end of the vegetation season. According to Therriault & Kolasa (2000), communities (or assemblages) are not static, they change in species composition and abundances both in space and in time – from date to date. *M. spicatum* nematode assemblage has changed in species composition littoral periphyton communities in two field experiments conducted in the Lake Erken, Sweden, showed a conspicious dominance of nematodes, dominated by epistrate feeding species (Peters & Hillebrand, 2003). 'Chewers' represented the dominant feeding group in association with three macrophyte species in the Čonakut Channel, followed by epistrate feeders (Vidaković & Bogut, 2006). Also, 'chewers' were the major feeding group of nematofauna at the eulittoral sandy sediment sites of the Lake Sakadaš – they comprised between 54 and 70% of total nematofauna (Bogut & Vidaković, 2002). According to the same authors, epistrate feeders had the lowest abundance (< 2%) in the sediment. Moens *et al.* (2006), in a detailed overview of trends in the relative abundance of nematode feeding types in sediments of different freshwater habitats, considered that absolute dominance was by deposit feeders (62.4-86.1%), which feed mainly on bacteria. Other feeding groups were represented with considerably lower relative abundances. The difference in distribution of feeding types in sediments and on macrophytes is

due to the qualitative and quantitative composition of available food. According to Vermaat (2005), any submerged surface will rapidly be covered by a thin layer of bacteria and, if sufficient light is available, algae will subsequently attach and form the major structure of the developing periphyton. Dominance of epistrate feeders towards the end of the vegetation season was expected as a result of a large amount of periphyton present on *M. spicatum* stems and leaves.

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REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION (APHA) 1985. *Standard methods for examination of water and wastewater.* 16th edition. Washington, DC, 1268 pp.

BALCI, P. & KENNEDY, J. J. 2003. Comparison of Chironomids and other macroinvertebrates associated with *Myriophyllum spicatum* and *Heteranthera dubia. Journal of Freshwater Ecology* 18(2): 235-247.

BOGUT, I. & VIDAKOVIĆ, J. 2002. Nematode feeding-types at the eulittoral of Lake Sakadaš (Kopački rit Nature Park, Croatia). *Natura Croatica* 11: 321-340.

BOGUT, I., VIDAKOVIĆ, J. & PALIJAN, G. 2003. Stupanj trofije i kvaliteta voda Kopačkog rita tijekom 2002. godine. In: *3. hrvatska konferencija o vodama. Hrvatske vode u 21. stoljeću. Zbornik radova* (Gere, D. Ed.). pp. 173-180. Zagreb, Hrvatska, Hrvatske vode. [In Croatian].

CATTANEO, A., GALANTI, G., GENTINETTA, S. & ROMO, S. 1998. Epiphytic algae and macroinvertebrates on submerged and floating-leaved macrophytes in an Italian lake. *Freshwater Biology* 39: 725-740.

CLARKE, K. R. & WARWICK, R. M. 2001. *Change in marine communities: an approach to statistical analysis and interpretation.* 2nd edition. Plymouth, UK, Plymouth Marine Laboratory, Primer-E Ltd. 144 pp.

CROLL, N. A. & ZULLINI, A. 1972. Observations on the bionomics of the freshwater nematode *Chromadorina bioculata. Journal of Nematology* 4: 256–260.

DEATH, R. G. 1995. Spatial patterns in benthic community structure: products of habitat stability or are they habitat specific? *Freshwater Biology* 33: 455-467.

DVOŘÁK, J. & IMHOF, G. 1998. The role of animals and animal communities in wetlands. In: *The production ecology of wetlands* (Westlake, D. F., Květ, J. & A. Szczepański. Eds.) pp. 211-318. Cambridge, UK, Cambridge University Press.

GRESSENS, S. E. 1995. Grazer density, competition and respose of the periphyton community. *Oikos* 73: 336-346.

