

A CONTRIBUTION TO KNOWLEDGE OF FRESHWATER MOLLUSCS (MOLLUSCA) OF THE KRKA RIVER IN THE KRKA NATIONAL PARK (CROATIA)

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The results of a malacological survey of the Krka River between Knin and Skradinski buk waterfalls in the Krka National Park are presented. The molluscan assemblages of this karstic river were studied from 2009 to 2013. Altogether, 27 species of freshwater molluscs (19 gastropods, 8 bivalves) were found at 14 sites. *Theodoxus fluviatilis*, *Bithynia tentaculata*, *Valvata piscinalis*, *Stagnicola fuscus*, *Physa fontinalis* and *Anodonta anatina* were dominant at most of the sites. A population of the endangered *Anisus vorticulus* was found upstream of the Skradinski buk waterfalls and in Visovac Lake.

Key words: Mollusca, Gastropoda, Bivalvia, *Anisus vorticulus*, faunistic, Krka, river, Croatia

Beran, L.: Doprinos poznavanju faune slatkovodnih mekušaca (Mollusca) rijeke Krke u Nacionalnom parku Krka (Hrvatska). Nat. Croat., Vol. 25, No. 2., 295–304, 2016, Zagreb.

U radu se prezentiraju rezultati malakološkog istraživanja rijeke Krke između Knina i slapova Skradinski buk u NP Krka. Zajednice mekušaca ove krške rijeke istraživane su od 2009. do 2013. godine. Ukupno je na 14 lokaliteta nađeno 27 vrsta slatkovodnih mekušaca (19 puževa, 8 školjkaša). *Theodoxus fluviatilis*, *Bithynia tentaculata*, *Valvata piscinalis*, *Stagnicola fuscus*, *Physa fontinalis* i *Anodonta anatina* su na većini lokaliteta bili dominantni. Populacija ugrožene vrste *Anisus vorticulus* nađena je uzvodno od slapova Skradinski buk i u jezeru Visovac.

Ključne riječi: Mollusca, Gastropoda, Bivalvia, *Anisus vorticulus*, faunistika, Krka, rijeka, Hrvatska

INTRODUCTION

The Krka is a well known river in Croatia's Dalmatia region, noted for its numerous waterfalls. It is 73 km long and its basin covers an area of more than 2000 km². An area of 109 square km encompassing part of the basin and course of the Krka River (from 2 km downstream of Knin to Skradin) was declared to be the Krka National Park in 1985. Freshwater molluscs of this river have not been investigated sufficiently. Findings of small hydrobiids living primarily in springs and underground waters in surroundings exist. Shells of these hydrobiids can occasionally also be found in sediments of the Krka River. These records are concentrated at Skradinski Buk waterfalls and its surroundings. BOLE (1992) described *Lanzaia skradinensis* (Bole, 1992) from two springs downstream of the power plant station at Skradinski buk while empty shells of *Kerkia jadertina* (Kuščer, 1933) were found under Skradinski buk waterfalls (BERAN *et al.*, 2014). There are however insufficient data concerning the occurrence of freshwater gastropods and bivalves inhabiting the Krka River. GLÖER *et al.* (2007) described *Pseudobithynia kirka* (Glöer, Al-

brecht & Wilke, 2007) from the Skradinski buk waterfalls. BERAN (2009) found *Anisus vorticulus* there. This find was the first record of this endangered snail in the western part of Croatia belonging to the Adriatic Sea drainage area. Molluscan assemblages of this river were recently also studied by VUČKOVIĆ (2013). This author recorded 29 species of aquatic molluscs (20 freshwater snails, 1 brackish snail, 8 freshwater bivalves).

The main aim of this research was to provide an inventory of freshwater molluscs living in the Krka River and adjacent freshwater habitats (e. g. pools), examine their population densities, as well as the occurrence of endangered and non-native molluscs.

