

ACTA CARSOLOGICA	30/2	18	257-265	LJUBLJANA 2001
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COBISS: 1.01

**RATIO OF COPEPODS (CRUSTACEA: COPEPODA)
IN FAUNA OF PERCOLATION WATER IN
SIX KARST CAVES IN SLOVENIA**

**DELEŽ CEPONOŽCEV (CRUSTACEA: COPEPODA) V FAVNI
PRENIKLIH VODA V ŠESTIH KRAŠKIH JAMAH V SLOVENIJI**

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Prejeto / received: 4. 10. 2001

Izvleček

UDK: 595.34:551.44(497.4)

Tanja Pipan & Anton Brancelj: Delež ceponožcev (Crustacea: Copepoda) v favni preniklih voda v šestih kraških jamah v Sloveniji

Predstavljena je podzemna favna v prenikli vodi in v lužah, ki se polnijo s preniklo vodo v šestih kraških jamah v Sloveniji in je bila nabrana v obdobju 2000/2001. Prikazanje delež ceponožcev (Crustacea: Copepoda) v vzorcih favne. Vzorci so bili pobrani iz štirih različnih tipov vodnih teles: curek vode, ki priteče s stropa, luže na kapniku, ki se neposredno polnijo iz curka, luže s pretežno ilovnatim dnom ter luže na zasiganem dnu rova, polnijo pa se izključno s preniklo vodo. Favnišični podatki so dopolnjeni s podatki o geološki sestavi in geografskem položaju jam, o hidrologiji, o fizikalnih in kemijskih lastnostih vode ter tipu vegetacije nad jamo.

Ključne besede: Copepoda, ceponožci, jame, prenikla voda, kras, Slovenija.

Abstract

UDC: 595.34:551.44(497.4)

Tanja Pipan & Anton Brancelj: Ratio of copepods (Crustacea: Copepoda) in fauna of percolation water in six karst caves in Slovenia

Hypogean fauna from percolation water and from puddles, filled with percolation water from six cave systems in Slovenia, was studied in the period 2000/2001. Special attention was given to the ratio of copepods (Crustacea: Copepoda) to the other taxa in the samples. Four categories of small water-bodies were distinguished: direct water jets from the ceiling, permanent small depressions on stalagmites filled with water, puddles on clay and puddles on calcareous sinter. Faunal data are supplemented with other information, including geographical position of the caves, physical and chemical parameters of water quality, cave roof thickness, geological structure of the limestone strata, hydrology and vegetation above the caves.

Key words: Copepoda, caves, percolation water, karst, Slovenia.

INTRODUCTION AND BACKGROUND

Copepods (Copepoda) is a rich group of 0.5 to 2 mm large crustaceans which species inhabit various subterranean waters. Chappuis (1928, 1936) and Kiefer (1930, 1931, 1933) were most important specialists who contributed to the knowledge to the cave-dwelling Copepoda on the territory of Slovenia before the Second World War. After the War, Petkovski (1983, 1984) additionally contributed to knowledge about them. More intense research of the copepod fauna in Slovenia was conducted after 1985, including in caves. By the end of 2000, 106 species and subspecies were registered in the territory of Slovenia, including about 40 cave-dwelling species. The number consistently grows, mainly on account of underground habitats providing ever new species (Brancelj, 2000a, b). Many of them are limited only to Slovenia (endemics), and often to a single location. So far about 15 such species are known (Brancelj & Pipan, 2001). The paper illustrates the ratio between two groups of Copepoda in selected caves: the Cyclopoida and the Harpacticoida. The quantitative ratio of the copepods is presented, in relation to other groups living in tricklets of the percolation water as well as the differences between the samples collected in the puddles of the six karstic caves. Results of the copepod fauna research are supplemented with data on the thickness of the cave ceilings, the exterior vegetation cover and the water's physical and chemical properties.

