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COMPOSITION AND STRUCTURE OF BENTHIC MACROINVERTEBRATE COMMUNITIES IN THE MEDITERRANEAN KARST RIVER THE CETINA AND ITS TRIBUTARY THE RUDA, CROATIA

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Vučković, I., Božak, I., Ivković, M., Jelenčić, M., Kerovec, M., Popijač, A., Previšić, A., Širac, S., Zrinski I., Kučinić, M.: Communities in the Mediterranean karst River the Cetina and its tributary the Ruda, Croatia. Nat. Croat., Vol. 18, No. 1., 49–82, 2009, Zagreb.

Benthic invertebrate communities of the Cetina River and the upper reach of the Ruda River were sampled monthly at 11 sites from August 2004 to August 2005. The sampling sites were located along the longitudinal gradient of the Cetina and in the upper reach of the Cetina's largest tributary, the Ruda River. Throughout the study, a total of 310225 animals were collected in 366 samples. In the upper and middle reaches the most numerous taxa were Amphipoda and Gastropoda, while the most numerous taxon in the lower reaches was Gastropoda. The highest and the lowest population density of benthic invertebrates were recorded at the sites Preočki Most in June 2005 (22728 individuals/m^2) and Radmanove Mlinice in November 2004 (90 individuals/m^2), respecti-

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vely. At sites Trilj I and Trilj II, the most numerous taxa were Oligochaeta and Chironomidae, indicators of watercourses with higher organic loads. The composition of benthic invertebrate communities at sites along the entire course of Cetina does not reflect the situation expected under natural conditions due to flow regulation and construction of hydroelectric power plants and reservoirs.

Key words: physico-chemical parameters, macroinvertebrate community structure, Mediterranean karst river, regulated river

Vučković, I., Božak, I., Ivković, M., Jelenčić, M., Kerovec, M., Popijač, A., Previšić, A., Širac, S., Zrinski I., Kučinić, M.: Sastav i struktura zajednica makrozoobentosa mediteranske krške rijeke Cetine i njene pritoke Rude. Nat. Croat., Vol. 18, No. 1., 49–82, 2009, Zagreb.

Istraživanje bentičkih beskralježnjaka rijeke Cetine i izvorišnog dijela toka rijeke Rude provedeno je u razdoblju od kolovoza 2004. do kolovoza 2005. godine. Cilj istraživanja bio je utvrditi sastav i strukturu bentičkih beskralježnjaka duž toka rijeke Cetine i izvorišnog dijela rijeke Rude. U razdoblju od 13 mjeseci u 366 uzoraka ukupno je prikupljeno 310225 jedinki bentičkih beskralježnjaka. Najbrojnije su bile skupine Amphipoda i Gastropoda, i to u gornjem i srednjem dijelu toka, dok je u donjem dijelu toka najbrojnija skupina bila Gastropoda. Udio predstavnika čistih voda iz skupina Plecoptera, Ephemeroptera i Trichoptera smanjivao se od izvora prema ušću. Najveća gustoća bentičkih beskralježnjaka bila je na gornjem dijelu toka, na postaji Preočki most u lipnju 2005. godine (22728 jedinki/m^2), a najmanja na postaji na donjem dijelu toka, Radmanovim mlinicama, u studenom 2004. godine (90 jedinki/m^2).

Na postajama Trilj I i Trilj II najzastupljenije su bile skupine Oligochaeta i Chironomidae koje su karakteristične za organski opterećenije vodotoke. Uzrok tome je vjerojatno neriješena odvodnja otpadnih i komunalnih voda grada Trilja i okolnih područja. Sastav zajednica makrozoobentosa na postajama duž cijelog toka rijeke Cetine ne odražava situaciju koju bismo očekivali u prirodnim uvjetima, zbog regulacije samog toka i izgradnje hidroelektrana i akumulacija.

Ključne riječi: fizikalno-kemijski parametri, sastav bentičkih beskralježnjaka, mediteranska krška rijeka, regulirana rijeka

INTRODUCTION

Physical (e.g. structure of the substrate, temperature, light, water flow velocity, depth) and chemical properties (e.g. alkalinity, dissolved oxygen, pH value) of surface waters affect the composition and structure of invertebrate community inhabiting the riverbed, commonly known under the term macrozoobenthos.

Stream and river communities also show high spatial and temporal variation in their structure and taxonomic composition over a different scale (BOYERO & BOSCH, 2002; BOYERO, 2003). The spatial density (density at particular sampling sites), species richness, taxonomic and functional composition of benthic invertebrates often show seasonal changes, reactions to torrents (MILLER & GOLLADAY, 1996) or leaf litter availability (ABELHO & GRACA, 1998). Aquatic invertebrates are present in the lentic and lotic parts of the watercourse, with different adaptations to water temperature (ŽIVIĆ *et al.*, 2006), pollution load (VIĐINSKIENË, 2005), water flow velocity and structure of the substrate (STATZNER *et al.*, 1998).

Since benthic organisms largely participate in the trophic relations, changes in their abundance and biomass considerably influence the quality of surface waters. Some benthic invertebrates are good indicators of organic water pollution, for in-

stance, Oligochaeta and Syphiidae (Diptera) larvae. In general, high population density of above mentioned groups indicates high organic pollution (VIÐINSKIENË, 2005).

However, the density and diversity of benthic organisms are influenced not only by organic pollution; there are other pressures, such as regulation of running water, habitat alteration etc. The Cetina River is regulated; there are five hydroelectric power plants in the river basin (HPP Peruča, HPP Đale, HPP Kraljevac, HPP Zakučac and HPP Orlovac) and three reservoirs (Peruča, Đale and Prančevići). Overall, there are few studies dealing with the dynamics of benthic invertebrates in regulated rivers; for instance WARD & STANFORD (1979) and later CRAIG & KEMPER (1987) studied the ecology of regulated streams and rivers.

Croatia has a large number of regulated rivers, but there are few studies that address the issue.

In the last few years a new approach to the study of different aspects of aquatic organisms has been applied in Croatia, mainly focusing on faunistics, ecology, taxonomy and distribution of freshwater taxa (Boca *et al*., 2006; BUJ *et al*., 2008a; 2008b, DELIĆ *et al*., 2003, HABDIJA *et al*., 2002, 2004; IVKOVIĆ *et al*., 2007; IVKOVIĆ & HORVAT, 2007a, 2007b; KLOBUČAR *et al*., 2006 a, 2006 b, KUČINIĆ *et al*., 2008; LAJTNER *et al*., 2004; MAGUIRE *et al*., 2002, 2003, 2004; MALICKY *et al*., 2007; MATONIČKIN *et al*., 2001; MERDIĆ *et al*., 2005; MIČETIĆ *et al*., 2008; MIHALJEVIĆ *et al*., 2004; MILIŠA *et al*., 2006; MRAKOVČIĆ *et al*., 2000; MUSTAFIĆ *et al*., 2003, 2008; PEROVIĆ *et al*., 2006; PREVIŠIĆ *et al*. 2007a; 2007b; SCHNEIDER *et al*., 2000; SKET *et al*., 2001; STANKOVIĆ & TERNJEJ, 2007; ŠPOLJAR *et al*., 2005; TEMUNOVIĆ *et al*., 2007; TERNJEJ & STANKOVIĆ, 2007).

Studies focusing on the faunistics of invertebrates of the Cetina and Ruda rivers began during 2004 and have resulted in some important new data regarding the diversity and distribution of Empididae (Diptera) (IVKOVIĆ & HORVAT, 2007; IVKOVIĆ *et al.* 2007), Neuroptera (RAUSCH & WEIßMAIR 2007) and taxonomy of caddisflies (Trichoptera) (GRAF *et al.* 2008; WARINGER *et al.* in press). However, the majority of animal taxa are still understudied.

The aim of this study was to investigate the composition and structure of macroinvertebrate communities along the Cetina River and its tributary the Ruda. Since macroinvertebrate communities in permanent Mediterranean rivers are generally poorly investigated, our study represents an important contribution to the knowledge of their composition and structure.

RESEARCH AREA

The Mediterranean part of Croatia is characterized by numerous water flows, of which, in terms of fauna and ecology, the most significant are the Krka, Zrmanja and Cetina rivers, with their smaller tributaries. This study was conducted in the area of the Cetina River, the longest Mediterranean river in Croatia, and its largest tributary the Ruda (Fig. 1). The length of the Cetina River is 106 km; its spring is located 50 km from the coast, and its mouth into the Adriatic Sea is located in the town of Omiš.

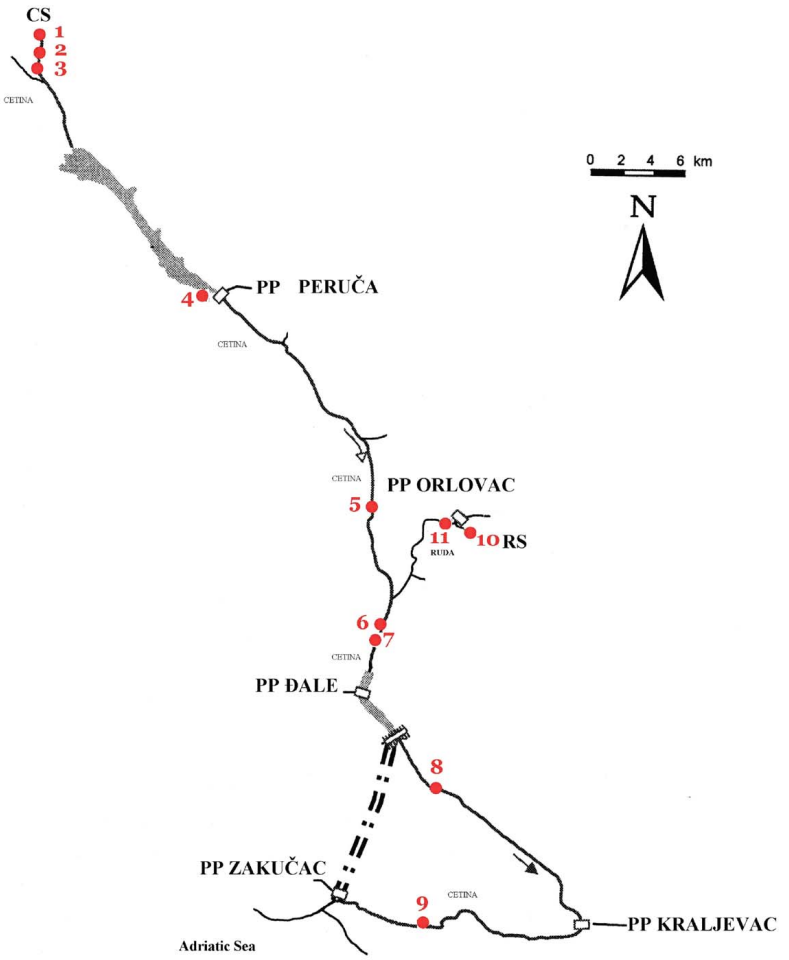

Fig. 1. Map of research area showing location of sampling sites on the Cetina and Ruda rivers. Names and corresponding numerals of the sites are listed in Tab. 1.