MATERIAL AND METHODS

Material was collected during the author's field research in summer 2009-2013. Freshwater molluscs of the Krka River and adjacent habitats (e. g. pools) between Knin and Skradinski buk waterfalls were studied. The main sampling method for aquatic molluscs used in the current research was washing vegetation or sediments using a metal sieve (diameter 20 cm, 0.8 mm mesh) combined with collection by hand, searching stone, wood and artificial material (e.g. plastic bags and bottles) surfaces. Diving (snorkelling) in shallow parts (ca to 3 m deep) was also used.

Freshwater molluscs were determined using shell characteristics or dissected and then identified using their copulatory organs if identification based only on shells was impossible. Specimens for dissection were killed in hot water and then fixed in 70% ethanol. Selected material of shells and killed specimens in 70% ethanol is deposited in the author's collection.

SURVEY OF INVESTIGATED SITES

Data in the list are as follows: site number, geographical co-ordinates (<http://itouch-map.com>), name of the nearest settlement, description of the site, date of investigation. Sites are depicted in Fig. 1.

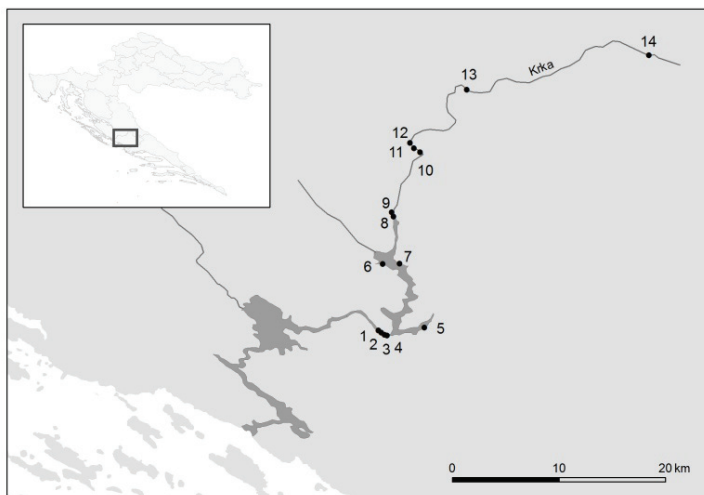


Fig. 1. The map of the Krka River with sites under study. Orig. H. Kaňková.

- 1 – 43°48'20"N, 15°57'46"E, Lozovac, the Krka River downstream of Skradinski buk waterfalls, 1.8.2012;
- 2 – 43°48'13"N, 15°57'54"E, Lozovac, the Krka River along the paths by Skradinski buk waterfalls, **a)** 11.8.2009, **b)** 10.7.2010;
- 3 – 43°48'08"N, 15°58'00"E, Lozovac, small lakes (pools) of the Krka River at the bus stop near Skradinski buk waterfalls, **a)** 11.8.2009, **b)** 10.7.2010;
- 4 – 43°48'07"N, 15°58'04"E, Lozovac, Visovac Lake upstream of Skradinski buk waterfalls, 1.8.2012;
- 5 – 43°48'29"N, 16°00'06"E, Goriš, left bank of Visovac Lake in the bay of the inflow of the Čikola River, 13.8.2013;
- 6 – 43°51'43"N, 15°57'59"E, Visovac, right bank of Visovac Lake opposite Visovac Monastery, **a)** 6.7.2012, **b)** 13.8.2013;
- 7 – 43°51'44"N, 15°58'50"E, Visovac, left bank of Visovac Lake Visovac Monastery, 10.7.2010;
- 8 – 43°54'07"N, 15°58'32"E, Laškovića, Krka River downstream of Roški slap in Visovac Lake, 10.7.2010 (Fig. 2 and 3);
- 9 – 43°54'20"N, 15°58'26"E, Laškovića, Krka River in Roški slap (Fig. 4), **a)** 11.8.2009, **b)** 10.7.2010;
- 10 – 43°57'23"N, 15°59'53"E, Kistanje, Krka River 300 m downstream of Krka Monastery, 1.7.2012;
- 11 – 43°57'33"N, 15°59'31"E, Kistanje, the eastern bank of the extensive pool near Krka Monastery, 1.7.2012;
- 12 – 43°57'41"N, 15°59'07"E, Kistanje, the northwestern bank of the extensive pool near Krka Monastery (Fig. 5), 1.7.2012;



Fig. 2. The Krka River downstream of the Roški slap in Visovac Lake (site No. 8). All photos by author.