HANN, B. J. 1995. Invertebrate associations with sumbersed aquatic plants in a praire wetland. *UFS (Delta Marsh) Annual Report* 30: 78-84.

JÁVORKA, S. & CSAPODY, V. 1991. *Iconographia Floral Partis Austro-Orientalis Europae Centralis.* Budapest, Akademia Kiady. 567 pp.

JENSEN, P. 1984. Ecology of benthic and epiphytic nematodes in brackish waters. *Hydrobiologia* 108: 201-217.

KAENEL, B. R., MATTHAEI, C. D., UEHLINGER, U. 1998. Disturbance by aquatic plant management in streams: effects on benthic invertebrates. *Regulated Rivers: Research and Management* 14: 341-356.

LINHART, J., UVHRA, V., RULÍK, M. & RULHKOVÁ, K. 1998. A study of the composition of phytomacrofauna in *Batrachium aquatile* vegetation. *Acta Universitatis Palacki. Olomucensis, Facultas Rerum naturalium, Biologica* 36: 39-60.

MIHALJEVIĆ M. , GETZ, D., TADIĆ, Z., ŽIVANOVIĆ, B., GUCUNSKI, D., TOPIĆ, J., KALINOVIĆ, I. & MIKUSKA, J. 1999. *Kopački rit. Pregled istraživanja i bibliografija.* Zagreb-Osijek, HAZU, Zavod za znanstveni rad Osijek. 188 pp. [In Croatian].

MOENS, T., BERGTOLD, M. & TRAUNSPURGER, W. 2006. Feeding ecology of free-living benthic nematodes. In: *Freshwater nematodes: ecology and taxonomy* (Eyualem-Abebe, W. Traunspurger & I. Andrássy. Eds.). pp. 105-131. UK, Wallingford. CAB International. CABI Publishing.

MOSS, B. 1998. *Ecology of fresh water. Man and medium, past to future.* 3rd edition. UK, Blackwell Science Ltd. 557 pp.

MURPHY, J. & RILEY, J. 1962. A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27: 31-36.

PETERS, L. 2005. *Periphyton as a Habitat for Meiofauna – a case of a neglected community.* Dissertation, Germany, University of Konstanz. 135 pp.

PETERS, L. & HILLEBRAND, H. 2003. Spatio-temporal variability of grazing in periphyton communities. In: *Do Meiofauna Matter? Contibutions to Aquatic Ecosystem Biodiversity, Structure, and Function I.* The NABS Annual meeting, Athens, Georgia. On-line: http://www.benthos.org/meeting/nabs2003/ display-session.cfm/id/12

PETERS, L. & TRAUNSPURGER, W. 2005. Species distribution of free-living nematodes and other meiofauna in littoral periphyton communities of lakes. *Nematology* 7(2): 267-280.

PIECZYŃSKA, E. 1960. Prelimiary studies on the effect of environmental changes on nematode fauna in the periphyton. *Bulletin de L' Académie Polonaise des Sciences* 8: 19-22.

PIECZYŃSKA, E. 1961. Investigation of the scope of groupings of periphyton Nematoda and the factors regulating their occurrance. *Ekologia Polska* 18: 299-315.

PIECZYŃSKA, E. & SPONDIEWSKA, I. 1963. Occurrence and colonization of periphyton organisms in accordance with the type of substrate. *Ekologia Polska* 22: 533-545.

PREJS, A. 1987. Risk of predation and feeding rate in tropical freshwater fishes: field evidence. *Oecologia (Berlin)* 72: 259-262.

PREJS, K. & WIKTORZAK, M. 1976. The fauna of the root region of macrophytes. In: *Selected Problems of Lake Littoral Ecology* (Pieczyńska, E. Ed.) pp .145-153. Warsaw University.

PREJS, K. & PREJS, A. 1992. Importance of predation in regulating density of meio-and macrofauna in seasonal tropical waters. *Hydrobiologia* 242: 77-86.