MATERIAL AND METHODS

Physico-chemical parameters were measured and macrozoobenthos was sampled monthly, from 25 August 2004, to 27 August 2005, at 9 sites along the Cetina River and two additional sites at its tributary the Ruda River (Tab. 1, Fig. 1). The study encompassed a sampling site at one of the springs of the Cetina River (No. 1), two sites in the upper reach (Nos. 2 and 3), a site in the reservoir (No. 4), three sites in the middle reach (Nos. 5, 6 and 7) and two sites in the lower reach of the Cetina (Nos. 8 and 9). Additionally, the spring and upper reach of the Ruda River were sampled (Nos. 10 and 11).

Tab. 1. List of sampling sites at the Cetina and Ruda rivers, showing geographic position and dominant substrate type for each site.

Sampling site	GPS position	Elevation	Dominant substrate
1. Cetina Spring (Glavaš)	N 43° 58' 36.1'' E 16° 25' 48.6''	386 m	gravel and sand, submersed vegetation
2. Preočki most	N 43° 57' 59'' E 16° 25' 53''	371 m	sand
3. Crveni most	N 43° 57' 35.7'' E 16° 25' 46.6''	367 m	gravel, sand
4. Peruča reservior	N 43° 51' 02.7'' E 16° 37' 24.3''	350 m	sand
5. Obrovac Sinjski	N 43° 40' 01.4'' E 16° 41' 04.7''	301 m	cobbles of 5–10 cm, boulders covered in green algae
6. Trilj I	N 43° 36' 49.8'' E 16° 43' 49.2''	297 m	sand, silt
7. Trilj II	N 43° 36' 21.1'' E 16° 43' 46.2''	296 m	sand, silt
8. Čikotina Lađa	N 43° 31' 58.4'' E 16° 44' 42.3''	236 m	pebbles, pebbles covered in moss
9. Radmanove Mlinice	N 43° 26' 16.2'' E 16° 45' 11.3''	15 m	pebbles , moss
10. Ruda Spring	N 43° 40' 07.1'' E 16° 47' 56''	320 m	boulders, pebbles , moss
11. Ruda II	N 43° 40' 07.5'' E 16° 47' 49.2''	308 m	pebbles , boulders

The following physico-chemical parameters of water were measured in the field:

pH value (with the *WTW ph 330* pH-meter); concentration of dissolved oxygen and water temperature (with the *WTW Oxi 330/SET* oximeter); electrical conductivity (with the *WTW LF 330* conductivity meter) and alkalinity (by titration with 0.1 M HCl).

Macrozoobenthos samples were collected using a Surber sampler of an area of 0.1 m^2, mesh size 500 μm. Only at the sites Trilj I and Trilj II and at the Peruča Reservoir wasa a drag sample of 0.5 m taken using a 20 cm wide triangular dredge (»*kratzer* net«, also of an area of 0.1 m^2, mesh size 500 μm). Macroinvertebrate samples covered all habitat types, e.g. springs, upper, middle and lower reaches and HPP reservoirs. At each site three or four different microhabitats were sampled (such as cobbles, fine sand, fine pebbles, algae covering the cobbles, moss or submersed vegetation), with the exception of sites at the Peruča reservoir, Trilj I and Trilj II, where samples were taken from one habitat due to the homogeneity of the substrate.

Altogether 366 macroinvertebrate samples were collected.

Collected material was conserved in 80% ethanol and sorting and identification of the fauna were carried out in the laboratory. Macroinvertebrates were identified to the level of class or order, with the exception of Diptera and Arachnida, where identification was performed to the level of the family for the larval Chironomidae and Hydrachnidae (NILSSON, 1996; GHETTI, 1992; SCHMEDTJE & KOCHMAN, 1992), respectively.

The number of individuals (population density) was calculated on a surface of 1 m^2, and all data were entered into the tables using Microsoft Excel 2003.

Physico-chemical parameters were analysed using StatSoft Statistica 7.

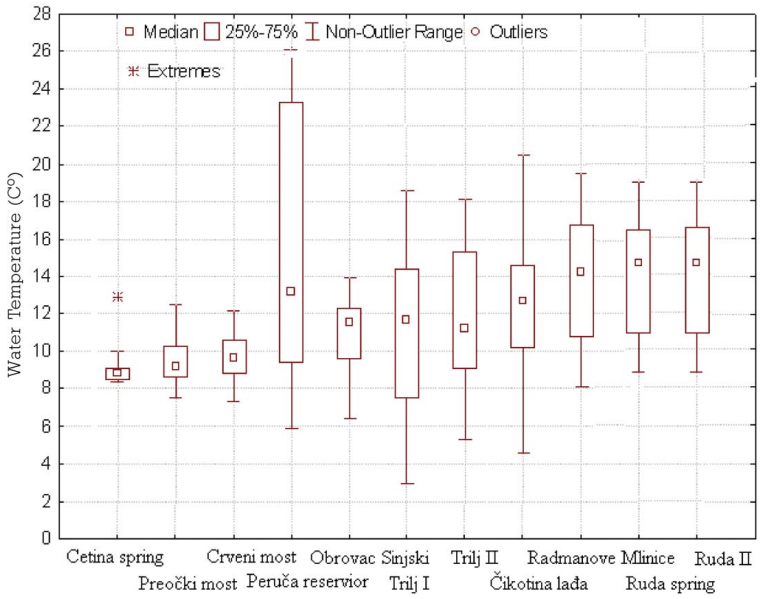

Fig. 2. Water temperature (C°) recorded monthly from August 2004 to August 2005 at 11 sampling sites at Cetina and Ruda rivers.

RESULTS

Physico-chemical parameters

During the study, water temperature ranged from 4.6 °C to 26.3 °C (Fig. 2). The lowest mean value of 9.2 °C was measured at the highest site, the Cetina Spring in the upper reach, and the highest mean value of 14 °C was measured at the lowest site, Radmanove Mlinice, in the lower reach of the Cetina River.

The concentration of dissolved oxygen was used to measure the level of organic production. At all sampling sites, concentration of dissolved oxygen did not vary significantly, thus there is no significant difference in oxygen concentration between the spring and the estuary (Fig. 3). Oxygen concentration ranged from 10.40 to 15.52 mg/l at sites in the upper reach. In no month did oxygen saturation fall below 90% (Fig. 4). Sites in the middle reach of the Cetina River did not show a significantly lower oxygen concentration than the sites in the upper reach. At sites in the middle reach, values ranged from 8.5 to 14.74 mg/l. The highest value, of 14.74 mg/l, was recorded at the site Obrovac Sinjski in April. Similarly, sites in the lower reach of the Cetina River did not show a significant difference of oxygen concentration compared to the middle reach, except for one month (August), when the oxygen concentration was 8.80 mg/l at Čikotina Lađa, while the mean values for Čikotina Lađa and Radmanove Mlinice were 11.39 mg/l and 11.27 mg/l, respectively.

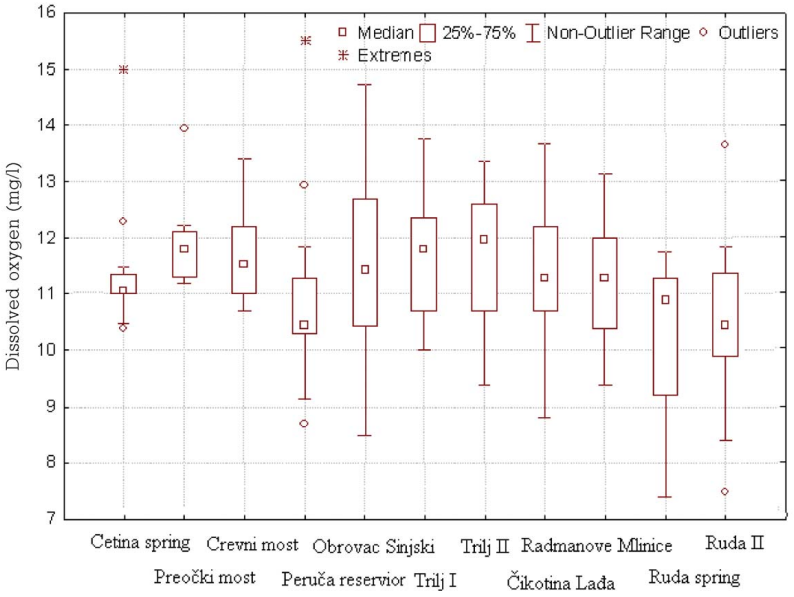

Fig. 3. Dissolved oxygen (mg/l) recorded monthly from August 2004 to August 2005 at 11 sampling sites in the Cetina and Ruda rivers.

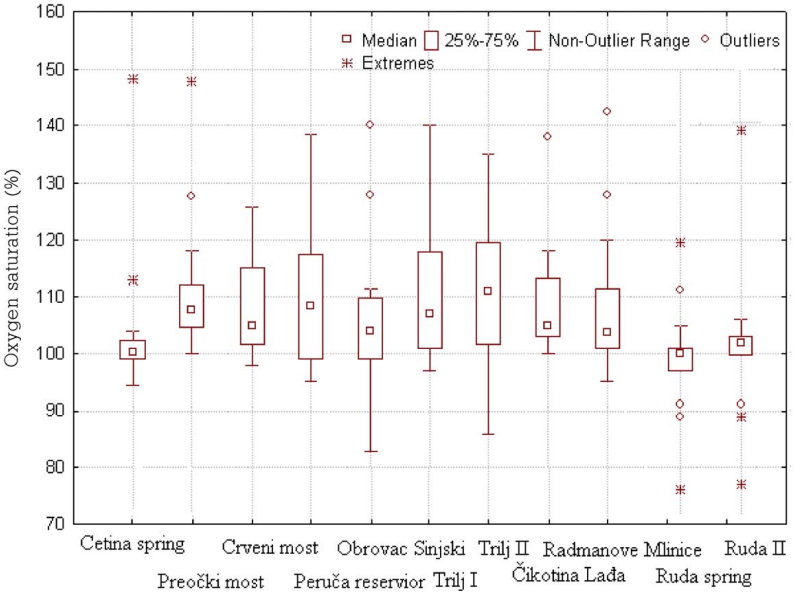

Fig. 4. Percent of oxygen saturation (%) recorded monthly from August 2004 to August 2005 at 11 sampling sites in the Cetina and Ruda rivers.