Fig. 3. A detail of a place in which *A. vorticulus* occurs (site No. 8).



Fig. 4. The Krka River at Roški slap (site No. 9).



Fig. 5. The extensive pool near Krka Monastery (site No. 12).

- 13** – 44°00'33"N, 16°02'15"E, Puljane, Krka River in Brljansko jezero near a bridge of a road, **a)** 11.8.2009, **b)** 25.8.2011;
14 – 44°01'55"N, 16°11'25"E, Knin, Krka River near the bridge on the Knin-Drniš road, 25.8.2011.

RESULTS

Altogether 27 species of freshwater molluscs (19 gastropods, 8 bivalves) were found in the Krka River and adjacent habitats in the Krka NP during the investigation period. A list of molluscs found at particular sites and an estimation of the density of their populations are shown in Tab.1. The number of species found at particular sites varied from 4 to 17. *Theodoxus fluviatilis*, *Bithynia tentaculata*, *Valvata piscinalis*, *Stagnicola fuscus*, *Physa fontinalis* and *Anodonta anatina* were dominant at most of the sites while *Emmericia patula*, *Valvata cristata*, *Galba truncatula*, *Physa acuta*, *Planorbis planorbis*, *Gyraulus albus*, *Hippeutis complanatus*, *Musculium lacustre*, *Pisidium milium*, *Pisidium personatum* were recorded at only one to three sites. Most of the recorded molluscs belong to common species in this part of Croatia. *Unio mancus* is listed in the IUCN Red List in the category Near Threatened (LOPES-LIMA & SEDDON, 2014). This species is among the most common bivalves in the lower stretch of the Krka River. *Anisus vorticulus*, an endangered species listed in the EU Habitat Directive (see Discussion) and a Data Deficient species according to IUCN Red List (VAN DAMME, 2012), was found at 6 sites (Figs. 2 and 3). A population of this gastropod inhabits Visovac Lake and pools upstream of the Skradinski buk waterfalls. Upstream of Roški slap, this species was not found. The highest densities were recorded at sites No. 3, 4 and 6. The population density of this species varied from a few specimens to over 80 ind./m².

On the other hand only one non-native species, *Physa acuta*, was found in the extensive pool near Krka Monastery (Fig. 5).

Tab.1. List of aquatic molluscs according to localities.
 x – a few specimens, xx – scattered occurrence, xxx – abundant occurrence, (x) – old shells.