SCHEINER, D. 1976. Determination of ammonia and Kjeldahl nitrogen by indophenol method. *Water Resources* 10: 31-36.

SEINHORST, W. 1959. A rapid method for the transfer of nematodes from fixative to anhydrous glyzerin. *Nematologica* 4: 67-69.

THERRIAULT, T. W. & KOLASA, J. 2000. Patterns of commuinty variability depend on habitat variability and habitat generalists in natural aquatic microcosms. *Community Ecology* 1(2): 195-203.

TRAUNSPURGER, W. 1997. Bathymetric, seasonal and vertical distribution of feeding-types of nematodes in an oligotrophic lake. *Vie et Milieu* 47: 1-7.

VERMAAT, J. E. 2005. Periphyton Dynamics and Influencing Factors. In: *Periphyton ecology, exploitation and management* (M. E. Azim, M. C. J. Verdegem, A. A. van Dam & M. C. M. Beveridge. Eds.). pp. 35-50. UK, Wallingford. CAB International. CABI Publishing.

VIDAKOVIĆ, J., BOGUT, I. & ŽIVANOVIĆ, B. 2001. Factor(s) influencing meiofauna and nematodes of the submerged eulittoral zone of Lake Sakadaš (Nature Reserve Kopački rit, Croatia). *Acta Zoologica Academiae Scientiarum Hungaricae* 47(4): 269-284.

VIDAKOVIĆ, J. & BOGUT, I. 2004. Aquatic nematodes of Sakadaš lake (Kopački rit Nature Park, Croatia). *Biologia* 59(5): 567-575.

VIDAKOVIĆ, J., BOGUT, I., PALIJAN, G., ČERBA, D. & ZAHIROVIĆ, Ž. 2005. Trophic indicators and the state of waterbodies within Kopački rit Nature Park (Croatia) in 2003 and 2004. *Abstracts of Fourth Symposium for European Freshwater Sciences.* Krakow, Poland. 154 p.

VIDAKOVIĆ, J. & BOGUT, I. 2006. Aquatic macrophytes as a habitat for free-living nematodes. *Nematology* 8(5): 691-701.

WETZEL, R. G. 1983. *Limnology.* 2nd edition. Philadelphia, Saunders College Publishing, 860 pp.

Vidaković, J., Bogut, I. Нематоды перифитона ассоциированные с *Myriophyllum spicatum* L. в оз. Сакадаш, Хорватия.

Резюме. На трех станциях наблюдения на озере Сакадаш (Хорватия) исследованы группы видов нематод, ассоциированные с перифитоном погруженного макрофита *Myriophyllum spicatum* L. Обилие и разнообразие нематод исследовали на протяжении одного вегетационного сезона (с июля по сентябрь 2004). Существенные показатели среды в пределах зарослей макрофитов оказались одинаковыми для всех трех станций, однако менялись от начала к концу сезона. Значительно более низкая численность нематод была отмечена для станций I и II, по сравнению со станцией III. Число выявленных видов нематод было незначительным (максимум 12 видов на станцию) при отсутствии различий в разнообразии между станциями. Вариации в биотических и абиотических факторах позволили разделить период исследований на начало колонизации (пробы июля), период стабилизации (пробы августа) и период климакса (пробы сентября). Статистически достоверные различия в уровне хлорофилла А, концентрации растворенного кислорода, глубине и состоянию биомассы макрофитов были отмечены между тремя месяцами наблюдений. Определение различий методом MDS-анализа показало отличие в обилии нематод между пробами июля и августа, с одной стороны, и пробами, собранными в сентябре. С конца вегетационного периода наблюдали повышение общей численности нематод, что совпадало со понижением числа видов. Нематоды, питающиеся с поверхности растений, были основными первичными консументами и доминировали во всех пробах, увеличиваясь в числе с июля по сентябрь. Хищные и всеядные нематоды оказывались второй по численности группой.