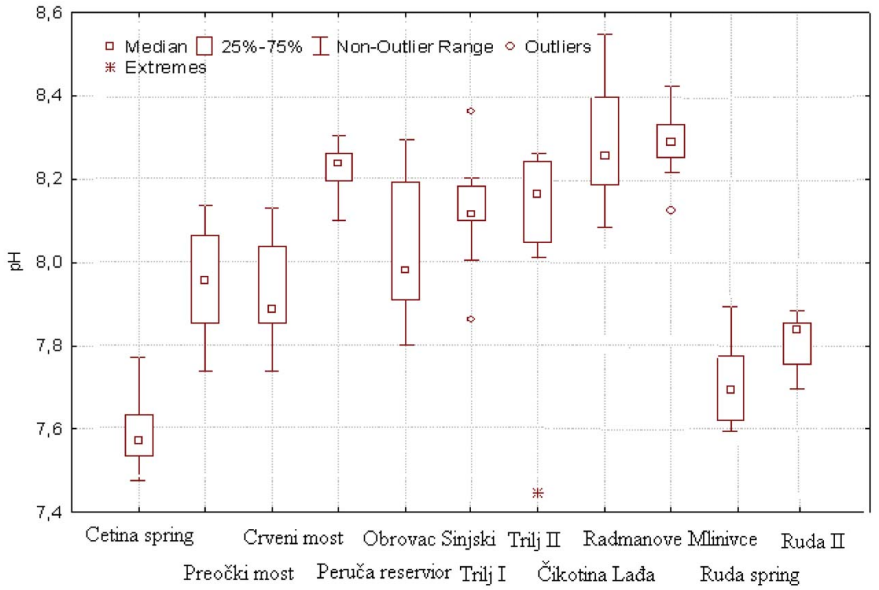

Fig. 5. pH value recorded monthly from August 2004 to August 2005 at 11 sampling sites in the Cetina and Ruda rivers.

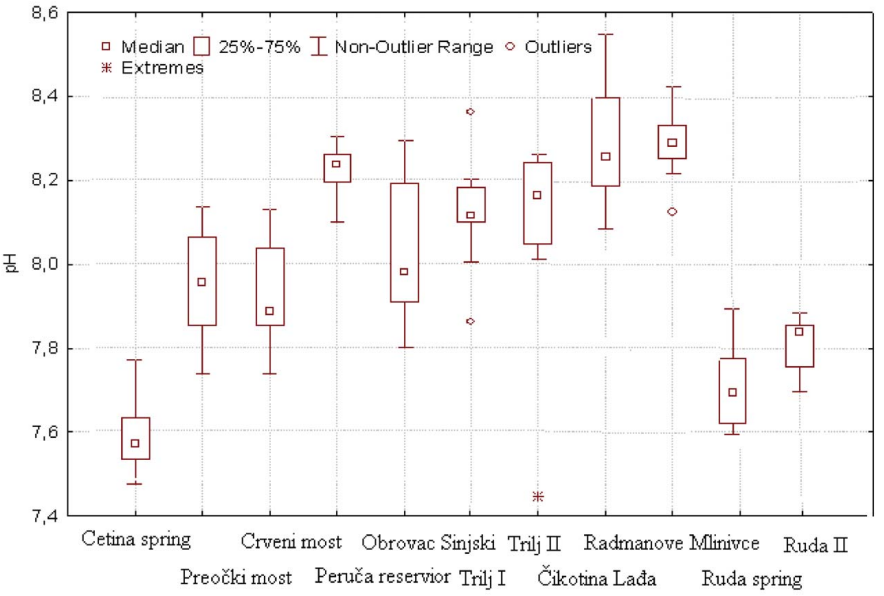

Fig. 6. Electroconductivity (μS/cm) recorded monthly from August 2004 to August 2005 at 11 sampling sites in the Cetina and Ruda rivers.

The pH value ranged from 7.45 to 8.55, which means that the waters of the Cetina River are mildly alkaline (Fig. 5).

Electrical conductivity was used to measure the concentration of ionized substances in the water. The values of electrical conductivity ranged from 282 to 588 μS/cm (Fig. 6). At sites located in the middle and the lower reach of the Cetina River (Obrovac Sinjski, Trilj I, Trilj II, Čikotina Lađa and Radmanove Mlinice), higher values of electrical conductivity were recorded, with significantly higher annual oscillations.

The values of alkalinity (140 to 215 mg/l CaCO3) showed that the rivers Cetina and Ruda have moderately hard water (Fig. 7).

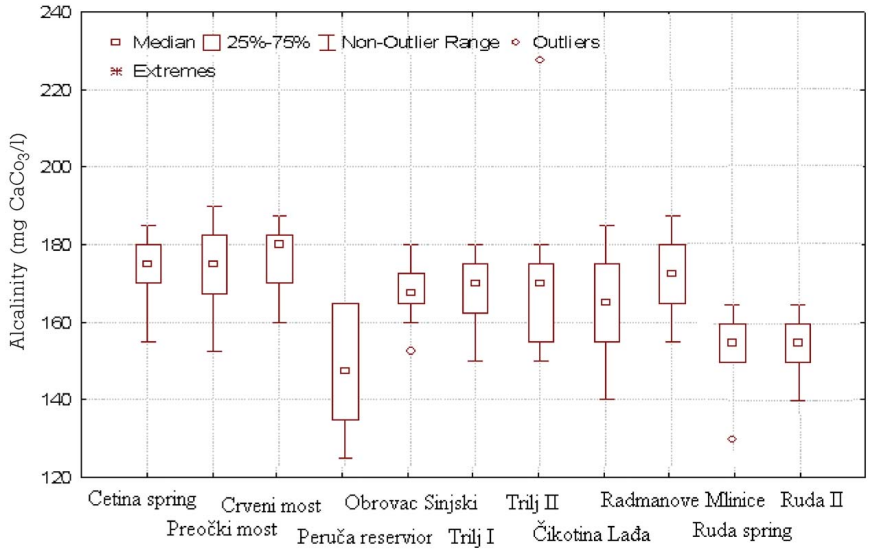

Fig. 7. Alkalinity (mg $CaCO_3$/l) recorded monthly from August 2004 to August 2005 at 11 sampling sites in the Ruda and Cetina Rivers.

Macroinvertebrate community structure

The Cetina River is characterized by a relatively high diversity of macrozoobenthos. During 13 month surveys, in 366 samples a total of 310225 animals were collected and all values were calculated per square meter (m^2). A total of 24 different macroinvertebrate taxa were recorded. Macroinvertebrate samples were collected from various microhabitats (cobbles, fine sand, fine pebbles, algae covering the cobbles, moss and submersed vegetation).

At sampling sites in the spring and upper reach of the Cetina River 20–23 macroinvertebrate taxa were recorded (Tabs. 2–4, Figs. 8–10). The average density of

Tab. 2. Density of macroinvertebrates per m^2 at sampling site Cetina Spring (Glavaš) during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/08	09	10	11	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	3899	5831	41623	3613	533	2820	9628	6398	3298	2308	9400	7668	7828	104847	83.83
Araneae	3	0	3	0	0	0	0	0	0	0	3	0	0	9	0.00
Bivalvia	27	7	197	0	0	3	263	0	23	103	328	110	335	1396	1.11
Chironomidae	566	17	583	0	7	0	158	0	43	3	200	0	108	1685	1.35
Coleoptera Ad	43	3	0	0	0	0	0	5	3	0	5	3	0	62	0.08
Coleoptera Lv	20	0	7	20	0	0	5	508	25	0	10	8	5	608	0.49
Collembola	0	0	10	0	3	0	0	0	5	0	0	0	0	18	0.02
Copepoda	0	37	43	0	33	8	223	23	63	8	125	8	230	801	0.64
Diptera	7	137	17	43	10	8	10	33	3	95	60	90	0	513	0.41
Ephemeroptera	0	0	0	0	0	0	75	0	5	0	5	0	3	88	0.07
Gastropoda	1022	255	316	70	3	535	1203	193	208	18	1228	933	985	6969	5.57
Heteroptera	0	0	3	0	0	0	0	0	5	0	0	0	0	8	0.01
Hirudinea	0	0	0	0	0	0	0	5	0	0	0	0	0	5	0.00
Isopoda	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0.00
Megaloptera	0	0	0	0	7	3	8	18	5	0	0	0	0	41	0.05
Nematoda	0	0	33	0	0	0	15	0	93	0	58	0	3	202	0.16
Oligochaeta	0	43	243	147	53	45	1163	93	1063	103	1488	518	525	5484	4.37
Ostracoda	10	0	30	3	3	0	433	0	68	0	118	3	103	771	0.61
Plecoptera	3	0	0	0	7	0	255	0	3	0	0	0	0	268	0.21
Trichoptera	20	53	30	17	3	85	115	73	13	75	18	58	116	676	0.54
Turbellaria	0	67	37	110	0	23	118	25	33	53	23	8	115	612	0.48
Total	5620	6450	43175	4023	662	3530	13672	7374	4959	2769	13069	9407	10356	125066	100.00

Tab. 3. Density of macroinvertebrates per m^2 at sampling site Preočki Most during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/08	09	10	11	12	01	02	03	04	05	06	7	2005/08	Total	Proportion
Amphipoda	3673	1046	1911	859	3330	7060	12141	4336	7859	2468	14663	5891	9347	15238	22.52
Bivalvia	147	0	0	0	216	0	0	0	10	0	70	0	33	476	0.70
Chironomidae	3183	0	909	0	926	0	107	0	293	0	976	0	816	7210	10.65
Coleoptera Ad	17	3	57	7	0	17	20	0	7	10	13	33	43	227	0.33
Coleoptera Lv	426	176	230	176	536	193	639	186	703	113	1002	310	713	23151	34.22
Collembola	0	0	0	0	0	0	3	0	3	0	0	0	0	6	0.01
Copepoda	3	0	246	0	180	10	3	13	7	3	7	13	60	545	0.81
Diptera	47	0	50	13	186	3	30	3	7	7	27	30	57	460	0.68
Ephemeroptera	629	10	200	313	999	306	676	40	746	153	939	293	4053	1011	1.49
Gastropoda	5561	210	1941	1981	3170	549	2037	120	4492	50	4662	2121	4039	6160	9.11
Heteroptera	0	0	0	0	223	0	0	0	0	0	0	0	0	223	0.33
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0.01
Hydrachnidia	17	0	3	0	30	0	7	0	27	0	27	0	67	178	0.26
Isopoda	0	0	0	0	107	7	3	0	3	0	10	0	7	137	0.20
Megaloptera	3	0	0	0	113	20	20	0	10	0	10	0	57	233	0.34
Nematoda	0	0	3	0	50	0	10	0	3	0	10	0	7	83	0.12
Oligochaeta	0	0	127	60	233	13	30	0	90	0	90	0	616	7017	10.36
Ostracoda	3	0	0	0	23	3	3	0	7	0	0	0	17	56	0.08
Plecoptera	77	0	37	0	2817	20	273	20	160	17	35	63	230	3749	5.54
Trichoptera	370	30	40	63	0	30	53	67	196	33	114	60	130	1186	1.75
Turbellaria	0	0	47	0	43	3	3	3	60	0	73	0	100	332	0.49
Total	14156	1475	5801	3472	13182	8234	16058	4788	14683	2854	22728	8814	20395	67681	100.00

Tab. 4. Density of macroinvertebrates per m^2 at sampling site Crveni most during 2004/2005 (Ad – adults, Lv – larvae).

