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AQUATIC MOLLUSCAN FAUNA (MOLLUSCA) OF THE KORANA RIVER (CROATIA)

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Results of a malacological survey of the Korana River are presented. The molluscan assemblages of this karstic river between its outflow from Plitvice Lakes and the inflow to the Kupa River at Karlovac were studied from 2009 to 2012. Altogether 33 aquatic molluscs (21 gastropods, 12 bivalves) were found at 13 sites. *Theodoxus danubialis*, *Esperiana esperi*, *Microcolpia daudebartii*, *Holandriana holandrii* and *Bithynia tentaculata* were dominant at most of the sites. A population of the endangered thick-shelled river mussel *Unio crassus* was recorded. The occurrence of three non-native molluscs (*Physella acuta*, *Ferrissia fragilis*, *Sinanodonta woodiana*) was documented. The results of this research were compared with those of previous investigations and also with those for molluscan assemblages of the adjacent part of the Kupa River.

Key words: Mollusca, Gastropoda, Bivalvia, *Unio crassus*, *Sinanodonta woodiana*, *Ferrissia fragilis*, Korana, river, Croatia

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U radu se predstavljaju rezultati malakološkog istraživanja rijeke Korane. U razdoblju od 2009. do 2012. proučavane su zajednice mekušaca ove krške rijeke, od njena izlaska iz Plitvičkih jezera do ušća u Kupu kod Karlovca. Na 13 lokacija nađeno je ukupno 33 vrste vodenih mekušaca (21 vrsta puževa, 12 vrsta školjkaša). Na većini lokacija dominirali su *Theodoxus danubialis*, *Esperiana esperi*, *Microcolpia daudebartii*, *Holandriana holandrii* i *Bithynia tentaculata*. Zabilježena je populacija ugroženog riječnog školjkaša obične lisanke *Unio crassus*, kao i pojava tri alohtona mekušca (*Physella acuta*, *Ferrissia fragilis*, *Sinanodonta woodiana*). Rezultati istraživanja su uspoređeni s onima iz prijašnjih istraživanja te s istraživanjima zajednica mekušaca rijeke Kupe.

Ključne riječi: Mollusca, Gastropoda, Bivalvia, *Unio crassus*, *Sinanodonta woodiana*, *Ferrissia fragilis*, Korana, rijeka, Hrvatska

INTRODUCTION

The Korana is a river in central Croatia and west Bosnia and Herzegovina belonging to the Danube drainage area (the Black Sea basin). Macroinvertebrates including aquatic molluscs of the Korana River were studied 40 years ago by PAVLETIĆ & MATONIČKIN (1972) who mentioned the occurrence of 15 aquatic molluscs from 7 sites and more recently also by KEROVEC *et al.* (2008) and MIHALJEVIĆ *et al.* (2011) who altogether found 9 aquatic molluscs at 4 sites. More detailed research based only on the aquatic molluscs of this river was made from 2009 to 2012, and its results are presented in this paper.

MATERIAL AND METHODS

Data were obtained from field surveys conducted in the years 2009–2012. In total, 13 sites downstream of Plitvice Lakes were studied (Fig. 1.). The main sampling method for freshwater molluscs is washing vegetation or sediments using a metal sieve (a kitchen strainer, diameter 20 cm, 0.8 mm mesh) combined with collection by hand, searching the surfaces of stones, wood and artificial materials (e.g. plastic bags and bottles). These methods were used in this research. Unionids were searched for in this case also by means of diving (snorkelling). Freshwater molluscs were determined using various shell characteristics or dissected and then identified using their copulatory organs if an identification based on shells alone was impossible (e. g. genus *Stagnicola*). 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.

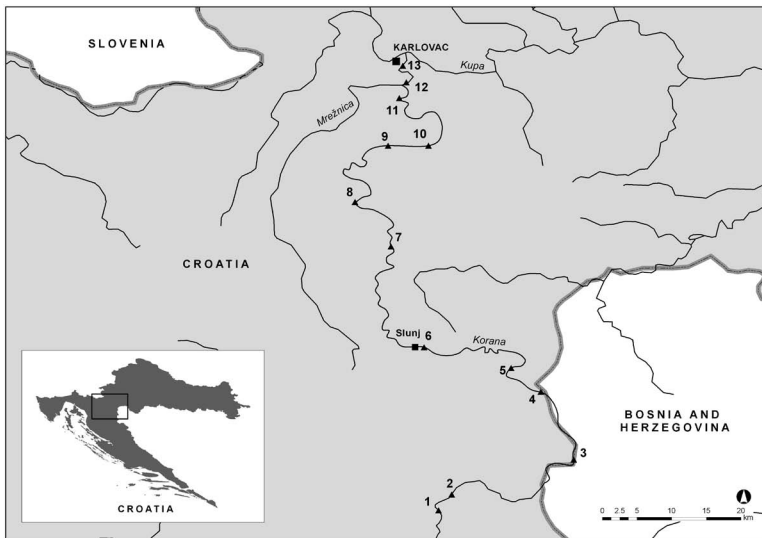


Fig. 1. Map of the Korana River with the sites under study. Drawn by M. Dolejš.

