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FRESHWATER MOLLUSCS OF THE ZRMANJA AND KRUPA RIVERS (CROATIA) – THE ROLE OF THESE RIVERS AS A REFUGE OF THREATENED AND ENDEMIC SPECIES

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ABSTRACT: The Balkan region is inhabited by hundreds of endemic species of freshwater molluscs but the information on their distribution, as well as that on the distribution of more common and widespread species, is still insufficient; most areas have no complete inventories of their mollusc faunas. The Zrmanja is one of the largest rivers in the Adriatic part of Croatia. Its freshwater molluscs were studied in the last decade, resulting in a substantial body of distributional data. The main objective of this study was to summarise and analyse the recent distributional information on its freshwater molluscs, with special reference to endemic or threatened species. In total 33 freshwater mollusc species were found in the Zrmanja River and its tributaries at 73 sites. The middle section of the Zrmanja River and its largest tributary, the Krupa River, were the richest studied parts. *Dalmatinella fluviatilis* Radoman, *Tanousia zrmanjae* (Brusina) and *Islamia zermanica* Radoman, endemic to the Zrmanja catchment area, were found in the middle and lower sections of the river. Their occurrence is scattered and limited in area; *T. zrmanjae* is probably on the verge of extinction. The occurrence of the endemic *Belgrandiella kusceri* (Wagner), *Hadziella sketi* Bole and *Kerkia* sp. in springs or underground waters and an abundant population of *Unio elongatulus* C. Pfeiffer in the Zrmanja and Krupa Rivers is also noteworthy. The area can be regarded as an important part of the Balkan region, one of world's hotspots of global biodiversity. Although it is protected, there are still anthropogenic factors that are negatively affecting or may affect the mollusc assemblages.

KEY WORDS: Mollusca; hotspot; endemics; threatened species; Zrmanja

INTRODUCTION

The Balkan region holds a rich freshwater fauna and belongs among the world's hotspots of global biodiversity (GRIFFITH et al. 2004). Dalmatia is regarded as a global hotspot of hydrobiids (MILLER et al. 2018). Many mollusc species (mostly gastropods) in the region have small, restricted ranges and are only found in small hydrographic systems: rivers, lakes or springs (RÉGNIER et al. 2009). Most rivers arising and flowing within the Mediterranean watershed typically drain small catchments (THORNES et al. 2009). This is also the case of the Zrmanja River which is one of the largest rivers in the Adriatic part of Croatia, despite its length of only 69 km and the catchment area of 907 km^2.

The Zrmanja River is ranked as one of the European or global hotspots of freshwater gastropod diversity (STRONG et al. 2008, BERAN et al. 2015). *Tanousia zrmanjae* (Brusina, 1866), *Hadziella sketi* Bole, 1961, *Belgrandiella krupensis* Radoman, 1973, *B. zermanica* Radoman, 1973, *Dalmatinella fluviatilis* Radoman, 1973 and *Islamia zermanica* Radoman, 1973 were described from the Zrmanja River and

its catchment area. Research focusing on freshwater gastropods was done in this area in the last decade (e.g. BERAN 2011, 2017, FALNIOWSKI & SZAROWSKA 2013, FALNIOWSKI & BERAN 2015, BERAN et al. 2015, 2016).

The research yielded a considerable set of distributional data. The main objective of this study was to summarise and analyse the recent distributional information on freshwater molluscs with special reference to endemic or threatened species, their status and preferable habitats, and to provide an assessment of the current situation of freshwater molluscs and support for the conservation of the Zrmanja and Krupa rivers catchment area.

MATERIAL AND METHODS

STUDY AREA

The Zrmanja is a river (Figs 1–5) in southern Lika and northern Dalmatia (Croatia). It is 69 km long and its basin is 907 km² in area. The source of the Zrmanja River is located in the southern part of Lika below Postak, the southern peak of the Pljesevica Mt., and close to the southern end of the Velebit Mts. It flows southward through the narrow and long arable valley which encircles the southern end of the Velebit through a deep canyon, then turns westwards to reach Obrovac, and after a few kilometers flows into the Adriatic Sea in the bay of Novigradsko more (BERAN 2011). Its most important tributary is the Krupa River. The waters of two sinking rivers, Ričica and Žižinka, which flow through the north-eastern part of the Gračac Plateau, reappear in many karst springs located on the right bank of the Zrmanja and Krupa rivers (BONACCI & ROJA-BONACCI 2015a, b). The Krupa River and the Zrmanja River downstream of the inflow of the Krupa River differ in character from the upper section of the Zrmanja River. The upper course of the Zrmanja River has a torrential character and is almost devoid of travertine cascades and waterfalls (Fig. 5). This section occasionally dries up. The Krupa River (Figs 1, 6), as well as the middle (Figs 3, 4) and the lower (Fig. 2) sections of the Zrmanja River hold numerous natural barriers (travertine cascades and waterfalls), resulting in alternation of shallow torrents with deeper, slow-flowing sections. The reversible hydroelectric power plant Velebit (RHEPP Velebit), which started operating in

