Proteus survival close to an industrial, agricultural and urbanized basin – the case of Kočevsko polje

Preživetje človeške ribice na meji močno industrializiranega, kmetijskega in urbaniziranega prostora – primer s Kočevskega polja

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Together with interconnected Ribniško polje, Kočevsko polje represents the biggest karst polje in Slovenia. Varied geological and geomorphological settings make it heterogeneous and hydrologically complex. Outflow from the middle part of Kočevsko polje is radial due to impermeable strata with thin layers of mined Pliocene brown coal. Water either flows underground directly toward the Radeščica (catchment of the Krka River) or to the Bilpa (catchment of the Kolpa River) via the Rinža River (Fig. 1). The latter forms a parallel hydrological system, draining the waters of the Stojna mountain ridge into sinks between Kočevje and Črni Potok. The presence of sulfide and its oxidation to sulfuric acid at the impervious Pliocene sediments generates highly undersaturated waters (aggressive with respect to calcite) that flow to the contact between non-carbonate and carbonate bedrock. As a result, several cave systems were formed near the settlements Željne, Mahovnik, and Klinja vas. More detailed information on hydro(geo)logy and speleology of Kočevsko polje is provided by Kranjc (1972), Kranjc & Lovrenčak (1981) and Novak (1974, 1987), while Kogovšek & Petrič (2010) provide an overview of all reliable underground water tracing tests in the region.

Anthropogenic pressure at Kočevsko polje is high due to the presence of Kočevje as a regional urban centre surrounded by a suburban belt (wastewater, solid wastes), coal mining (mine wastes; abandoned in 1978) and extensive agricultural production accompanied by intensive animal farming (fertilization, plant protection products, overuse of manure). Especially in the late 1960s, 1970s and 1980s, all of these activities devastated underground habitats which led to the elimination of extremely rich *Proteus anguinus* populations known from two caves (Jama v Šahnu and Vodna jama 1 pri Klinji vasi; Mramor 1968, Belšak 1973, Kranjc 1981). To support and direct concrete conservation actions within the LIFE project Kočevsko, the following research needs were identified:

- definition of current underground water quality and identification of the main polluters responsible for bad water quality,
- the degree of proteus' tolerance to pollution, and
- the use of a biospeleological inventory to estimate the ecological status of underground waters.

To address the first two topics, water was analyzed once per season during 2015/2016 in the stream caves of Kočevsko polje (Vodna jama pri Klinji vasi 1 and 3, Željnske jame, Velika and Mala Stankova jama, Vodna jama pri Cvišlerjih, and Jama v Šahnu), regional springs (Radeščica and Bilpa), and sinking streams (Rinža River, Remihov mlin; Fig. 1; Prelovšek 2016). Water temperature, electrical conductivity, and the saturation as well as the concentration of oxygen were measured in the field. Water samples were taken to the lab to determine alkalinity, as well as concentrations of Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, PO_4^{3-}, and Cl^-. Some parameters were calculated (calcite saturation index (SI_{Cal}), equilibrium CO_2 pressure (pCO_2) before and after CO_2 outgassing. Parameters were chosen to describe basic water quality, to roughly delineate catchment area and to identify possible present-day pollutants. At two sites formerly holding rich proteus populations (Jama v Šahnu and Vodna jama 1 pri Klinji vasi), continuous monitoring with an Eijkelkamp CTD Diver with 15-minute sampling interval was performed to get more details on pollution characteristics and sources.

In addition to known localities of proteus at Kočevsko polje (Trata quarter, springs at the foot of the Stojna mountain ridge), two new ones were identified: Velika Stankova jama and a sink near Remihov mlin. The latter, together with much better known Željnske jame, was severely degraded by several metres high deposits of coal washing material (Novak 1974) – during pollution these sites were not likely to be suitable for proteus and represent site where proteus were

naturally recolonized after mine closure. In the first lake of Velika Stankova jama, 2–5 animals per visit were usually observed despite poor water quality that may also be a result of an illegal deposit of 30–40 m^3 waste in Mala Stankova jama, located upstream. Observations in Jama v Šahnu and Vodna jama 1 pri Klinji vasi confirmed the absence of any proteus. Natural recolonization of proteus into the cave Jama v Šahnu (if some fraction of the population survived) is not likely due to:

- continued poor water quality as a result of organic pollution that reduced saturation with oxygen below 20% (1.83 mg/L),
- relatively high concentrations of Cl^- and PO_4^{3-} (up to 21.40 mg/L and 2.14 mg/L, respectively) indicating city and agricultural sources, and
- the occasional presence of fish specimens in water.

The source of pollution might be the settlement Spodnji Cvišlerji, which currently has no sewage system and probably drains through the cave (we detected occasionally very high pCO_2 characteristic of percolation water), agricultural production and the Rinža River. Underground flow of the Rinža River was identified by regular daily oscillations of water temperature for more than 1 °C during summer using the CTD Diver in the cave (daily temperature oscillation of percolation water should be in much narrower range) and underground stream discharge (several hundreds of litres per second) that can be supplied only by the Rinža River in Kočevje region. During low water level, underground connection of Jama v Šahnu and Rinža River was successfully proved by tracing test (Novak 1974). Proteus were never observed in Vodna jama 1 pri Klinji vasi despite much better quality of water in comparison with Jama v Šahnu and past conditions. Other caves do not seem to be favourable habitat for proteus due to small upstream water bodies characteristic of the shallow vadose zone and, in the case of Vodna jama pri Cvišlerjih, also severe ongoing pollution.