STUDY AREA

The Korana is a river in central Croatia and west Bosnia and Herzegovina. The river has a total length of 134 km and a watershed area of 2 595 km² and belongs to the Danube drainage area (Black Sea basin). The river rises in the eastern parts of Lika and creates the world-famous Plitvice Lakes. Downstream of Plitvice Lakes the Korana forms a 25 kilometer long border between Croatia and Bosnia and Herzegovina. From there it flows northwards through Croatia, where it finally reaches the river Kupa (tributary of the Sava River) at Karlovac. The river Slunjčica flows into the Korana at Slunj, and the river Mrežnica flows into the Korana at Karlovac.

The Korana River has a natural character (Fig. 2–4) over most of the course except for several weirs and a short river section at Karlovac (Fig. 5). The river stream is frequently overgrown with macrophytes (Fig. 2–5). In the upper river section the watercourse often dries out.



Fig. 2. The Korana River near Salopek Luke (site No. 5). All photos by author.



Fig. 3. The Korana River near Koranska Strana (site No. 7).

LIST OF INVESTIGATED SITES

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



Fig. 4. The Korana River at Barilovič (site No. 9).



Fig. 5. The Korana River at Karlovac (site No. 13).

1 – 44°54'35"N, 15°36'28"E, Rastovača, the Korana River on the southern edge of the Plitvice Lakes NP, 15.8.2009;

2 – 44°55'49"N, 15°37'29"E, Selišće Drežničko, the Korana River below a bridge of the road Gračac – Karlovac, 16.7.2010, 25.8.2011;



Fig. 6. Living individuals of *Unio crassus* (site No. 5).

3 – 44°58'32"N, 15°47'00"E, Tržačka Raštela, the Korana River at Tržačka on the boundary between Croatia and Bosnia and Herzegovina, 7.7.2012;

4 – 45°03'49"N, 15°44'26"E, Donji Furan, the Korana River by a bridge near the boundary between Croatia and Bosnia and Herzegovina, 30.6.2012;

5 – 45°05'40"N, 15°42'07"E, Salopek Luke, the Korana River by the bridge near Salopek Luke (Fig. 2), 3.8.2012;

6 – 45°07'17"N, 15°35'20"E, Slunj, the Korana River at Slunj, 15.8.2011, 28.7.2012;

7 – 45°15'08"N, 15°32'45"E, Veljun, the Korana River near a bridge, 7.7.2011;

8 – 45°18'36"N, 15°29'57"E, Koranska Strana, the Korana River by a bridge (Fig. 3), 7.7.2012;

9 – 45°22'43"N, 15°32'45"E, Barilović, the Korana River by a bridge (Fig. 4), 3.8.2012;

10 – 45°23'29"N, 15°35'43"E, Donji Velemerić, the Korana River by a bridge, 19.8.2011;

11 – 45°26'42"N, 15°33'24"E, Belajske Poljice, the Korana River at Belajske Poljice, 28.7.2012;

12 – 45°27'56"N, 15°33'57"E, Turanj, the Korana River at Turanj on the inflow of the Mrežnica River, 7.7.2011, 7.7.2012, 28.7.2012;

13 – 45°29'13"N, 15°33'40"E, Karlovac, the Korana River downstream of a weir about 3 km upstream of the inflow to the Kupa River (Fig. 5), 28.7.2012.

RESULTS

In total, 33 aquatic mollusc species (21 gastropods, 12 bivalves) were found at 13 sites of the Korana River between its outflow from Plitvice Lakes and the inflow to the Kupa River at Karlovac. A list of molluscs found at particular sites and an estimation of the density of their populations are shown in Tab. 1. Molluscan assemblages of the first two

Tab. 1. List of aquatic molluscs recorded at studied sites.