Species/Site No.	1	2a	2b	3a	3b	4	5	6a	6b	7	8	8a	9b	10	11	12	13a	13b	14
<i>Theodoxus fluviatilis</i> (Linnaeus, 1758)	xxx	xxx	xx	xx	xxx	xx	xxx	x	x	xx	xx	xx	xxx				x		10
<i>Viviparus contectus</i> (Millet, 1813)					x	x	x	x	x	xx									5
<i>Bithynia tentaculata</i> (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xx	xxx	xx	xx	xx	xx	xxx	xxx	xx	x		xxx	xxx	12
<i>Radomaniola curta</i> (Küster, 1853)											x		xx	xx			xxx	xxx	5
<i>Emmericia patula</i> (Brumati, 1838)											xxx			xx			xxx	xxx	3
<i>Valvata cristata</i> O. F. Müller, 1774														xxx					1
<i>Valvata piscinalis</i> (O. F. Müller, 1774)	x	xx	x	xx	xx	xxx	xxx	xxx	xxx	xx	xx				xxx		xx	xxx	10
<i>Aceroloxus lacustris</i> (Linnaeus, 1758)						xx	x	xx	xx	xxx			x	x	x				8
<i>Galba truncatula</i> (O. F. Müller, 1774)																			1
<i>Stagnicola fuscus</i> (C. Pfeiffer, 1821)	xx	xx	xx	x	x	xxx	xx	xx	xx	xxx	xx	xx	x	x	x	x	xxx	xx	13
<i>Radix ampla</i> (Hartmann, 1821)	x		x		x	x	x	x	x	xx	xx		x	x	x	x	x	xx	8
<i>Radix auricularia</i> (Linnaeus, 1758)						x	x	x	x				x	x	x	x	x	xx	7
<i>Physa acuta</i> Draparnaud, 1805																xxx			1
<i>Physa fontinalis</i> (Linnaeus, 1758)		x	xx	x	x	xx		xx	xx	xx	xxx	x	xxx	xx			x	xx	10
<i>Planorbis planorbis</i> (Linnaeus, 1758)					x														1
<i>Anisus vorticulus</i> (Troschel, 1834)				xx	xxx	xxx	x	xxx	xx	x	x								6
<i>Bathyonphalus contortus</i> (Linnaeus, 1758)																			2
<i>Gyraulus albus</i> (O. F. Müller, 1774)							x	x	x	x	x	x		x	xx	x		xx	9
<i>Hippeutis complanatus</i> (Linnaeus, 1758)						xx	xx	x	x	x	x								3
<i>Unio mancus</i> (Lamarck, 1819)		xxx	xx	x	x	xx		x	x	x	x	xx	xx	xx					8
<i>Anodonta anatina</i> (Linnaeus, 1758)	x	xxx	xx	x	x	xx	xx	xx	xx	xx	xx	xx	xx	xx	x		x		12
<i>Musculium lacustre</i> (O. F. Müller, 1774)														x					1
<i>Pisidium milium</i> Held, 1836																			1
<i>Pisidium subtruncatum</i> Malm, 1855								x	x	x	x			x			x	xx	5
<i>Pisidium nitidum</i> Jenyns, 1832	x					x	x	xx	x	x	x	x	x	x			x	xx	9
<i>Pisidium personatum</i> Malm, 1855											x								1
<i>Pisidium casertanum</i> (Poli, 1791)								x					x	x			x		4
Number of species	6	7	8	7	11	13	12	17	16	12	17	6	11	15	6	4	6	14	8

DISCUSSION

Rich molluscan assemblages inhabit the Krka River. The river is inhabited by both molluscs living in flowing waters (e. g. *Theodoxus fluviatilis*, *Radomaniola curta*, *Emmericia patula*, *Radix ampla*) and species preferring stagnant waters (e. g. *Viviparus contectus*, *Stagnicola fuscus*, *Planorbis planorbis*). The reason for this is the character of the river, where lakes (Visovac Lake) or stagnant parts are interrupted by waterfalls and fast-flowing sections. The finding of the endangered gastropod *A. vorticulus* is the most important record due to the fact that populations of this snail have been declining in many European countries (VAN DAMME, 2012). This dramatic change led the species being considered for inclusion in the EU Habitats Directive (a proposal of the Czech Republic during expansion, 2004) (COLLING & SCHRÖDER, 2006; ZETTLER & WACHLIN, 2010). This species is listed in both Annex II (species of community interest requiring special areas for conservation) and Annex IV (strict protection) of the Directive.