Month:	2004/8	9	10	11	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	5182	4662	7076	3047	1988	2890	11389	5228	4496	2774	9464	11166	3956	73318	45.68
Araneae	3	0	10	3	0	0	0	0	0	0	0	0	0	16	0.01
Bivalvia	7	0	27	0	0	50	123	0	7	203	256	0	30	703	0.46
Chironomidae	6284	0	1708	0	110	10	443	0	516	0	1046	0	939	11056	6.88
Coleoptera Ad	10	3	10	3	8	10	7	3	7	10	13	0	3	87	0.06
Coleoptera Lv	390	77	73	290	170	147	216	53	240	173	193	117	160	2299	1.44
Collembola	0	0	0	0	18	0	0	0	0	0	0	0	0	18	0.02
Copepoda	656	0	3243	0	10	13	87	13	0	13	13	0	20	4068	2.53
Diptera	73	550	13	107	25	110	27	3	7	110	320	433	57	1835	1.14
Ephemeroptera	107	13	872	946	1225	1072	1469	87	839	599	2571	170	1975	11945	7.44
Gastropoda	4965	2434	3889	743	3170	776	6856	2324	3503	2171	3523	440	1648	36442	22.70
Heteroptera	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0.00
Hirudinea	13	3	0	3	0	0	3	0	3	0	0	0	0	25	0.02
Hydrachnidia	403	0	53	0	3	0	27	0	10	0	37	0	80	613	0.39
Hydrozoa	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0.00
Isopoda	0	0	0	0	23	13	13	23	47	60	7	17	17	220	0.14
Lepidoptera	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0.00
Megaloptera	50	0	7	20	3	3	13	13	0	0	20	37	47	213	0.14
Nematoda	13	0	0	0	3	0	0	0	23	0	3	0	0	42	0.02
Odonata	0	0	0	0	3	0	0	0	0	0	0	0	0	3	0.00
Oligochaeta	177	0	220	0	13	23	173	0	186	20	50	147	296	1305	0.81
Ostracoda	36	0	17	0	0	3	23	0	3	0	0	0	0	82	0.05
Plecoptera	0	0	270	10	266	23	147	0	316	13	12763	37	137	13982	8.71
Trichoptera	177	110	147	230	5	280	20	73	96	503	63	67	200	1971	1.20
Turbellaria	0	0	13	20	60	3	67	20	30	0	7	3	40	263	0.16
Total	18546	7852	17651	5422	7103	5426	21103	7840	10332	6649	30352	12634	9605	160515	100.00

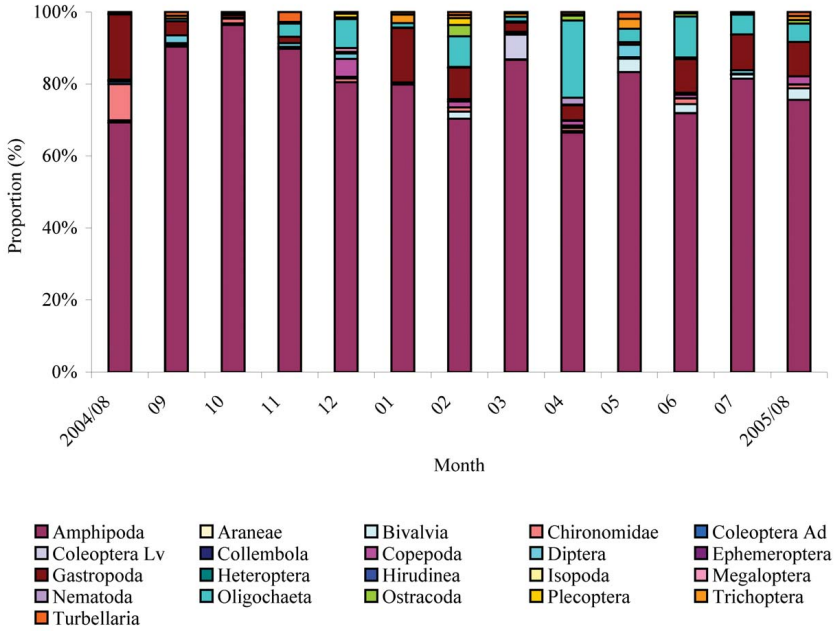

Fig. 8. Proportion of macroinvertebrate taxa per m^2 at the sampling site Cetina Spring (Glavaš) collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

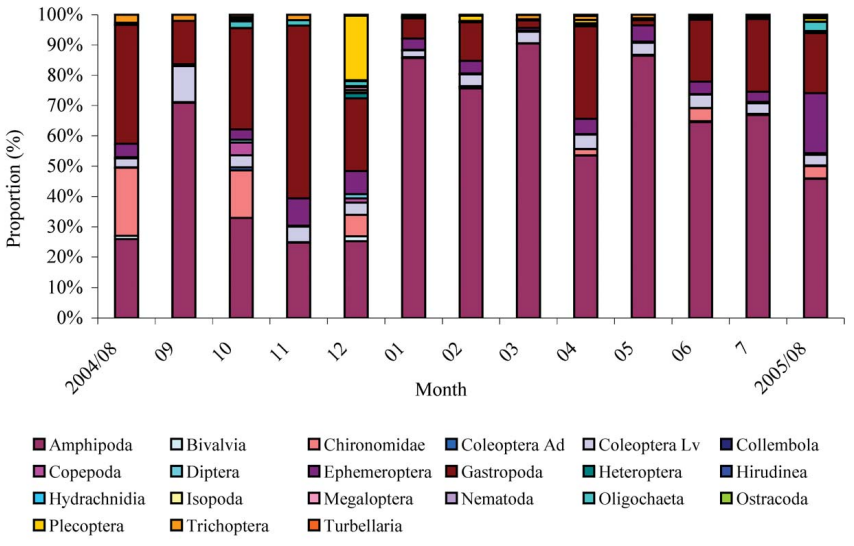

Fig. 9. Proportion of macroinvertebrate taxa per m^2 at sampling site Preočki Most collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

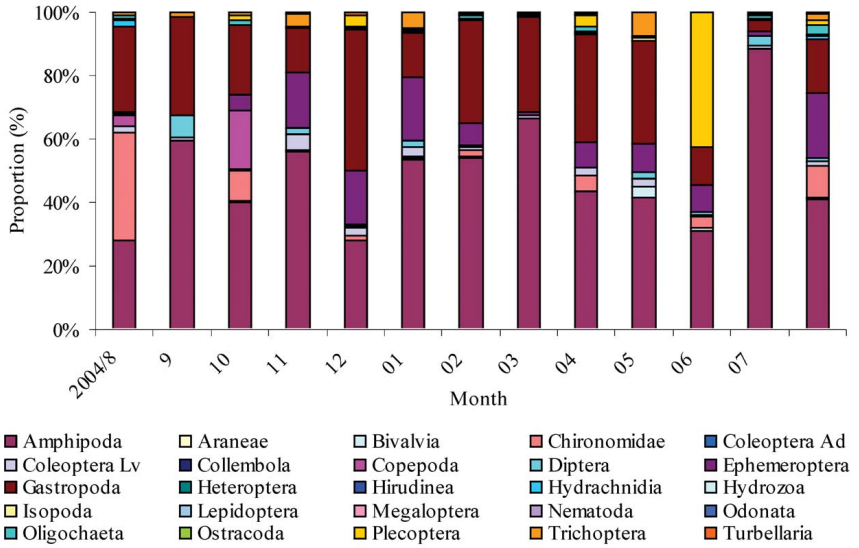

Fig. 10. Proportion of macroinvertebrate taxa per m^2 at the sampling site Crveni Most collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

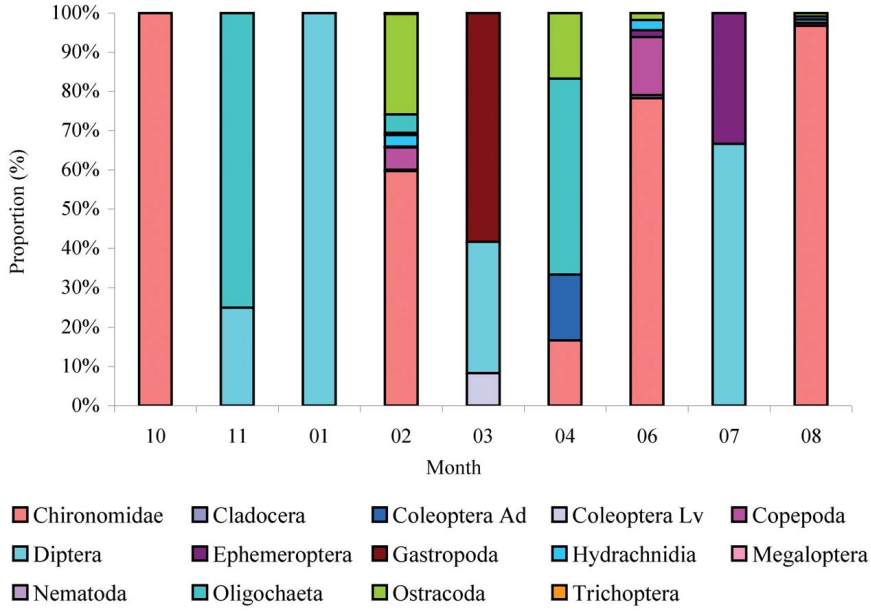

Fig. 11. Proportion of macroinvertebrate taxa per dm^2 at the sampling site Peruča Reservior collected with a triangular dredge monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