Despite significantly improved quality of the Rinža River water in the last decade, organic pollution levels are still too high for potential natural recolonization of proteus in the area of Jama v Šahnu. The problem of another source of pollution (untreated sewage water from Spodnji Cvišlerji) should also be resolved to reach adequate water quality during high water levels. The impact of agricultural production above passages of Vodna jama 1 pri Klinji vasi can be observed with increased concentrations of NO_3^- and PO_4^{3-}, but these do not seem to be limiting factors for the recolonization by proteus since water quality in Velika Stankova jama is even worse with respect to NO_3^-, PO_4^{3-} and Cl^-. A more probable reason for the absence of natural recolonization seems to be a complete elimination of the proteus population in the past. Recolonization in areas where sources of pollution were abolished (e.g. Kočevje coal mine closure, sewage system built in the catchment area of Željnske jame) is possible only if some fractions of proteus populations survived in less affected parts of the aquifer – population of 4–14 small animals (up to 15 cm long) in once devastated Remihov mlin seems to indicate proteus recolonization in the last decades. Further downstream toward the regional spring of Bilpa, dilution of polluted waters from Jama v Šahnu with clean percolation water is strong enough to sustain proteus populations even during low discharge when water quality is usually worse. This strongly differentiates the vulnerability of local upstream aquifers in comparison with the downstream regional ones.

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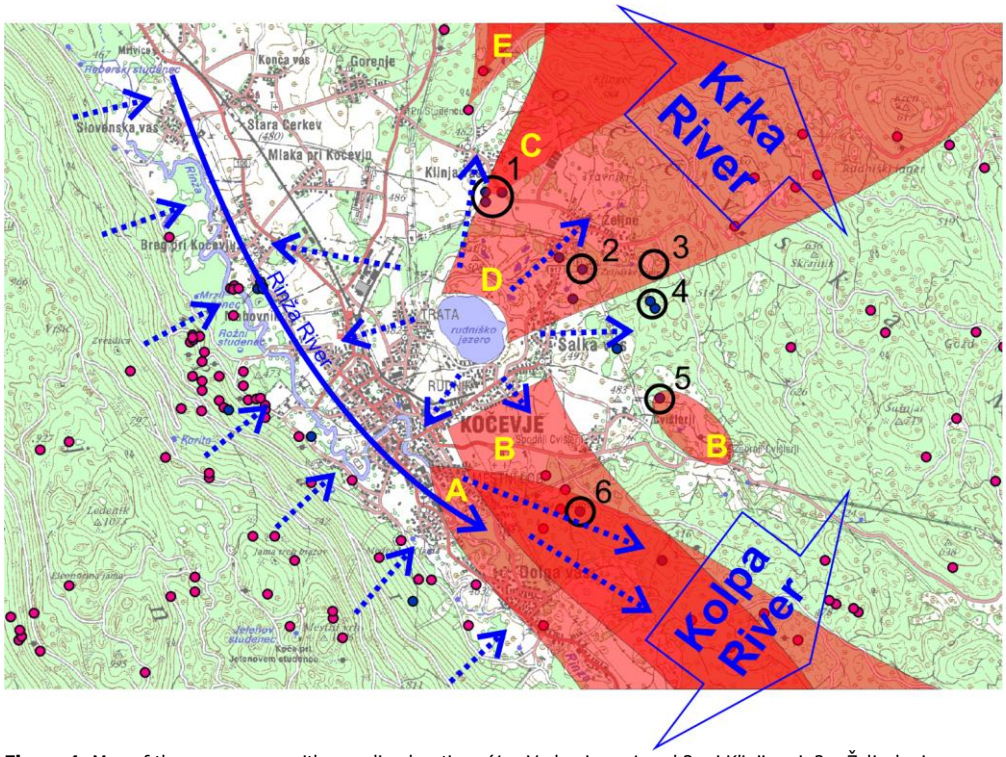

Figure 1. Map of the survey area with sampling locations (1 – Vodna jama 1 and 3 pri Klinji vasi, 2 – Željnske jame, 3 – Remihov mlin, 4 – Velika and Mala Stanova jama, 5 – Vodna jama pri Cvišlerjih, 6 – Jama v Šahnu), general outflow from Kočevsko polje (blue arrows) and major known sources of pollution (A – city of Kočevje/Rinža River (problem partly solved), B – intensive agricultural production, C – untreated manure from pig farm (problem solved), D – coal mining activity (problem partly solved), E – caves with 50+ m^3 of illegally disposed waste). Source of topographic map: Geodetska uprava Republike Slovenije.

Slika 1. Karta raziskovalnega območja z mesti vzorčevanja (1 – Vodna jama 1 in 3 pri Klinji vasi, 2 – Željnske jame, 3 – Remihov mlin, 4 – Velika in Mala Stanova jama, 5 – Vodna jama pri Cvišlerjih, 6 – Jama v Šahnu), generalnim vodnim tokom na Kočevskem polju (modre puščice) in glavnimi identificiranimi viri onesnaževanja (A – mesto Kočevje/reka Rinža (problem deloma odpravljen), B – intenzivno kmetijstvo, C – iztok neobdelane gnojevke iz prašičje farme (problem odpravljen), D – premogovništvo (problem deloma odpravljen), E – jame s preko 50 m^3 ilegalno odloženih odpadkov). Vir topografske podlage: Geodetska uprava Republike Slovenije.