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KARST GROUNDWATER CONNECTIONS IN THE VALLEY OF THE SEVEN TRIGLAV LAKES

PODZEMELJSKE VODNE ZVEZE V DOLINI SEDMERIH JEZER

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Anton Brancelj & Janko Urbanc: Podzemeljske vodne zveze v Dolini sedmerih jezer

Predstavljeni so rezultati seldilnega poskusa v visokogorskem Jezeru v Ledvici (Dolina sedmerih jezer). Sledilni poskus je potrdil obstoj vodne zveze med Jezerom v Ledvici, Močivcem in Dvojnim jezerom. Prispevek se ukvarja tudi s primerjavo značilnosti favne in flore v posameznih triglavskih jezerih, ki se glede tega med seboj precej razlikujejo. Zaenkrat še ni jasne razlage tega pojava; predlagane so tudi nadaljnje raziskave, ki naj bi te pojave bolje pojasnile.
Ključne besede: fauna, flora, fitoplankton, visokogorsko jezero, kras, izvir, sledenje, uranin.

Abstract UDC: 556.55:556.34

Anton Brancelj & Janko Urbanc: Karst groundwater connections in the valley of the Seven Triglav Lakes

Results of a tracing test in the high mountain lake of Jezero v Ledvici (Triglav Lakes area) are presented. The tracing experiment proved hydraulic connections between lakes Jezero v Ledvici, Močivec and Dvojno jezero. The article also deals with a comparison of the faunistic and floristic characteristics of the Triglav lakes. The occurrence of biotic species in different lakes is not very similar. No clear explanation for this phenomenon was found up to now, so further investigations of this system are proposed.
Key words: fauna, flora, plankton, high-mountain lake, karst, springs, tracing, uranin.

INTRODUCTION

The Triglav Lakes Valley contains seven small lakes, located at elevations from 2000 m to 1325 m a.s.l. The lakes are arranged in a chain with no surface water-flow connections and no surface outlets. Up to now, no hydrogeological investigations have been carried out in the area, which would give us some idea about the nature of water circulation between the lakes and also about individual lake water dynamics. So, the aim of our research was to determine possible hydraulic connections between the lakes and to compare results with the faunistic and floristic characteristics of the lakes.

GENERAL DESCRIPTION OF THE TRIGLAV LAKES AREA

The Triglav Lakes area is comprised mainly of Triassic and Jurassic carbonate rocks (Ramovš, 1974, Buser, 1986, Jurkovšek, 1986). Triasic limestones are very intensively karstified. Due to their marl component, the Jurassic rocks are rather impermeable and played a great role in the formation of the Triglav lakes. Some Pleistocene sediments and Holocene gravel can also be found in this area.

The biggest lake in the valley is Jezero v Ledvici (area 2.33 ha, max. depth 14 m, volume about 135 000 m^3). The lakes in the area were measured by Gams (1962) who did not mention a sinkhole on the southern bank of lake Jezero v Ledvici. The sinkhole is filled with boulders, but the water flow into it is well discernible. 170 m lower and 2000 m south of the lake is located the Močivec spring (elevation of 1690 m) with an unknown water source (average flow is about 10 l/s). Around the year 1930 a dam was built in the valley downstream for water supply for a near-by alpine hotel. The lake behind the dam is about 100 m long, 10 m wide and 2 m deep. Surplus water from the Močivec flows on the surface for about 100 m and disappears into a sinkhole with unknown direction. After heavy rain or snowmelt part of the water from the spring flows directly into lake Dvojno Jezero which is about 10 m below the spring and about 100 m south of the sinkhole.

Lake Dvojno Jezero has two basins (northern and southern basin) which are interconnected only during high water level. The northern basin is bigger (area of 0.5 ha, maximum depth of 8 m). On the SW bank there is a sinkhole with unknown underground connections.

A small spring (named Izvir pod Rušnato Glavo; 1660 m a.s.l., average discharge about 1 l/s) is located in an alpine forest 1100 m south of the Močivec spring. It has a short surface flow of about 500 m, falls over the cliff and sinks into gravel.

TRACING EXPERIMENT

A tracing experiment was carried out in Jezero v Ledvici, the largest among the seven Triglav lakes. Six kilograms of uranine were injected in the north-easternmost part of the lake on 9th June,1999 between 16 and 18 PM.