THE STUDY AREA

The **Postojnska Jama Cave System** is the longest cave system in Slovenia (about 20.000 m of galleries) and cave **Postojnska Jama** is a part of it. It has 13.500 m galleries, which are built by the Upper Cretaceous carbonate rocks (Šebela, 1995). Beside Postojnska Jama the system includes also caves **Pivka Jama** and **Črna Jama**, which are the part of the investigated region. In Pivka Jama the thickness of the cave ceiling above the sampling points is between 45 m and 70 m. A tourist camp is built above the cave. The area above Črna Jama is mostly covered with coniferous forest. The thickness of the ceiling above the five sampling points in Črna Jama varies between 30 m and 60 m. The entire area above Postojnska Jama is also mainly fir forest, and the cave ceiling's thickness above the sampling points ranges from 30 m up to 90 m. Accessible channels of **Škocjanske Jame** were developed in Turonian and Senonian, mostly thick-bedded limestones, with exception of Tiha Jama, built in thin layered Cretaceous and Paleocene limestone (Kranjc et al., 1997). In Škocjanske Jame the thickness of the cave ceiling above the sampling points varies between 60 m and 110 m. The vegetation above the cave is diverse, ranging from grassland and shrubs to mixed forest. Cave **Županova Jama** was developed in bedded limestone of NE synclinal wing. The cave has two fossil levels 450 and 425 a. s. l. hanging in the karst ridge (Gospodarič, 1987). The thickness of the cave ceiling in Županova Jama, at the points where we collected samples of percolation water, ranges from a minimum 15 m to a maximum 50 m. The cover above the cave is mainly deciduous forest. In cave **Dimnice** the ceiling's thickness ranges from 10 m to 70 m. The vegetation cover above the cave is mainly coniferous forest (mostly fir). The entrance to the cave is in a doline, where the stairs lead in 35 m deep pothole. The cave was developed in the upper cretaceous rocks.

MATERIAL AND METHODS

The sampling places were selected during the dry season, so that the choosen tricklets of the percolation water were present all the year round. In caves Postojnska Jama, Pivka Jama and Črna Jama jets of the percolating water were filtered into container permanently for half of the year. Samples of fauna as well as samples for water quality analysis were collected each week from the container. In the other three caves the frequency of collecting samples from the containers was done once a month. In Postojnska Jama ten tricklets (i.e. ten sampling points) were selected. In the other caves we selected five tricklets. The tricklets samples were collected through a funnel into plastic containers with holes on two sides covered with a net (mesh size 60 μm) to retain animals in the container. The content of the plastic containers was fixed with 4% formaline at the sampling spot and stored for further processing. In the laboratory we separated by means of stereomicroscope the organisms at 40x magnification and stored them in a 70% ethanol. Further processing and identification of the organisms was performed under a microscope.

Samples from puddles were collected separately into plastic containers by means of an adjusted sucking pump. We pumped various quantities of the puddle water at the different sampling points and filtered it through a 60 μm net. The samples were then processed in the same way as those from the tricklets.

PHYSICAL AND CHEMICAL SETTING

The pH value, temperature and conductivity at the individual sampling points inside the caves did not change during the nine-month sampling periods. Differences between the caves are presented in Table 1. The main differences occurred in the measured discharge, which is a result of the dry or rainy season. The thickness of the cave ceilings connected to the surface vegetation and soil permeability, also influence the discharge values. The highest discharge were measured in November 2000 and the lowest discharge in June and September 2000, during the dry season.

Table 1: Minimum and maximum values for some of the physical and chemical parameters, measured in six caves between April and December 2000.

Tabela 1: Najnižje in najvišje vrednosti nekaterih fizikalnih in kemijskih parametrov v šestih jamah, merjeno od aprila do decembra l. 2000.

CAVES:	$T_{\min} - T_{\max}$ (°C)	Conductivity ($\mu\text{S cm}^{-1}$) min-max	$\text{pH}_{\min} - \text{pH}_{\max}$	Discharge (ml min^{-1}) min-max
ŽUPANOVA JAMA	8.3-8.8	290-490	7.4-8.0	1-64
ŠKOCJANSKE JAME	10.3-12.6	186-384	7.4-8.2	1-514
DIMNICE	6.1-6.9	299-446	7.0-8.1	1-163
POSTOJNSKA JAMA	5.7-10.4	322-464	7.4-8.8	2-291
CAVE SYSTEM				