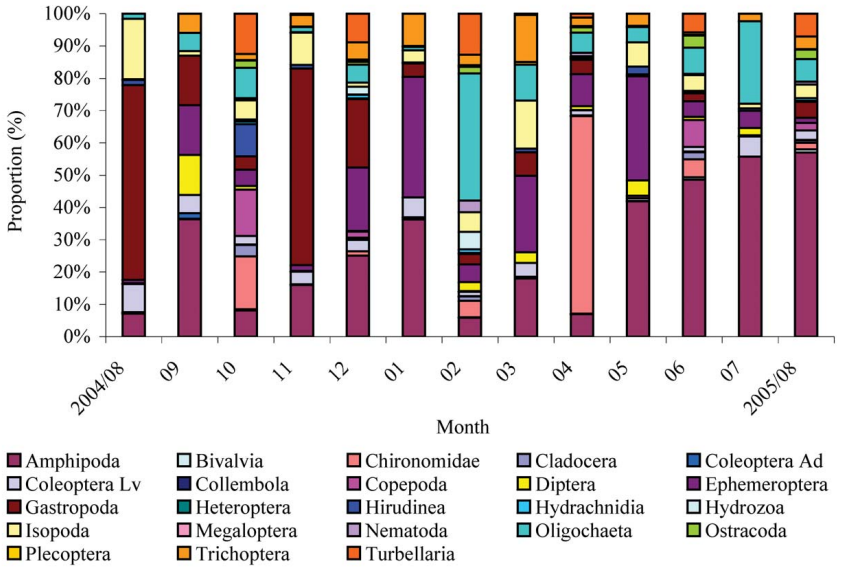

Fig. 12. Proportion of macroinvertebrate taxa per m^2 at the sampling site Obrovac Sinjski collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

macroinvertebrates during 13 months was 9620 individuals/m^2 at Cetina Spring-Glavaš, 15741 individuals/m^2 at the Preočki most and 12347 individuals/m^2 at the Crveni Most. Amphipoda and Gastropoda were dominant groups in samples from all sites in the upper reach (Cetina Spring-Glavaš; 83.83% and 5.57%, Preočki Most; 22.52% and 9.11%, Crveni Most; 45.68% and 22.70%, respectively).

In addition to the contribution of Coleoptera larvae (34.22%), a considerable portion of the catch at the site Preočki Most consisted of Chironomidae (10.65%), Oligichaeta (10.36%) and Plecoptera (5.54%). Moreover, Plecoptera (8.71%), Ephemeroptera (7.44%) and Chironomidae (6.88%) also accounted for a considerable portion of the catch at the site Crveni Most.

At the Peruča Reservoir 13 macroinvertebrate taxa were recorded (Tab. 5, Fig. 11). More than 66.00% of individuals collected during the entire research period belonged to Chironomidae. A considerable portion of the catch consisted of the crustaceans Ostracoda (17.65%) and Copepoda (5.88%) as well as Oligochaeta (4.04%). The average density of macroinvertebrates during 13 months was 565 individuals/m^2.

A total of 21 macroinvertebrate taxa were recorded at the site in the middle reach of the Cetina River, Obrovac Sinjski (Tab. 6, Fig. 12). As in the upper reach, the dominant group was Amphipoda (27.01%) but Chironomidae (16.71%), Oligochaeta (12.90%), Gastropoda (8.27%) and Ephemeroptera (7.45%) also accounted for a considerable portion of the catch. The average density of macroinvertebrates throughout the 13 months was 5128 individuals/m^2.

Tab. 5. Density of macroinvertebrates per m^2 at sampling site Peruča Reservoir during 2004/2005 (Ad – adults, Lv – larvae).

Month	10	11	01	02	03	04	06	07	08	Total	Proportion
Chironomidae	50	0	0	3260	0	10	900	0	1200	5420	66.42%
Cladocera	0	0	0	20	0	0	10	0	0	30	0.37%
Coleoptera Ad	0	0	0	0	0	10	0	0	0	10	0.12%
Coleoptera Lv	0	0	0	0	10	0	0	0	0	10	0.12%
Copepoda	0	0	0	310	0	0	170	0	0	480	5.88%
Diptera	0	10	10	0	40	0	0	200	0	260	0.98%
Ephemeroptera	0	0	0	100	0	0	20	100	0	220	0.49%
Gastropoda	0	0	0	0	70	0	0	0	10	80	0.98%
Hydrachnidia	0	0	0	160	0	0	30	0	10	200	2.45%
Nematoda	0	0	0	30	0	0	0	0	0	30	0.37%
Oligochaeta	0	30	0	260	0	30	0	0	10	330	4.04%
Ostracoda	0	0	0	140	0	10	20	0	10	180	17.65%
Trichoptera	0	0	0	10	0	0	0	0	0	10	0.12%
Total	50	40	10	4290	120	60	1150	300	1240	7250	100.00%

Tab. 6. Density of macroinvertebrates per m^2 at sampling site Obrovac Sinjski during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/08	09	10	11	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	90	693	376	559	113	353	649	366	1026	709	4701	1695	6676	18006	27.01
Bivalvia	0	3	20	0	0	0	13	0	27	0	70	0	110	243	0.36
Chironomidae	3	0	759	0	6	0	566	0	9038	0	536	0	236	11144	16.71
Cladocera	0	0	167	0	0	7	147	10	0	0	213	0	93	637	0.96
Coleoptera Ad	0	33	10	7	0	0	3	0	17	3	20	0	17	110	0.16
Coleoptera Lv	110	107	120	137	16	60	153	87	233	13	137	190	340	1703	2.55
Collembola	0	0	3	0	3	0	0	0	0	0	0	0	3	9	0.02
Copepoda	0	0	666	0	9	0	23	0	7	13	806	10	266	1800	2.70
Diptera	3	236	53	7	1	0	306	67	186	80	93	70	3	1105	1.65
Ephemeroptera	13	293	233	63	88	363	606	483	1465	546	473	163	183	4972	7.45
Gastropoda	763	293	193	2125	96	40	363	147	659	10	236	0	589	5514	8.27
Heteroptera	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0.00
Hirudinea	20	0	466	40	1	3	23	24	40	40	33	20	23	733	1.09
Hydrachnidia	3	0	37	0	5	0	127	0	30	0	37	0	107	346	0.52
Hydrozoa	0	0	27	0	11	0	606	0	80	0	3	0	0	727	1.11
Isopoda	236	27	280	350	6	37	666	303	12	127	473	47	493	3057	4.59
Megaloptera	0	0	0	3	0	0	3	0	0	0	0	0	0	6	0.01
Nematoda	0	0	33	0	0	0	393	0	153	0	37	0	110	726	1.08
Oligochaeta	20	107	436	57	25	10	4346	226	919	80	783	776	809	8594	12.90
Ostracoda	0	0	103	0	4	0	223	0	250	0	360	0	350	1290	1.94
Plecoptera	0	0	10	3	3	3	60	17	50	7	20	0	17	190	0.29
Trichoptera	0	113	87	127	24	97	353	296	386	63	77	70	456	2149	3.23
Turbellaria	0	0	579	13	40	0	1402	7	180	0	556	0	823	3600	5.40
Total	1264	1905	4658	3491	451	973	11031	2033	14758	1691	9667	3041	11704	6665	100.00

Tab. 7. Density of macroinvertebrates per m^2 at sampling site Trilj I during 2004/2005 (Ad – adults, Lv – larvae).

Month	09	10	12	01	02	03	04	05	06	07	2005/08	Total	Percente
Amphipoda	0	20	60	0	60	0	90	10	150	1700	0	2090	3.00%
Araneae	0	30	0	0	0	0	10	0	0	0	0	40	0.07%
Bivalvia	0	32	0	0	0	0	120	0	330	20	1520	2022	3.29%
Chironomidae	0	1470	890	0	17040	0	5690	0	1460	0	4500	31050	44.41%
Cladocera	0	0	0	0	60	0	0	0	30	0	0	90	0.15%
Coleoptera Lv	0	20	130	50	60	0	90	10	30	150	0	540	0.77%
Collembola	0	0	0	0	10	0	0	0	0	0	0	10	0.01%
Copepoda	0	0	10	0	10	0	90	0	430	0	20	560	0.79%
Diptera	30	0	10	80	30	30	0	360	0	130	50	720	1.03%
Ephemeroptera	0	0	30	100	20	0	0	10	70	50	0	280	0.40%
Gastropoda	0	300	30	10	190	0	3100	0	2110	760	90	6590	9.42%
Heteroptera	0	0	0	0	0	0	0	0	0	0	10	10	0.01%
Hirudinea	20	0	10	0	20	100	460	60	170	0	190	1030	1.47%
Hydrachnidia	0	0	50	0	430	0	230	0	80	0	10	800	1.13%
Isopoda	0	0	90	10	50	10	200	40	60	0	0	460	1.43%
Nematoda	0	70	10	0	80	0	160	0	120	0	910	1350	1.93%
Odonata	0	0	10	0	0	0	0	0	0	0	0	10	0.01%
Oligochaeta	0	2390	180	20	1100	30	2320	30	2370	0	9020	17460	25.37%
Ostracoda	0	130	1480	0	410	0	360	0	300	0	280	2960	4.24%
Trichoptera	0	0	10	0	0	0	20	0	170	390	0	590	0.84%
Turbellaria	0	0	0	20	0	0	120	0	20	0	0	160	0.23%
Total	50	4462	3000	290	19570	170	13060	520	7900	3200	16600	68822	100.00%

Tab. 8. Density of macroinvertebrates per m^2 at sampling site Trilj II during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/09	10	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	90	0	110	80	380	100	260	210	770	0	280	2280	4.42%
Bivalvia	0	300	0	0	310	30	190	0	60	0	160	1050	2.01%
Chironomidae	0	800	380	0	1440	0	2290	0	3190	0	1050	9150	17.72%
Cladocera	0	0	0	0	10	0	30	0	130	0	10	180	0.35%
Coleoptera Ad	0	0	10	0	0	0	0	0	0	0	0	10	0.02%
Coleoptera Lv	0	60	20	10	30	0	3210	0	220	10	480	4040	2.01%
Collembola	0	0	10	0	0	0	0	0	0	0	0	10	0.02%
Copepoda	0	20	10	0	140	0	160	0	570	0	0	900	1.74%
Diptera	0	200	20	70	380	150	100	220	0	1	10	1151	2.25%
Ephemeroptera	0	10	30	10	80	60	220	30	1060	0	20	1520	2.95%
Gastropoda	0	20	40	0	170	100	450	0	130	40	400	1350	2.97%
Heteroptera	0	270	0	0	120	0	400	0	10	0	10	810	1.55%
Hirudinea	0	0	0	0	10	10	10	0	60	0	230	320	0.67%
Hydrachnidia	0	270	160	0	240	0	110	0	110	0	160	1050	2.03%
Hydrozoa	0	0	0	0	0	0	0	0	10	0	10	20	0.04%
Isopoda	0	0	40	10	10	0	150	40	1760	0	180	2190	4.25%
Nematoda	0	80	0	0	20	0	1290	0	20	0	20	1430	2.78%
Oligochaeta	0	110	200	100	2020	190	17060	1910	1300	0	330	23220	44.97%
Ostracoda	0	390	80	0	140	0	620	0	450	0	870	2550	4.94%
Plecoptera	0	0	10	0	0	0	0	0	0	0	0	10	0.02%
Trichoptera	0	0	0	70	80	30	20	20	10	0	190	420	0.82%
Turbellaria	0	30	0	10	10	0	100	0	340	0	270	760	1.48%
Total	90	2560	1120	360	5590	670	26670	2430	10200	51	4680	54421	100.00%

At sampling sites Trilj I and Trilj II 20 macroinvertebrate taxa were recorded (Tabs. 7–8, Figs. 13–14). The benthic community of these sites was dominated by Chironomidae and Oligochaeta, which accounted for more than 40% of the total catch. The average macroinvertebrate density was similar at these two sites throughout the whole period of the study (5294 individuals/m^2 and 4186 individuals/m^2 at sites Trilj I and Trilj II, respectively).