The dye spread along the lake for two days, so that on 11th June the water was rather evenly coloured over the whole lake. Then the colouring disappeared rather quickly and on 14th June the colour was no longer perceptible with the unaided eye.

The appearance of tracer in the lower lakes and in the spring is illustrated in Figure 1.

The tracer was most explicitly evident in the Močivec spring above the hotel at the Triglav lakes. The concentration varied considerably and reached more than 9 µg/l on 15th June.

The tracer appeared in lake Dvojno Jezero on 15th June and the highest value was measured on 18th June. It is interesting that in spite of the distance being only about one hundred metres the highest tracer concentration was reached three days later than in Močivec. This fact could lead to the conclusion that the hydraulic connection between the lakes Jezero v Ledvici and Dvojno Jezero is not as direct as between Jezero v Ledvici and Močivec.

No tracer was found in lake Črno Jezero. The lake is apparently situated completely out of the main path of ground water flow from the central and upper part of the Triglav lakes valley.

A slight occurence of the tracer was also found in the spring of the Savica waterfall. Uranine concentration reached its peak on 18th June, but it did not exceed 1 mg/l. Lower tracer concentrations are the result of dilution due to large quantities of ground water inflow. However, higher background concentrations of tracer were determined in the Savica water. These results can be related to previous tracing experiments, carried out in various parts of the Triglav area. (Trišič et al., 1997).

BIOLOGICAL OBSERVATIONS

In the period from 1991 to 1999, an intensive study of fauna and flora of the lakes and springs in the valley was performed. Investigations were focused particularly on different groups of algae (including diatoms) and microcrustaceae (particularly Copepoda and Cladocera). A complete list of taxa was made for each lake and reservoir (Brancelj *et al*., 1995; 1997) For lake Jezero v Ledvici about 100 different taxa (species) of algae and animals were found and a similar number of taxa was recorded in lake Dvojno Jezero. In the Močivec reservoir, which is actually a dammed spring, somewhat less diverse biota was recorded due to specific environmental conditions (water-level and temperature oscillations).

The flora and fauna found in the lakes Jezero v Ledvici, Dvojno Jezero and Močivec could be divided into three ecological groups which have influence on active and passive dispersion of organisms along epigean and subterranean water courses. Benthic organisms are in contact with the substrate, being free moving or sesile. The majority of organisms in the mentioned lakes belong to this, i.e. benthic group. The next group is a relatively small group of planktonic species, which could be easily transported downstream by water flow. In most rivers originating from lakes, planktonic organisms are an allochthonous, but constant element of material, transported by water flow. The third group of organisms are so-called water insects. Part of their life cycle (egg and larva) is connected to water, whilst adults can fly from one location to another, searching for mates and/or places for egg deposition.

Our hypothesis was that lakes with more intensive water-flow connection have a higher percentage of species in common originating from the upstream lake. We also took into consideration the ecological peculiarity of each group of organisms (benthic *vs*. planktonic *vs*. "amphibian").

Parallel to the tracing experiment, we made a detailed analysis, based on recent data and data from the literature, of water flora and fauna in lake Jezero v Ledvici as well as in both the near-by down-stream lakes Močivec and Dvojno Jezero. Groups of special interest were algae (Cyanobacteria, Chlorophyta and Bacyllariophyta), microinvertebrates (Cladocera, Copepoda,