The occurrence of *A. vorticulus* is also known from Mediterranean part of Croatia from the Vrana Lake Nature Park (BERAN *et al.*, 2013) but only a small population was found there in the dried Benča Lake. The population found in the Krka National Park is much more extensive and *A. vorticulus* is widespread in Visovac Lake and adjacent habitats. *A. vorticulus* was found in Visovac Lake for the first time in 2009 (BERAN 2009). VUČKOVIĆ (2013) also found this species in Visovac Lake between Roški slap and Skradinski buk waterfalls. Due to the large size of this lake and the existence of suitable habitats there we can conclude that the population is the most extensive one known in the western part of Croatia belonging to the Adriatic Sea drainage area.

GLÖER *et al.* (2007) described *Pseudobrythina kirka* (Glöer, Albrecht & Wilke, 2007) from Skradinski buk waterfalls. This species was sought during this research, and it was expected that this species would be detected. *P. kirka* was not found although more than 50 specimens of *Bithyniidae* from different habitats at the locus typicus and its surroundings were dissected and several specimens collected were also revised by P. Glöer. Only the common *B. tentaculata* was identified. During her research, VUČKOVIĆ (2013) also found only this common species.

The research was focused on the Krka River and adjacent habitats (e. g. pools). Springs, wells and underground waters were not studied. It is probable that research into them would detect the presence of other species especially small hydrobiids (see Introduction).

Only one non-native gastropod was found during this research. *Physa acuta* was not found in the main stream of the Krka River but only in a pool situated near Krka Monastery (site No. 12). This species probably inhabits suitable sites in the surroundings of the Krka National Park because it was found by the author in the small pool (Konjevrat-ska lokva) near the cemetery in Konjevrate and also in the Butižnica River in Knin. The record of only one non-native mollusc showed that molluscan assemblages of the Krka River are only marginally attacked by non-native species.

VUČKOVIĆ (2013) who conducted her own research in 2012 and 2013 practically simultaneously with the author found very similar results. Nearly all the species were found by both authors. VUČKOVIĆ (2013) recorded two more species – brackish *Adriohydrobia gagatinella* (Küster, 1852) found below Skradinski buk waterfalls and the common *Gyraulus crista* (Linnaeus, 1758), recorded from one site. Brackish molluscs were not studied by L. Beran so it is the reason why *A. gagatinella* is not mentioned in this research and *G. crista* could be overlooked. VUČKOVIĆ (2013) mentioned *Radix labiata* (Rossmässler,

Tab. 2. Comparison of molluscan assemblages of the Krka River and the Zrmanja River.

* in BERAN (2011) mentioned as *B. zermanica* Radoman, 1973 and *B. krupensis* Radoman, 1973 but molecular data strongly suggest that both species are identical with *B. kusceri* (FALNIOWSKI & BERAN, 2015).

** in BERAN (2011) mentioned only as *Radix labiata* but later *R. ampla* was identified in lower part of the Zrmanja River (L. Beran, unpublished records).