A total of 22 and 24 macroinvertebrate taxa were recorded at sites in the lower reach of the Cetina River, Čikotina Lađa (Tab. 9, Fig. 15) and Radmanove Mlinice (Tab.10, Fig. 16), respectively. At the site Čikotina Lađa, the average density of macroinvertebrates collected was 6875 individuals/m^2, whereas at the site Radmanove Mlinice the average density was 4064 individuals/m^2.

At the former site, 21.58% of the catch consisted of Chironomidae, but Ephemeroptera (18.95%), Amphipoda (13.30%), Oligochaeta (11.17%), coleopteran larvae (7.15%), Gastropoda (6.78%) and Trichoptera (4.25%) also accounted for a considerable portion of the catch. At the site Radmanove Mlinice 40.95% of the catch consisted of Gastropoda, followed by coleopteran larvae (17.84%), Ephemeroptera (7.49%), Amphipoda (7.42%) and Trichoptera (5.93%).

At Ruda Spring, a total of 20 macroinvertebrate taxa were collected (Tab. 11, Fig. 17). The dominant taxa were Amphipoda (25.60%), Chironomidae (20.44%), Gastropoda (17.53%), coleopteran larvae (15.16%), Ephemeroptera (11.03%) and Plecoptera (5.48%). Downstream, at the site Ruda II, in total, 23 macroinvertebrate taxa were recorded (Tab. 12, Fig. 18). As with the spring site, the community was dominated

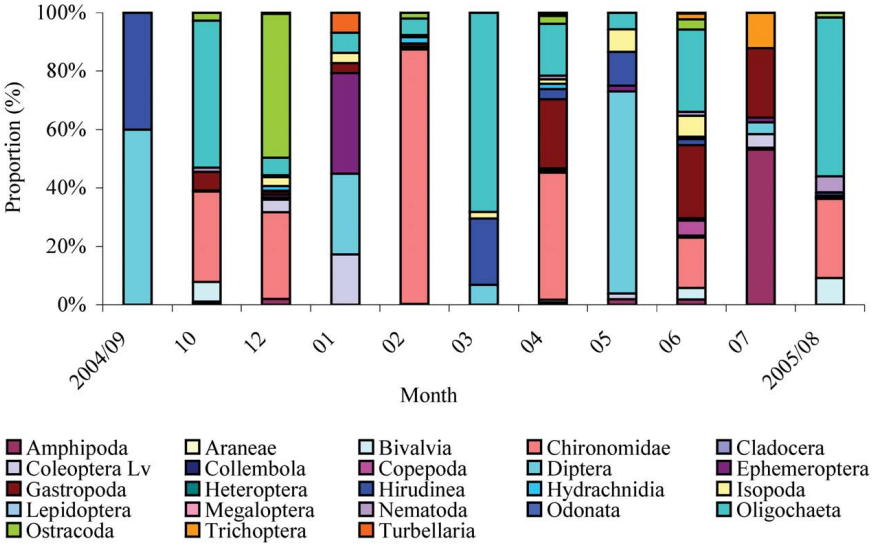

Fig. 13. Proportion of macroinvertebrate taxa per dm^2 at the sampling site Trilj I collected with a triangular dredge monthly from August 2004 to August 2005.

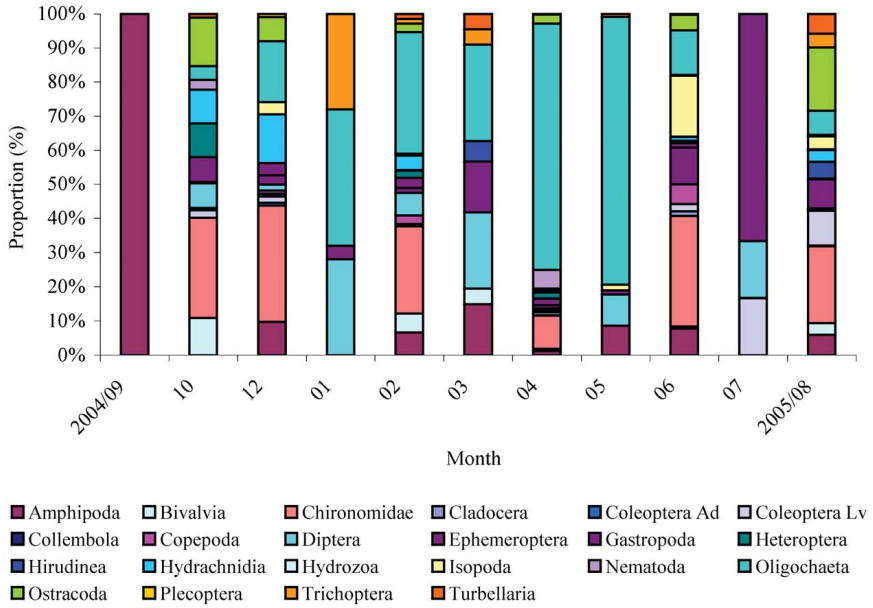

Fig. 14. Proportion of macroinvertebrate taxa per dm^2 at the sampling site Trilj II collected with a triangular dredge monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

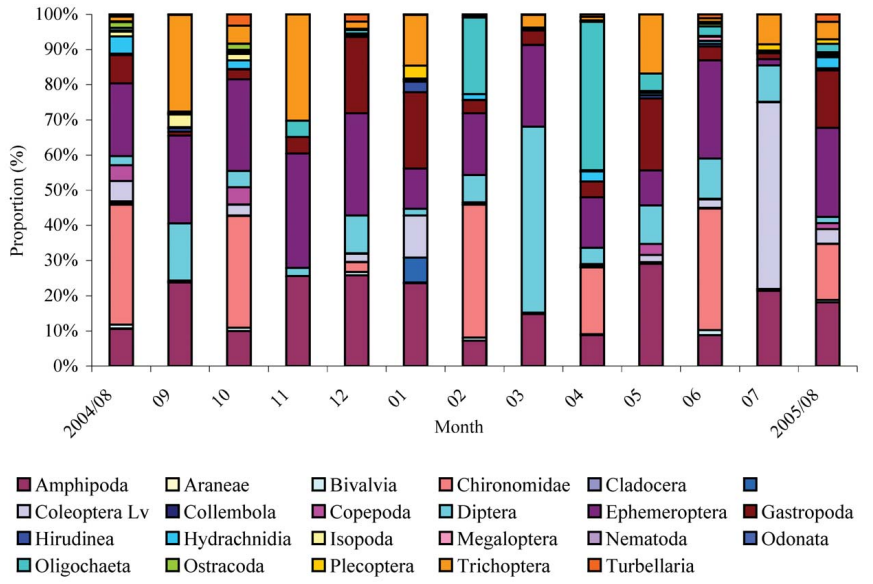

Fig. 15. Proportion of macroinvertebrate taxa per m^2 at the sampling site Čikotina Lađa collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

Tab. 9. Density of macroinvertebrates per m^2 at sampling site Čikotina Lađa during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/08	09	10	11	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	1535	569	1472	110	1359	533	809	476	1452	986	450	1725	437	11913	13.30%
Araneae	3	3	0	0	0	3	0	3	0	0	0	0	0	12	0.00%
Bivalvia	173	0	140	0	50	0	97	3	47	7	73	0	15	605	0.60%
Chironomidae	4918	0	4662	0	147	0	4229	0	3124	3	1768	43	382	19276	21.58%
Cladocera	90	0	13	0	0	0	0	0	0	0	0	0	2	105	1.18%
Coleoptera Ad	43	0	10	0	3	160	13	0	20	7	7	0	0	263	0.29%
Coleoptera Lv	846	10	450	0	123	270	50	7	67	70	120	4282	100	6395	7.15%
Collembola	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0.00%
Copepoda	649	0	719	0	7	0	20	0	73	107	10	10	40	1635	1.83%
Diptera	376	390	686	10	566	43	862	1702	756	370	589	832	42	7224	8.04%
Ephemeroptera	2987	599	3826	140	1528	260	1961	749	2361	340	1422	147	610	16930	18.95%
Gastropoda	1152	27	410	20	1146	490	420	133	756	693	203	140	392	5982	6.78%
Hirudinea	67	23	27	0	7	67	10	10	0	30	40	7	15	303	0.34%
Hydrachnidia	713	7	353	0	27	10	180	7	470	23	40	3	78	1911	2.15%
Isopoda	200	87	286	0	3	7	3	0	13	10	0	43	13	665	0.74%
Megaloptera	0	0	0	0	0	3	0	0	0	0	63	7	5	78	0.08%
Nematoda	17	0	33	0	3	0	0	0	47	0	10	0	0	110	0.12%
Odonata	30	7	43	0	10	0	0	0	0	10	0	0	15	115	0.13%
0Oligochaeta	103	3	93	20	53	0	2441	10	6950	166	140	0	58	10037	11.17%
Ostracoda	243	0	236	0	17	0	60	0	30	0	37	0	0	623	0.69%
Plecoptera	27	10	23	0	3	83	0	0	37	0	30	147	33	393	0.44%
Trichoptera	193	659	749	130	107	326	0	117	166	573	50	683	120	3873	4.25%
Turbellaria	90	3	466	0	107	3	37	3	110	0	57	0	50	926	1.04%
Total	14455	2397	14700	430	5266	2258	11192	3220	16479	3395	5109	8069	2407	89377	100.00%