BIOTA IN THE PERCOLATION WATER

In addition to copepods in the percolation water samples there were numerous Nematoda and Oligochaeta and few specimens of Turbellaria, Gastropoda, Acarina, Ostracoda, Isopoda, Amphipoda, Myriapoda and dipteran larvae. The absolute number of all the organisms in the percolation water samples in individual caves correlated to the measured discharge values. After the greatest measured discharge (64 ml min^{-1}) in November 2000 in Županova Jama we registered the greatest abundance; primarily adult copepods and their nauplia. The next most frequent organisms were the Nematoda. A slight lapse occurred in Škocjanske Jame. The greatest abundance was registered in December 2000, although the greatest discharge (514 ml min^{-1}) was measured in November. Copepods prevailed in Škocjanske jame too (60% Copepoda out of 104 total specimens present); with Harpacticoida being the most abundant (87% out of the 62 Copepoda). In Dimnice the greatest number of specimens in the sample (47) was registered during the highest discharge (163 ml min^{-1}) in November 2000. The majority were dipteran larvae (Chironomidae) (51%) and copepods (19%). In Postojnska Jama the percolation water samples were poor by the number of organisms; the absolute number of the richest sample did not exceed 6 (2 Turbellaria, 1 Oligochaeta, 2 Harpacticoida, 1 larvae of Diptera). Among a total number of 234 organisms during the highest discharge in Pivka Jama (291 ml min^{-1}) in November 2000, 87% of all the organisms were copepods (40% nauplia, 38% Harpacticoida and 9% Cyclopoida). In the percolation water samples in Črna Jama in November 2000, 92% of the organisms belong to copepods

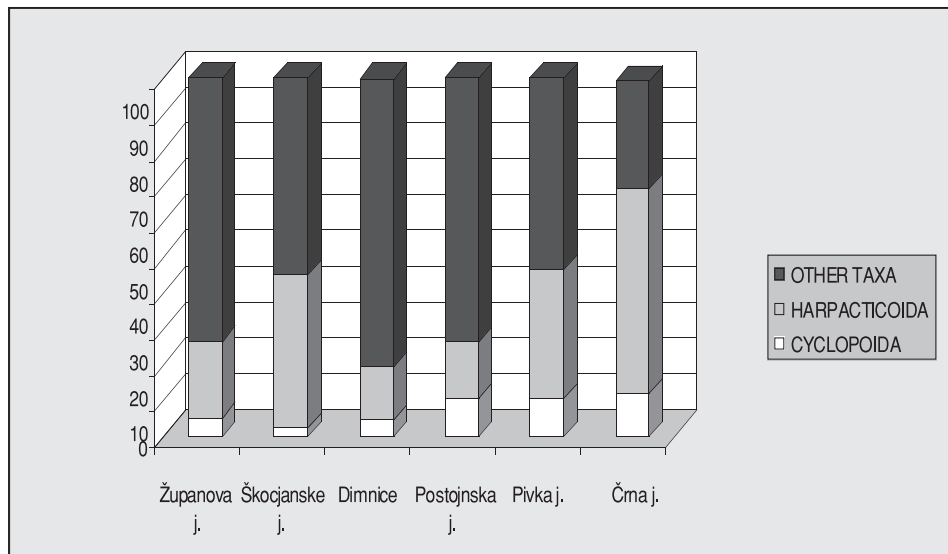


Fig. 1: Percentage of copepods in the samples of fauna of percolation water of the six caves. Monthly sampling from April to December 2000.

Sl. 1: Odstotek ceponožcev v vzorcih favne iz prenikle vode šestih jam. Mesečno vzorčenje od aprila do decembra l. 2000.

(57% Harpacticoida, 24% nauplia, 11% Cyclopoida), at a discharge of 75 ml min⁻¹ and a total abundance of 175 organisms.