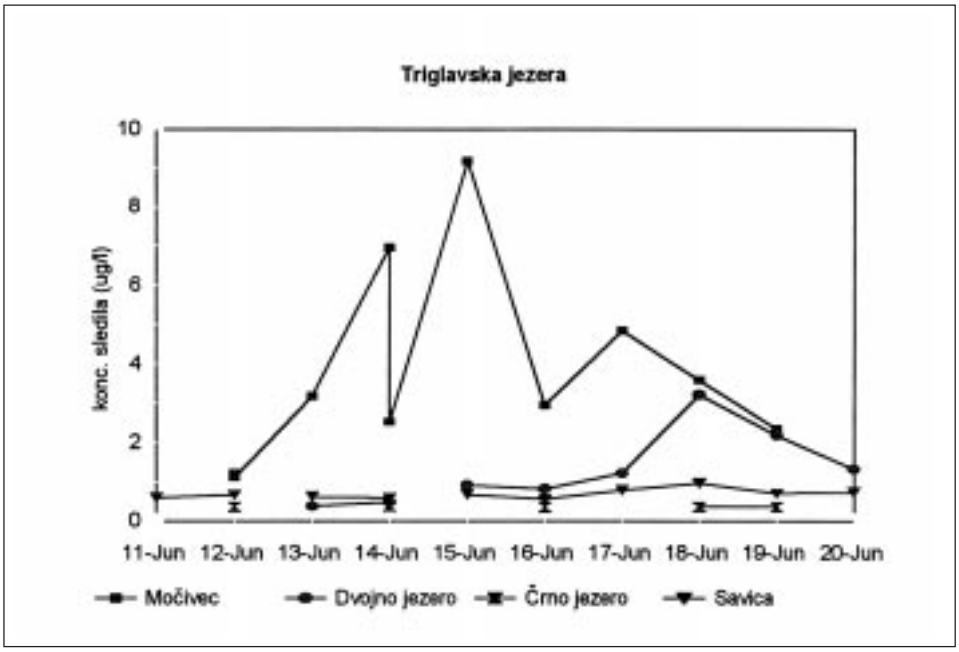

Fig. 1: Concentration of the dye (uranine) in different lakes and springs in the valley of the Seven Triglav lakes in the period from June 11 to June 20 (injection on June 9, afternoon).
Sl. 1: Koncentracija sledila (uranina) v posameznih jezerih v Dolini sedmerih jezer med 11.6. in 20.6. (injiciranje sledila 9.6. popoldne).

Ostracoda) and macroinvertebrates (Amphipoda, Ephemeroptera, Colleoptera and Trichoptera). We compared lists of flora and fauna of each lake and calculated the percentage of species in common versus the total number of species found in all three lakes. In the next step, we compared in the same way lake Jezero v Ledvici with the Močivec reservoir and lake Dvojno Jezero, as well as Močivec reservoir with lake Dvojno Jezero.

Dyeing proved connections between lake Jezero v Ledvici and the down-stream spring and reservoir of Močivec and lake Dvojno Jezero. Due to karstic geology, connections are subterranean. Water needs a relatively long time to travel between the lakes (see Fig. 1). From about 140 taxa of Cyanophyta, Chlorophyta and Bacyllariophyta recorded in lakes Jezero v Ledvici, Močivec and Dvojno Jezero (Brancelj et al., 1995) less than ten species are common to all three lakes (Table 1). The number of species, present only in the up-stream water body is relatively high in algae (ranging from 25 - 50%; Table 2). This indicates that passive transport via underground connections is very unlikely for plants (i.e. algae) and surface connections are very restricted. As lake Jezero v Ledvici is about 170 m higher than the Močivec reservoir and lake Dvojno Jezero, some ecological factors (particularly light and temperature) could be a limiting factor for survival of some algae species. But, according to our knowledge of ecology of algae inhabiting the three lakes under discussion, no species with such restrictions are present in the lakes.

In animals, which are much more mobile and more resistant to transport through subterranean galleries (Sket and Bole, 1981), results are slightly different. Within 7 groups of animals with 37 species in total, one third (=12 taxa) are common to all three lakes (Table 1). Considering only water-dwelling organisms (24 taxa; without insects) the results do not change much. Comparing the number of species in common for the two lakes, and the number of species present only in the up-stream lake it is evident that 16 - 33 % of species could be found only in the up-stream lake (Table 2). This suggests that among animals there are some connections between the lakes including underground transport. However, exchange with down-stream lakes is probably restricted as a result of the weak and lengthy water exchange. In nature, there is about a 2 km aerial distance between Jezero v Ledvici and the Močivec reservoir. Between the Močivec reservoir and lake Dvojno Jezero there is additionally about 100 m distance.

Most indicative is the absence of two planktonic species, *Daphnia longispina* and *Arctodiaptomus aplinus,* both very abundant in the summer in lake Jezero v Ledvici, from lake Močivec. Both species are usually very common in drift from the lakes. Both species can persist in underground streams for a short period, particularly their eggs, which could afterwards hatch in favourable conditions. Additionally, *Daphnia longispina* is absent from lake Dvojno Jezero but not *Arctodiaptomus alpinus*.

Table 1: Number of species of particular taxonomic groups and number of species in common in the Triglav Lakes.
Tabela 1: Število vrst posameznih taksonomskih skupin in število vrst, ki se pojavljajo v vseh triglavskih jezerih.