Tab.10. Density of macroinvertebrates per m^2 at sampling site Radmanove Mlinice during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/08	09	10	11	12	01	02	03	04	05	06	07	2005/08	Total	Proportion
Amphipoda	483	400	246	5	123	186	586	107	579	543	519	20	73	3870	7.42
Araneae	0	0	0	0	3	3	0	0	0	0	0	0	0	6	0.01
Bivalvia	30	0	13	0	80	7	130	0	87	0	130	0	203	680	1.31
Chironomidae	729	0	120	0	183	0	133	0	323	0	363	0	130	1981	3.75
Coleoptera Ad	576	416	43	0	17	0	23	83	93	463	30	13	7	1764	3.36
Coleoptera Lv	1672	789	509	20	190	470	3157	350	563	87	256	803	513	9379	17.84
Collembola	0	0	0	0	7	0	0	0	0	0	0	0	0	7	0.01
Copepoda	0	0	0	0	13	10	0	3	0	0	0	3	0	29	0.06
Decapoda	0	13	0	0	13	0	0	0	0	0	0	0	0	26	0.06
Diptera	669	743	176	5	163	13	20	260	130	157	73	616	137	3162	5.98
Ephemeroptera	303	410	486	5	253	163	673	147	523	370	47	253	326	3959	7.49
Gastropoda	969	909	759	30	1452	4492	2717	1618	3120	789	1625	886	2158	21524	40.95
Heteroptera	47	10	20	0	7	0	3	0	10	0	0	0	0	97	0.19
Hirudinea	7	13	7	0	0	27	0	7	30	50	40	17	3	201	0.40
Hydrachnidia	799	0	63	0	57	0	23	0	70	0	73	0	283	1368	2.70
Isopoda	13	33	7	0	7	3	17	0	7	3	13	7	0	110	0.22
Lepidoptera	0	0	0	0	7	0	0	0	0	0	0	0	0	7	0.01
Nematoda	0	0	27	0	23	0	3	0	0	0	3	0	30	86	0.16
Odonata	3	0	0	0	13	0	0	0	0	0	0	0	0	16	0.03
Oligochaeta	27	20	173	15	213	27	107	37	286	3	53	20	37	1018	1.20
Ostracoda	0	0	7	0	57	0	3	0	0	0	13	0	117	197	0.37
Plecoptera	7	3	7	0	0	0	0	0	83	0	10	7	0	117	0.23
Trichoptera	120	430	353	10	303	30	193	13	7	27	413	176	1006	3081	5.94
Turbellaria	0	0	3	0	0	0	0	0	10	0	23	17	103	156	0.31
Total	6454	4189	3019	90	3184	5431	7788	2625	5921	2492	3684	2838	5126	52841	100.00

Tab. 11. Density of macroinvertebrates per m^2 at sampling site Ruda Spring during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/8	9	10	11	12	1	2	3	4	5	6	7	2005/8	Total	Proportion
Amphipoda	4336	2248	6074	260	1702	3726	4309	996	1831	1262	3197	2584	6267	38792	25.60%
Araneae	3	0	0	10	0	3	0	3	0	3	0	0	0	22	0.01%
Bivalvia	43	20	3	0	0	27	0	0	0	0	0	0	0	93	0.06%
Chironomidae	1652	0	4429	0	300	0	693	0	1955	0	10270	0	11675	30974	20.44%
Coleoptera Ad	456	57	140	13	27	60	490	40	63	3	210	70	60	1689	1.11%
Coleoptera Lv	7609	0	4759	50	1888	210	3447	27	236	110	2155	176	2304	22971	15.16%
Collembola	0	0	0	0	7	0	0	0	0	0	0	0	0	7	0.00%
Copepoda	10	0	0	0	10	10	17	10	0	10	0	17	3	87	0.06%
Diptera	23	33	3	20	47	10	77	10	40	20	353	43	1022	1701	1.12%
Ephemeroptera	1412	0	390	63	376	649	1079	1059	150	80	3050	1515	6896	16719	11.03%
Gastropoda	373	83	4266	2081	5361	1092	2721	1169	1062	719	2085	1498	4056	26566	17.53%
Hirudinea	7	3	3	7	20	3	7	0	3	7	7	0	3	70	0.05%
Hydrachnidia	100	0	37	0	13	0	63	0	17	0	143	0	133	506	0.33%
Isopoda	0	3	0	0	0	13	0	0	3	0	0	0	3	22	0.01%
Nematoda	220	0	13	0	0	0	83	0	7	0	17	0	47	387	0.26%
Oligochaeta	353	3	17	3	27	0	40	3	10	7	97	0	33	593	0.39%
Ostracoda	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0.00%
Plecoptera	743	0	766	0	67	420	2228	1132	170	27	97	989	1655	8294	5.48%
Trichoptera	23	290	90	27	30	50	107	73	120	67	17	603	480	1977	1.30%
Turbellaria	0	0	3	7	0	3	23	7	13	0	0	0	20	76	0.05%
Total	17363	2740	20996	2541	9875	6276	15384	4529	5680	2315	21698	7495	34657	151549	100.00%

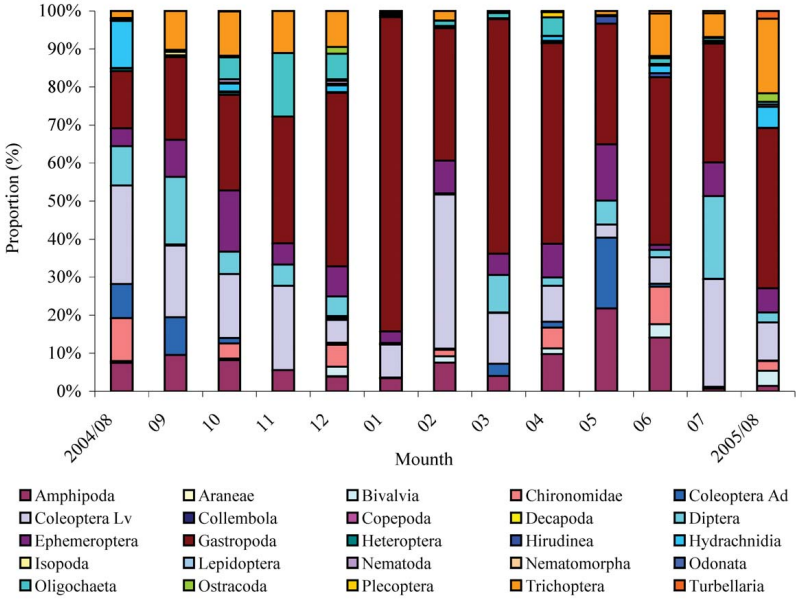

Fig. 16. Proportion of macroinvertebrate taxa per m^2 at the sampling site Radmanove Mlinice collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

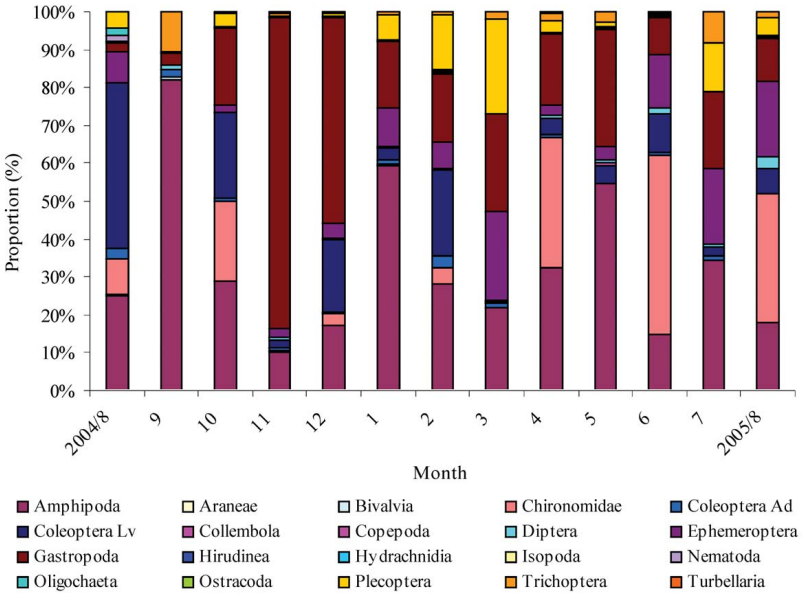

Fig. 17. Proportion of macroinvertebrate taxa per m^2 at the sampling site Ruda Spring collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

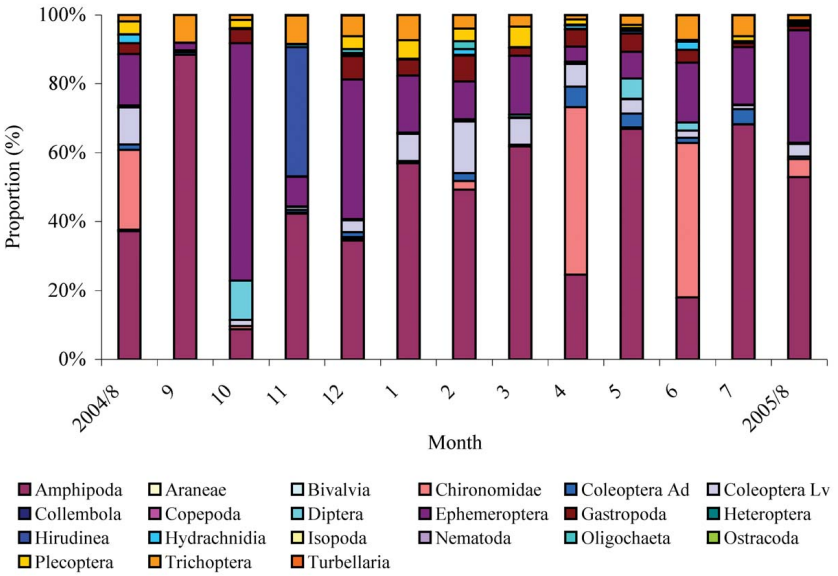

Fig. 18. Proportion of macroinvertebrate taxa per m^2 at the sampling site Ruda II collected with a Surber net monthly from August 2004 to August 2005 (Ad – adults, Lv – larvae).

by the following taxa groups; Amphipoda (43.78%), Ephemeroptera (18.62%), Chironomidae (18.24%), coleopteran larvae (4.97%) and Plecoptera (4.16%). The average macroinvertebrate density throughout the period of the study was 12629 individuals/m^2 at the site Ruda Spring and 9264 individuals/m^2 at Ruda II.