BIOTA IN PUDDLES

In the samples collected from puddles, there were in addition to copepods, numerous specimens of Nematoda and Oligochaeta and individual specimens of Turbellaria, Gastropoda, Acarina, Ostracoda, Isopoda, Amphipoda and dipteran larvae. The assemblages in the puddles were more abundant, compared to those in tricklets of percolation water. In Županova Jama we obtained 119 specimens from 50 l of water filtered in September 2000 of which 77% were copepods. Of the 95 specimens filtered from 13 l in November 2000 93% were copepods. In the 75 l of water filtered in Škocjanske Jame during autumn, 82% of the total 143 specimens were copepods and nauplia. In the second sampling in the beginning of winter 75% of the 274 specimens filtered from 160 l of water were copepods. In the 23 l of water filtered in Dimnice in September 2000, 33% out of the 300 specimens were copepods. Two months later, their number increased to 95%. In total 275 specimens were filtered from 73 l of water. In the puddles of Postojnska Jama we, like in the tricklets, found less specimens compared to other caves, but their relative frequency was similar. Out of the 97 specimens filtered from 17 l of water in Pivka Jama, 77% were copepods and from 40 l of water, filtered in Črna Jama, 93%, out of the 110 specimens, were copepods.

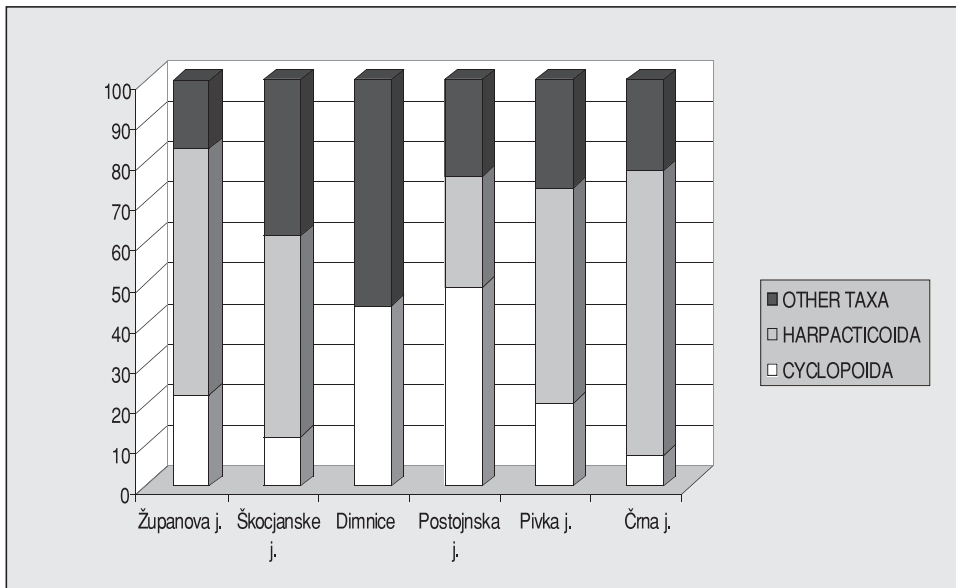


Fig. 2: Percentage of copepods in the samples of fauna from the puddles of the six caves. The samples were taken in August and November 2000.

Sl. 2: Odstotek ceponožcev v vzorcih favne iz luž šestih jam. Mesečno vzorčenje od aprila do decembra l. 2000.

CONCLUSIONS

The intensive survey of two different habitats in six karst caves showed that ratio of copepods in the tricklets of the percolation water is different than in the puddles filled with this water. It is important that in both habitats we found the same groups of specimens, which differed only in the frequency of their occurrence. Direct comparison between both habitats is difficult, because among other reasons also different quantities of water were filtered. In the jets of percolating water Harpacticoida prevailed over the Cyclopoida, while in the puddles it was opposite. High number of specimens and different ratio between Harpacticoida and Cyclopoida in the puddles could be a result of propagation of the copepods in the puddles. This could also explain high number of Copepoda over other groups of organisms in the puddles. On average up to 80% of the specimens, collected in the puddles were copepods, the rest belonged to other groups of specimens. In the tricklets of the percolation water the percentage of copepods was on average below 40%.

Among the six caves included in the research, Postojnska Jama deviates from general pattern concerning the frequency of specimens. We suspect that the cleaning of the flowstone with chemicals in the cave affects the number of the specimens. This is not an insignificant fact - in Pivka Jama and Črna Jama, which are a part of the same cave system, but not of interest for tourism, we recorded high populations of the specimens. As regards physical characteristics, the number of specimens in the samples correspond to the discharge values. This relation is also present in the puddles samples and changes only at very high flows resulting from abundant rainfall. We presume that in this case the specimens that otherwise reside in the smaller bowls are being washed out.