Taxon	**Ledvica (No. of taxa)**	**Močivec (No. of taxa)**	**Dvojno (No. of taxa)**	**Total No. of taxa**	**No. of taxa in common**
FLORA					
Cyanophyta	20	15	29	47	4
Chlorophyta	18	16	24	46	1
Bacyllariophyta	24	14	30	47	4
FAUNA					
Cladocera	4	2	5	6	2
Ostracoda	1	2	3	3	1
Copepoda	9	8	9	14	5
Amphipoda	1	1	1	1	1
Ephemeroptera*	1	2	2	2	1
Colleoptera*	3	1	3	5	0
Trichoptera*	4	5	2	6	2

** groups of Insecta.*

Table 2: Number of species of particular taxonomic groups and percentage of species in common in three pairs of the lakes of the Triglav National Park (Jezero v Ledvici, Močivec and Dvojno Jezero). In parenthesis the number of species present only in up-stream water is indicated.
Tabela 2: Število vrst posameznih taksonomskih skupin in delež vrst v treh parih jezer v Triglavskem narodnem parku (Jezero v Ledvici, Močivec in Dvojno jezero); v oklepaju je število vrst, ki se pojavljajo samo gorvodno.

Taxon	**Ledvica : Močivec** (No. of taxa)	% of taxa in common	**Ledvica : Dvojno** (No. of taxa)	% of taxa in common	**Močivec : Dvojno** (No. of taxa)	% of taxa in common
FLORA						
Cyanophyta	31 (14)	16.1	39 (9)	25.6	39 (8)	15.4
Chlorophyta	32 (15)	6.3	36 (12)	14.0	34 (10)	17.7
Bacyllariophyta	33 (19)	15.2	41 (9)	24.4	36(6)	22.2
FAUNA						
Cladocera	4 (2)	50.0	6 (1)	50.0	5 (0)	40.0
Ostracoda	3 (1)	33.3	2 (1)	50.0	2(1)	50.0
Copepoda	12 (4)	41.7	11 (2)	45.5	12 (3)	41.7
Amphipoda	1 (0)	100.0	1 (0)	100.0	1 (0)	100.0
Ephemeroptera*	2 (0)	50.0	2 (0)	50.0	2 (0)	100.0
Colleoptera*	4 (3)	25.0	4 (1)	50.0	4 (1)	25.0
Trichoptera*	6 (1)	50.0	4 (0)	50.0	5 (3)	40.0

** groups of Insecta.*

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PODZEMELJSKE VODNE ZVEZE V DOLINI SEDMERIH JEZER

Povzetek

Sledilni poskus v Dolini sedmerih jezer je dokazal obstoj vodne zveze med Jezerom v Ledvici, Močivcem in Dvojnim jezerom. Črno jezero ima drugo območje napajanja in ni povezano z glavno mrežo podzemnih kanalov. V prvih treh medsebojno povezanih jezerih je bilo ugotovljeno malo podobnosti v vrstni sestavi flore in favne. Od skupno 140 opaženih vrst alg se le 9 rodov pojavlja v vseh treh jezerih, od 27 živalskih vrst pa je v vseh treh jezerih prisotnih 12. Majhno število vrst, ki se pojavljajo v vseh treh jezerih, lahko pojasnimo s primerjavo jezer in izvirov oziroma njihovega zaledja. Ekološke razmere, kot so temperatura, pretok vode in nihanja gladine vode, koncentracija hranil itd., so v posameznih vodnih masah precej različne, kar večini vrst avtomatično onemogoči pojavljanje gorvodno. Nasprotno pa je razmeroma težko pojasniti tako velike razlike med obema jezeroma. Zelo verjetno je, da določeni ekološki parametri, ki niso bili vključeni v študijo, igrajo pomembnejšo vlogo pri kolonizaciji dolvodnega jezera, kot smo predpostavljali. Vsekakor so potrebna nadaljnje raziskave. Posebno pozornost je treba posvetiti študiju migracije vrst med jezeroma oziroma skozi zaledje v jezero. Zato je treba tudi natnačno določiti dotoke vode v Dvojno jezero iz Jezera v Ledvici in iz Močivca. Tudi vodno zvezo med Močivcem in Dvojnim jezerom je treba bolje raziskati. Sledilni poskus je pokazal, da ta ni tako neposredna kot bi lahko pričakovali glede na majhno razdaljo med jezeroma.