Macroinvertebrate density at all sampling sites during 2004/2005 is given in the appendix (Tab. 2–12).

DISCUSSION

Values of water temperature of the Cetina River recorded in the current study were in accordance with prior surveys of this river (ŠTAMBUK-GILJANOVIĆ, 2005). Water temperature is directly dependent on the temperature of the air (GILLER & MALMQUIST, 1998). In Mediterranean karst running waters, for instance in the Krka, Zrmanja, Jadro and Cetina, water temperature decreases with depth, and increases downstream (ŠTAMBUK-GILJANOVIĆ, 2002, 2005).

Values of dissolved oxygen ranged from 8.50 to 15.52 mg/l along sites at the Cetina River, which is in accordance with the mean values recorded from the other Mediterranean karst rivers, e.g. Zrmanja, Krka, etc. (about 10-12 mg/l; ŠTAMBUK-GILJANOVIĆ, 2002, 2005). The concentration of dissolved oxygen as a physico-chemical parameter is used to measure the level of organic production in a watercourse (GILLER & MALMQUIST, 1998). Generally, the concentration of oxygen decreases from

Tab. 12. Density of macroinvertebrates per m^2 at sampling site Ruda II during 2004/2005 (Ad – adults, Lv – larvae).

Month	2004/8	9	10	11	12	1	2	3	4	5	6	7	2005/8	Total	Proportion
Amphipoda	7166	8608	340	1002	992	1845	2554	2954	2497	1558	4362	5435	12910	52223	43.78%
Araneae	3	0	0	3	0	0	0	0	0	10	0	0	0	16	0.01%
Bivalvia	83	0	0	3	13	3	0	0	0	0	0	7	0	109	0.02%
Chironomidae	4469	0	35	0	17	0	130	0	4922	0	10892	0	1272	21737	18.24%
Coleoptera Ad	293	70	0	20	40	17	120	23	603	93	373	350	200	2202	1.80%
Coleoptera Lv	2071	57	70	20	100	256	779	370	666	97	490	90	892	5958	4.97%
Collembola	10	0	0	0	0	0	0	0	0	0	0	0	0	10	0.00%
Copepoda	0	0	0	0	0	10	0	10	0	3	0	7	0	30	0.02%
Diptera	103	0	445	3	10	3	30	37	67	137	576	7	77	1495	1.33%
Ephemeroptera	2870	210	2680	203	1165	536	569	816	446	180	4206	1329	7972	23182	18.62%
Gastropoda	599	7	160	3	196	150	390	110	513	123	902	90	303	3546	2.95%
Heteroptera	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0.00%
Hirudinea	3	0	0	889	7	0	13	10	7	20	7	27	67	1050	0.87%
Hydrachnidia	496	0	0	20	13	0	83	0	107	10	569	0	60	1358	1.13%
Isopoda	0	0	0	0	0	0	0	0	0	0	17	13	0	30	0.02%
Nematoda	0	0	0	0	3	0	0	0	13	0	37	0	3	56	0.05%
Oligochaeta	10	7	10	3	33	7	120	0	7	7	33	7	100	344	0.28%
Ostracoda	10	0	0	0	0	0	0	0	0	0	0	0	0	10	0.01%
Plecoptera	706	0	95	0	110	173	193	286	150	23	40	120	153	2049	1.68%
Trichoptera	360	776	55	196	173	240	203	160	123	63	1755	486	393	4983	4.16%
Turbellaria	3	3	0	3	3	0	0	0	10	3	13	3	0	41	0.04%
Total	19255	9738	3890	2368	2875	3240	5184	4776	10134	2327	24272	7971	24402	120432	100.00%

the surface towards the bottom and downstream (GILLER & MALMQUIST, 1998). In the surveyed area, there are no considerable differences in the concentration of dissolved oxygen at sites in the upper, middle and lower reaches; hence there is no large decrease of oxygen concentration from the spring to the estuary. The latter may be the consequence of the morphology of the lower reaches, since this section contains numerous cascades and large boulders that enable additional aeration of water, thus increasing the quantity of dissolved oxygen (MAYER, 1993).

The range of pH value recorded in this study is in accordance with the values typical of karst running waters in Central Dalmatia; from 6.5 to 8.5 (ŠTAMBUK-GILJANOVIĆ, 2005). These values are result of the limestone geological substrate of the karst running waters in the region. Waters on such substrates have a high buffering capacity (GILLER & MALMQUIST, 1998). When leaving the underground, the water, along with carbonates, also contains carbonic acid and free carbon (IV) oxide that lowers the pH value.

The highest values are measured in the summer, when the water level is lower and river flow slower. In the middle and lower reaches, the anthropogenic influence is increased (most households do not have wastewater sewerage) (ŠTAMBUK-GILJANOVIĆ, 2005).

The values of alkalinity measured in Cetina and Ruda are also within the range listed according to prior research (ŠTAMBUK-GILJANOVIĆ, 2002, 2005). Water in the Mediterranean karst rivers in the wider area of Dalmatia (the Jadro, Žrnovnica, Cetina, Ruda and Kosinac) is moderately hard, with 140 to 215 mg/l $CaCO_3$ (ŠTAMBUK-GILJANOVIĆ, 2002, 2005). Overall, the alkalinity of karst running waters in the upper reaches is directly influenced by the rainfall and groundwater levels (BONACCI, 1987; ŠTAMBUK-GILJANOVIĆ, 2002, 2005).

At sampling sites at the Cetina Spring and the Ruda Spring, the community is not dominated by insect taxa, which is in accordance with previous studies on similar rivers (DOLÉDEC, 1989; CIANFICCONI *et al.*, 1991). In hard waters, where pH is higher than 7.0 and alkalinity is higher than 25 mg/l $CaCO_3$, benthic communities are not dominated by insect taxa (WEBB *et al.*, 1998). The density and diversity of macroinvertebrates is generally higher in permanent springs, such as the springs of the Cetina and Ruda. However in some springs that occasionally run dry, the density of some taxa (Diptera and Ephemeroptera) may be higher, due to their capacity for fast colonization (GLAZIER & GOOCH, 1987).

At the Peruča reservoir, the dominant substrate is mud, and the sampling location was near the dam. Insect larvae that could be present in the substrate are lacking, and even if they were present (having drifted there), they are probably located in the substrate at the beginning of the reservoir. Drift densities are usually higher in the summer and spring (SCHREIBER, 1995) and lower in the winter (SHEARER *et al.*, 2002). High oscillation in water flow and physico-chemical parameters in Peruča Reservoir may have a negative impact on the macroinvertebrate community (CAZAUBON & GIUDICELLI, 1999).

In the middle reach, at sites Trilj I and Trilj II, the dominant taxa were Oligochaeta and Chironomidae. In general, the high population density of the above men-

tioned groups indicates high organic pollution (VIĐINSKIENË, 2005). Even though these two localities are similar to Peruča Reservoir in terms of substrate type, diversity was higher than in Peruča Reservoir, possibly due to the high oscillations in water level and physico-chemical parameters in the latter (CAZAUBON & GIUDICELLI, 1999). The previous study showed a similar macroinvertebrate community structure in the middle reach of the Cetina River. The anthropogenic influence in the form of abiotic factors such as the untreated reception of wastewater and flow regulation, have a negative impact on the ecosystem in this part of the Cetina River (CORTES *et al.*, 2002).

At Radmanove Mlinice, the sampling site in the lower reach, the benthic community was dominated by Gastropoda, coleopteran larvae and Ephemeroptera. Prior studies of the gastropods have shown that their population density is related to the biomass of macrophytes (CALOW, 1973; VINCENT *et al.*, 1991; COSTIL & CLEMENT, 1996). Accordingly, in the present study the highest gastropod population density was observed at the site with the largest biomass of macrophytes and mosses.

Benthic community structure at some of the investigated sites in Cetina River was noticeably influenced by the flow regulation. Changes in taxonomic and functional composition of benthic assemblages are expected (BOYERO, 2003). Different taxa usually respond in a particular way to flow regulation (WARD & STANFORD, 1979). According to the observed community structure the sites in the middle reach appear to be mostly influenced by flow regulation measures (CORTES *et al.*, 2002; WARD & STANFORD, 1979). RADER & BELISH (1999) found that most mayflies, simuliids, and some stoneflies and caddisflies were the least tolerant of low flow conditions, while chironomids and ostracods were the most tolerant.

During the entire study, throughout the 13 months, variations in the density of macroinvertebrates were recorded. Overall, the density of macroinvertebrates depends on the life cycle, specific behaviour, and may also be reduced by the alteration of biological conditions in the habitat (BÊCHE *et al.*, 2006). In order to obtain a detailed insight into the composition and structure of macroinvertebrate communities and their differences in various reaches of the river, a comprehensive study of macroinvertebrate community needs to be conducted.

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SAŽETAK

Sastav i struktura zajednica makrozoobentosa mediteranske krške rijeke Cetine i njene pritoke Rude

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Istraživanje bentičkih beskralježnjaka rijeke Cetine i izvorišnog dijela rijeke Rude provedeno je u razdoblju od kolovoza 2004. do kolovoza 2005. godine na 11 postaja. Mjerne postaje nalazile su se duž cijelog toka rijeke Cetine i na izvorišnom dijelu njezine najveće pritoke, rijeke Rude. Uzorci su prikupljani s triju različitih podloga

Surberovom mrežom te na postajama akumulacija Peruča, Trilj I i Trilj II kracer mrežom. U istraživanom razdoblju, u 366 uzoraka ukupno je prikupljeno 310225 jedinki. Najbrojnije su bile skupine Amphipoda i Gastropoda, i to u gornjem i srednjem dijelu toka, dok je u donjem dijelu toka najbrojnija skupina bila Gastropoda. Najveća gustoća makrozoobentosa bila je na gornjem dijelu toka, na postaji Preočki most u lipnju 2005. godine (22728 jedinki/m^2), a najmanja na postaji na donjem dijelu toka, Radmanove mlinice (90 jedinki/m^2), u studenom 2004. godine. Na postajama Trilj I i Trilj II najzastupljenije su skupine Oligochaeta i Chironomidae koje su karakteristične za organski opterećenije vodotoke. Sastav zajednica makrozoobentosa na postajama duž toka rijeke Cetine ne odražava situaciju kakvu bismo očekivali u prirodnim uvjetima, zbog regulacije samog toka i izgradnje hidroelektrana i akumulacija.