Species	Site No.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Gastropoda													
<i>Theodoxus danubialis</i> (C. Pfeiffer, 1828)			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
<i>Viviparus aceroseus</i> Bourguignat, 1862								xx			xxx	x	x
<i>Esperiana esperi</i> (A. Férussac, 1823)			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx
<i>Microcolpia daudebartii</i> (Prevost, 1821)			x	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
<i>Holandriana holandrii</i> (C. Pfeiffer, 1828)	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
<i>Bithynia tentaculata</i> (Linnaeus, 1758)						xx	xx	xx	xx	xx	xxx	xxx	xxx
<i>Sadleriana fluminensis</i> (Küster, 1852)			xxx			xxx	xx						
<i>Lithoglyphus naticoides</i> (C. Pfeiffer, 1828)					xx		xx	x	xx	x		xx	x
<i>Valvata piscinalis</i> (O. F. Müller, 1774)						xx					xx	x	xxx
<i>Acroloxus lacustris</i> (Linnaeus, 1758)							xxx			x			x
<i>Galba truncatula</i> (O. F. Müller, 1774)				xx	xxx		xxx			xx			
<i>Stagnicola palustris</i> (O. F. Müller, 1774)					xx							x	
<i>Radix auricularia</i> (Linnaeus, 1758)		x		x			xx	x	x	x	x		
<i>Radix labiata</i> (Rossmäessler, 1835)	x	xxx		xx	xxx	xxx	xxx	xx	x	xx			
<i>Lymnaea stagnalis</i> (Linnaeus, 1758)													x
<i>Physella acuta</i> (Draparnaud, 1805)					xxx	xxx	x				xx	xxx	xxx

Tab. 2. Comparison of results with previous research 1972 – PAVLETIĆ & MATONIČKIN (1972); 2008, 2011 – KEROVEC *et al.* (2008), MIHALJEVIĆ *et al.* (2011)

Species	1972	2008, 2011	this research
<i>Theodoxus danubialis</i> (C. Pfeiffer, 1828)	x*	x	x
<i>Viviparus acerosus</i> Bourguignat, 1862			x
<i>Esperiana esperi</i> (A. Férussac, 1823)	x	x	x
<i>Microcolpia daudebartii</i> (Prevost, 1821)	x	x	x
<i>Holandriana holandrii</i> (C. Pfeiffer, 1828)	x	x	x
<i>Bithynia tentaculata</i> (Linnaeus, 1758)	x	x	x
<i>Sadleriana fluminensis</i> (Küster, 1852)		x	x
<i>Lithoglyphus naticoides</i> (C. Pfeiffer, 1826)	x		x
<i>Valvata piscinalis</i> (O. F. Müller, 1774)	x		x
<i>Acroloxus lacustris</i> (Linnaeus, 1758)			x
<i>Galba truncatula</i> (O. F. Müller, 1774)	x		x
<i>Stagnicola palustris</i> (O. F. Müller, 1774)			x
<i>Radix auricularia</i> (Linnaeus, 1758)	x		x
<i>Radix labiata</i> (Rossmäessler, 1835)	x	x	x
<i>Lymnaea stagnalis</i> (Linnaeus, 1758)	x		x
<i>Physella acuta</i> (Draparnaud, 1805)		x	x
<i>Gyraulus albus</i> (O. F. Müller, 1774)			x
<i>Hippeutis complanatus</i> (Linnaeus, 1758)			x
<i>Planorbarius corneus</i> (Linnaeus, 1758)			x
<i>Ancylus fluviatilis</i> O. F. Müller, 1774		x	x
<i>Ferrissia fragilis</i> (Tryon, 1863)			x
<i>Unio crassus</i> Philipsson, 1788	x		x
<i>Unio pictorum</i> (Linnaeus, 1758)			x
<i>Unio tumidus</i> Philipsson, 1788			x
<i>Anodonta anatina</i> (Linnaeus, 1758)	x**		x
<i>Pseudanodonta complanata</i> (Rossmäessler, 1835)			x
<i>Sinanodonta woodiana</i> (Lea, 1834)			x
<i>Sphaerium corneum</i> (Linnaeus, 1758)	x		x
<i>Pisidium amnicum</i> (O. F. Müller, 1774)			x
<i>Pisidium casertanum</i> (Poli, 1791)	x***		x
<i>Pisidium henslowanum</i> (Sheppard, 1823)			x
<i>Pisidium nitidum</i> Jenyns, 1832			x
<i>Pisidium subtruncatum</i> Malm, 1855			x
Number of species	15	9	33