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DELEŽ CEPONOŽCEV (CRUSTACEA: COPEPODA) V FAVNI PRENIKLIH VODA V ŠESTIH KRAŠKIH JAMAH V SLOVENIJI

Povzetek

V prispevku je prikazano številčno razmerje med dvema skupinama rakov skupine Copepoda in sicer Cyclopoida in Harpacticoida, v posameznih jamah. Predstavljen je tudi delež ceponožcev v celotni sestavi vzorcev favne, posebej v curkih penikle vode in v lužah, ki jih ta oblikuje. Podatki o relativni pogostosti ceponožcev so dopolnjeni s podatki o debelini jamskega stropa, nadzemni pokrovnosti ter fizikalnimi in kemijskimi lastnostmi vode.

V Postojnski jami, Pivki jami in Črni jami je vzorčenje potekalo intenzivno in sicer vsak teden. Odvzeli smo vzorce favne in vzorce vode za kemijske analize. V ostalih jamah smo odvzemali vzorce mesečno. Razen v Postojnski jami, kjer smo imeli izbranih deset curkov in s tem vzorčnih mest, smo v ostalih jamah izbrali po pet curkov. Curke smo zbirali skozi lij v plastenko, ki je imela na dveh straneh odprtine, prevlečene z gosto mrežico (mlinarska svila) (60 μ m). Ob vzorčenjih smo vsebino iz plastenke fiksirali z dodatkom formalina, do končne 4% koncentracije in shranili za nadaljnjo obdelavo. V laboratoriju smo vzorce ponovno prefiltrirali skozi 60 μ m mrežico, pri 40x povečavi smo osebke ločili med seboj in jih shranili v 70% etanolu. Nadaljnje določevanje osebkov je potekalo pod mikroskopom. Vzorce iz luž smo ločeno zbirali v 5 l plastenko, s pomočjo posebej prirejene sesalne črpalke. Na vsakem vzorčnem mestu smo posesali različno količino vode iz luž. Usedlino na dnu luže smo predhodno premešali, posesano vodo nato precedili skozi 60 μ m mrežico, vzorec pa obdelali po enakem postopku kot pri curkih.

Sistematični pregled dveh različnih habitatov v šestih kraških jamah je pokazal, da je razmerje ceponožcev v penikajoči vodi različno od tistega v lužah, ki se polnijo s penikajočo vodo. Pomembno je dejstvo, da smo v obeh habitatih našli zastopane iste skupine živali, razlike so bile le v pogostosti pojavljanja. Za curke penikajoče vode je značilno, da so v vseh jamah prevladovali Harpacticoida, medtem ko so v lužah visok odstotek dosegli Cyclopoida, v Dimnicah in Postojnski jami celo večjega od Harpacticoida. Veliko število ceponožcev v lužah in obratno razmerje med Harpacticoida in Cyclopoida v obeh habitatih je lahko posledica razmnoževanja v lužah. Podobno lahko razložimo tudi višji delež ceponožcev v favni luž. V vzorcih iz luž so v povprečju do 80% vseh živali zavzemali ceponožci. V curkih penikajoče vode je bil odstotek, ki je pripadal rakom

Copepoda, v povprečju nižji od 40%. Med šestimi proučevanimi jamami odstopa glede na pogostost pojavljanja ceponožcev Postojnska jama. Domnevamo, da na nizko število osebkov v Postojnski jami vpliva čiščenje kapnikov, s pršenjem kemikalij po jami. To dejstvo ni zanemarljivo, saj smo v Pivki jami in Črni jami, ki spadata v sistem Postojnskih jam, pa nista turistično zanimivi mesti, zabeležili zelo veliko število živali. Pri višjih pretokih, kot posledica padavin, je bila gostota osebkov v precejani vodi določenega curka višja. Ta odnos je prisoten tudi pri lužah, poruši se le pri zelo visokih pretokih, ki so posledica velike količine padavin. Domnevamo, da takrat pride do odplavljanja živali, ki se sicer zadržujejo v manjših kotanjicah in lužah.