Species/River	Krka	Zrmanja
<i>Theodoxus fluviatilis</i> (Linnaeus, 1758)	x	x
<i>Viviparus contectus</i> (Millet, 1813)	x	
<i>Bithynia tentaculata</i> (Linnaeus, 1758)	x	x
<i>Sadleriana fluminensis</i> (Küster, 1852)		x
<i>Belgrandiella kusceri</i> (A. J. Wagner, 1914)*		x
<i>Radomaniola curta</i> (Küster, 1853)	x	x
<i>Dalmatinella fluviatilis</i> Radoman, 1973		x
<i>Tanousia zrmanjae</i> (Brusina, 1866)		x
<i>Pyrgula annulata</i> (Linnaeus, 1767)		x
<i>Emmericia patula</i> (Brumati, 1838)	x	x
<i>Valvata cristata</i> O. F. Müller, 1774	x	
<i>Valvata piscinalis</i> (O. F. Müller, 1774)	x	x
<i>Acroloxus lacustris</i> (Linnaeus, 1758)	x	x
<i>Galba truncatula</i> (O. F. Müller, 1774)	x	
<i>Stagnicola fuscus</i> (C. Pfeiffer, 1821)	x	x
<i>Radix ampla</i> (Hartmann, 1821)**	x	x
<i>Radix auricularia</i> (Linnaeus, 1758)	x	x
<i>Radix labiata</i> (Rossmäessler, 1835)		x
<i>Physa fontinalis</i> (Linnaeus, 1758)	x	
<i>Physa acuta</i> (Draparnaud, 1805)	x	
<i>Planorbis planorbis</i> (Linnaeus, 1758)	x	x
<i>Planorbis carinatus</i> (O. F. Müller, 1774)		x
<i>Anisus vorticulus</i> (Troschel, 1834)	x	
<i>Bathyomphalus contortus</i> (Linnaeus, 1758)	x	
<i>Gyraulus albus</i> (O. F. Müller, 1774)	x	
<i>Hippeutis complanatus</i> (Linnaeus, 1758)	x	x
<i>Ancylus fluviatilis</i> (O. F. Müller, 1774)		x
<i>Unio mancus</i> (Lamarck, 1819)	x	x
<i>Anodonta anatina</i> (Linnaeus, 1758)	x	x
<i>Musculium lacustre</i> (O. F. Müller, 1774)	x	
<i>Pisidium ammicum</i> (O. F. Müller, 1774)		x
<i>Pisidium milium</i> Held, 1836	x	
<i>Pisidium subtruncatum</i> Malm, 1855	x	x
<i>Pisidium nitidum</i> Jenyns, 1832	x	x
<i>Pisidium personatum</i> Malm, 1855	x	x
<i>Pisidium casertanum</i> (Poli, 1791)	x	x
Number of species	27	26

1835) while L. Beran referred to *Radix ampla*. The material of *R. ampla* was dissected by L. Beran and its identification was confirmed using DNA analysis (K. Schniebs, personal communication) so probably only *R. ampla* occurred in the Krka River. Some of the study sites of the two authors were situated in similar areas and their molluscan assemblages were often similar.

In comparison with the Zrmanja, the river situated to the north of the Krka River, which was studied recently (BERAN, 2011; L. Beran, unpublished records) the Krka River is significantly less occupied by small hydrobiids. No endemic species of this group was found in the Krka River. On the other hand gastropods preferring stagnant waters (*Viviparus contectus*, *Anisus vorticulus*, *Bathyomphalus contortus*) are more frequent there. The probable reason is the existence of the extensive Visovac Lake and other lakes and pools created by travertine cascades in this national park. Assemblages of bivalves are similar in the two rivers. The comparison of freshwater molluscs of these two rivers is given in Tab. 2.

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SUMMARY

A contribution to knowledge of freshwater molluscs (Mollusca) of the Krka River in the Krka National Park (Croatia)

L. Beran

This paper presents the results of a malacological survey of the Krka River and adjacent habitats (e. g. pools) in the Krka National Park. Freshwater molluscs were studied at 14 sites between Skradinski Buk waterfalls and Knin from 2009 to 2013. Altogether 27 species of freshwater molluscs (19 gastropods, 8 bivalves) were found. The number of species found at particular site varied from 4 to 17 species. *Theodoxus fluviatilis*, *Bithynia tentaculata*, *Valvata piscinalis*, *Stagnicola fuscus*, *Physa fontinalis* and *Anodonta anatina* were dominant molluscs. The river is inhabited by both molluscs living in flowing waters and species preferring stagnant waters, due to the character of this river.

Most of the recorded molluscs belong to common species in this part of Croatia. The endangered gastropod *Anisus vorticulus* was found at several sites and due to the large size of this lake and the existence of suitable habitats there we can conclude that the population is the most extensive one known in the western part of Croatia belonging to the Adriatic Sea drainage area. Only one non-native gastropod (*Physa acuta*) was found during this research.

Results of this research were compared with molluscan assemblages of the Zrmanja River situated to the north of the Krka River. The Krka River is significantly less occupied with small hydrobiids while gastropods preferring stagnant waters are more frequent there.