* – mentioned as *Theodoxus fluviatilis*** – mentioned as *Anodonta cygnea**** – mentioned as *Pisidium personatum* (see the Discussion)

sites are composed of 3 species (*Holandriana holandrii*, *Radix auricularia*, *R. labiata*) while from 10 (site No. 3 and 4) to 22 (site No. 13) species were recorded at other sites. *Theodoxus danubialis*, *Esperiana esperi*, *Microcolpia daudebartii*, *Holandriana holandrii* and *Bithynia tentaculata* were dominant at most sites and their numerous populations constituted the dominant component of molluscan biomass. *Lithoglyphus naticoides*, *Radix auricularia*, *R. labiata*, *Gyraulus albus*, *Unio crassus*, *Pisidium subtruncatum*, *P. nitidum* were found at more than half the studied sites. *Viviparus acerosus*, *Valvata piscinalis*, *Lymnaea stagnalis*, *Ferrissia fragilis*, *Unio pictorum*, *U. tumidus*, *Pseudanodonta complanata*, *Sinanodonta woodiana* and *Pisidium henslowanum* were recorded mostly or only in the lower river section of this river and *Sadleriana fluminensis* and *Ancylus fluviatilis* in the upper river stretch only.

Theodoxus danubialis, *Viviparus acerosus*, *Esperiana esperi*, *Microcolpia acicularis* and originally also *Lithoglyphus naticoides* are species occurring especially in the Danube drainage area and belong to species with Danubial or Pontic distribution ranges. *Sadleriana fluminensis* is known from Italy, Bosnia and Herzegovina, Slovenia and Croatia while *Holandriana holandrii* is known from Hungary to Albania and Bulgaria. Other recorded species except the non-native molluscs mentioned above belong to molluscs with extensive distribution ranges (Holarctic, Palaearctic, Euro-Siberian) or are known at least from a large part of Europe.

A population of the endangered *Unio crassus* (Fig. 6) was documented. This bivalve was found at 11 sites (all sites except of the first two studied localities). Density of population was not studied exactly but at several sites more than 5 specimens were found. At site No. 5 (Fig. 2) the density was approximately estimated at about one specimen for 1 m of course (about 7 m wide), 8 living specimens and more than 20 empty shells were found. The *Pseudanodonta complanata* unionid vulnerable or endangered in many European countries was found at site No. 13. Only one specimen was recorded.

On the other hand three non-native molluscs were recorded. The North American *Physella acuta* was found at 6 sites while *Ferrissia fragilis* also represented a North American element and was recorded only from one locality. *Sinanodonta woodiana* originally distributed in southeastern Asia was recorded only from the Korana in Karlovac (site No. 13).

DISCUSSION

Rich molluscan assemblages inhabit the Korana River at all except the first two sites. Drying of the watercourse documented e. g. at site No. 2 is the probable reason for poor malacofauna at these two sites located in the upper course of the Korana. Before this research the occurrence of 15 species was known from this river (Tab. 2). PAVLETIĆ & MATONIČKIN (1972) mentioned findings of 15 aquatic molluscs including a record of the endangered bivalve *Unio crassus* from the Korana at Veljun. In this paper *Theodoxus fluviatilis* (Linnaeus, 1758), *Anodonta cygnea* (Linnaeus, 1758) and *Pisidium personatum* Malm, 1855 are mentioned while the occurrence of *Theodoxus danubialis*, *Anodonta anatina* and other species of genus *Pisidium* was not recorded; the authors probably confused *T. danubialis* with *T. fluviatilis*, *A. anatina* with *A. cygnea* and also probably another *Pisidium* (*P. casertanum*?) with *P. personatum*. This confusion is evident but it is not possible to exclude the occurrence of *A. cygnea* especially in the lower stretch of the river. *T. fluviatilis* is known from the Kupa River (HABDIJA *et al.*, 1995) so this prosobranch can occur in the lower river section of the Korana River too. *P. personatum* is known from Croatian rivers (e. g. BERAN, 2011) so its occurrence cannot be excluded, but would probably be

in the upper section of this river. No introduced species were mentioned in this paper. Later research based on macroinvertebrates (KEROVEC *et al.*, 2008; MIHALJEVIĆ *et al.*, 2011) confirmed the occurrence of 9 aquatic molluscs (Tab. 2) while the more detailed research presented here documented 33 aquatic molluscs. The occurrence of all species recorded during previous studies was confirmed. In comparison with previous research projects, three non-native molluscs were found. *Physella acuta* was noticed by KEROVEC *et al.* (2008), MIHALJEVIĆ *et al.* (2011) while *Ferrissia fragilis* and *Sinanodonta woodiana* have not been documented from Korana yet. *Sinanodonta woodiana* were discovered in Croatia for the first time in the Danube River which forms the border between Croatia and Serbia (PAUNOVIC *et al.*, 2006). More than 50 other sites especially from the Danube, Sava and Drava rivers and their surroundings are mentioned in LAJTNER & CRNČAN (2011) but no record was published from the western part of Croatia including the Korana River. The exception is the finding of empty shells of this bivalve in Vrana Lake which were introduced probably by fishermen as a bait (LAJTNER & CRNČAN, 2011). The finding in the Korana River confirms the continuing expansion of this invasive species. *Ferrissia fragilis* was found at one site in the lower section of the Korana. This species is known from Croatia only from the Ilova River (tributary of the Sava R.) near the town of Kutina (Lajtner pers. comm.) but will be probably more common especially in the Danube drainage area. *Unio crassus* was mentioned from the Korana from Veljun (PAVLETIĆ & MATONIČKIN, 1972). The occurrence of this endangered bivalve which is declining in most European countries was confirmed, and the presence of *Unio crassus* at all sites except first two localities probably means the existence of a numerous and continual population but more detailed studies based on this species and also of its host fish are necessary.

The occurrence of *Stagnicola fuscus* (C. Pfeiffer, 1821) is known from the Croatian seashore (e. g. Pag Island, L. Beran unpubl. records), Vrana Lake (BERAN *et al.*, 2013) or rivers flowing into the Adriatic Sea, e. g. the Zrmanja (BERAN, 2011) or Krka (L. Beran, unpubl. records) while *S. palustris* and *S. corvus* (Gmelin, 1791) are known from the Danube drainage area. The occurrence of *S. palustris* was confirmed at two studied sites of the Korana River.

The Korana inflows into the Kupa River in Karlovac. HADBIJA *et al.* (1995) studied biomass of freshwater snails and its spatial distribution according to different substrate types and in this river near Karlovac recorded 10 gastropods (*Theodoxus danubialis*, *T. fluviatilis*, *Esperiana esperi*, *Microcolpia daudebartii*, *Holandriana holandrii*, *Bithynia tentaculata*, *Sadleriana fluminensis*, *Lithoglyphus naticoides*, *Valvata piscinalis*, *Acroloxus lacustris*, *Radix labiata*). All these species except *T. fluviatilis* were also found in the Korana River. In the Kupa River the species *Theodoxus danubialis*, *Holandriana holandrii* and *Esperiana esperi* formed most of biomass of gastropods. Similar situations were observed in the Korana River where these three species with *Microcolpia daudebartii* and often also with *Bithynia tentaculata* occurred in very numerous populations and their empty shells formed an important part of sediment.

CONCLUSIONS

Research into a Croatian karstic river, the Korana, documented the existence of rich molluscan assemblages composed of 33 species. Natural conditions together with low human impacts could be the reason for the existence of numerous populations of many freshwater molluscs. The occurrence of the endangered bivalve *Unio crassus*, which has declined in many European countries, is very important and more detailed research

based on this species is needed. Like other European rivers, the Korana too has been affected by the invasion of non-native species. Three non-native aquatic molluscs in the lower river section were recorded.

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SUMMARY

Aquatic molluscan fauna (Mollusca) of the Korana River (Croatia)

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This paper presents the results of a malacological survey of the Korana, a river in central Croatia and west Bosnia and Herzegovina belonging to the Danube drainage area (Black Sea basin). The river has a natural character over most of its course except for several weirs and a short river section at Karlovac. Freshwater molluscs of this river at 13 sites between its outflow from Plitvice Lakes and inflow to the Kupa River at Karlovac were studied from 2009 to 2012. Molluscan assemblages of the first two sites are composed of only 3 species (*Holandriana holandrii*, *Radix auricularia*, *R. labiata*). Drying of the river stream is the probable

reason for poor malacofauna at these two sites located in the upper part of the Korana. Rich molluscan assemblages comprising from 10 (site No. 3 and 4) to 22 (site No. 13) species were documented at other 11 sites. Altogether 33 aquatic molluscs (21 gastropods, 12 bivalves) were found in the Korana River. *Theodoxus danubialis*, *Esperiana esperi*, *Microcolpia daudebartii*, *Holandriana holandrii* and *Bithynia tentaculata* were dominant at most of the sites. Their numerous populations constituted the dominant component of molluscan biomass. The endangered thick-shelled river mussel *Unio crassus* was recorded at 11 sites and this finding probably means the existence of a numerous and continual population. The existence of a population of *Unio crassus* is very important and needs more detailed research. The occurrence of three non-native molluscs (*Physella acuta*, *Ferrissia fragilis*, *Sinanodonta woodiana*) was documented. Results of this research were compared with previous investigations and also with molluscan assemblages of the adjacent part of the Kupa River.