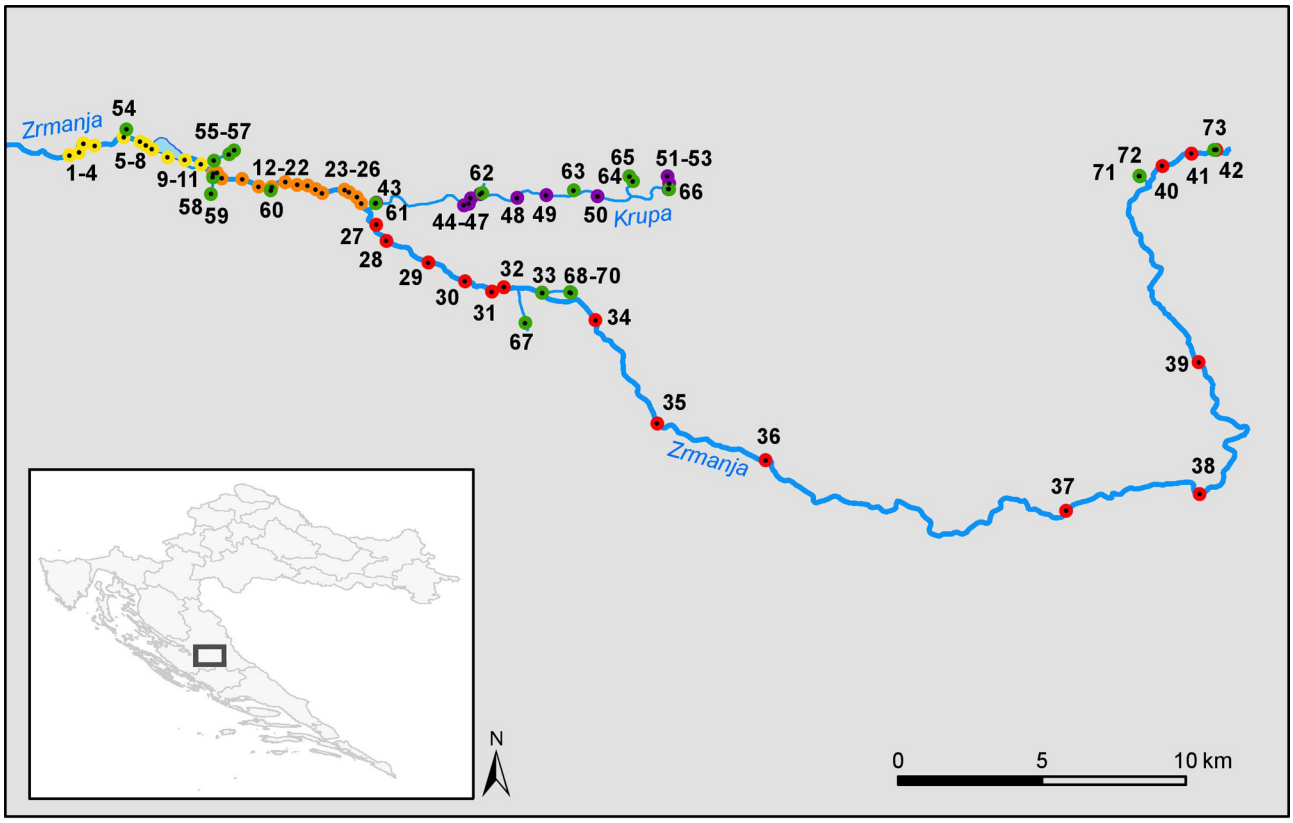

Fig. 1. Map of the Zrmanja River and its tributaries with the geographical distribution of the sampling sites. Yellow – Zrmanja I, orange – Zrmanja II, red – Zrmanja III, purple – Krupa, green – small tributaries and springs. Drawing H. MEDKOVÁ

1985, was built in the lower section of the Zrmanja River (Bonacci & Roja-Bonacci 2015b). It caused changes in the hydrological regime (Bonacci & Roja-Bonacci 2015b) and flooded a ca. 1.5 km long section of the river with two waterfalls.

During the Pleistocene, the Zrmanja River flowed southward, and fell into the Krka River. However, ca. 40,000 years ago it changed its course to what it is today. Its present bed is only a remain of the watercourse of the last Ice Age when the sea level was about 135 m lower than it is today. At that time the Zrmanja River flowed through the present area of the Novigrad Sea and continued farther through the Velebit channel between the islands of Pag and Rab, and then south near the islands of Cres, Lošinj and Premula to the confluence with the palaeo Po River.

The Zrmanja River and its tributaries are situated in the Velebit Nature Park. The Zrmanja River and the springs in Muškovci are the source of drinking water for Zadar.

SAMPLING AND MATERIAL PROCESSING

I collected the data in 2009–2020. The freshwater part of the Zrmanja River, the Krupa River, their small tributaries and the springs in their catchment area were studied at 73 sites (Fig. 1, Appendix 1). The freshwater part of the Zrmanja River was divided in three sections: Zrmanja I (loc. 1–11, Fig. 2) – the lower section of the river including the Razovac dam reservoir, Zrmanja II (loc. 12–26, Figs 3, 4) – the middle section between the Razovac dam reservoir and the inflow of the Krupa River, and Zrmanja III (loc. 27–42, Fig. 5) – the upper section upstream of the inflow of the Krupa River. Altogether 11 sites (loc. 43–53, Figs 6, 7) were located on the Krupa River and 20 sites (loc. 54–73) were in different small tributaries and springs. The main sampling method used was washing vegetation and sediments using metal sieves (diameter 20 cm, 0.8 mm mesh and/or diameter 10 cm, 0.5 mm mesh) combined with collecting by hand from the surface of stones, wood and artificial materials (e.g. plastic bags and bottles). Snorkelling in shallow parts (to ca. 3 m deep) was also used. The molluscs were identified based on their shell characters and, when necessary, on the structure of their copulatory organs. Specimens for dissection were killed in hot water and then fixed in 80% pure ethanol, while specimens for further DNA analysis were directly fixed in 80% pure ethanol. Selected shell material and specimens fixed in 80% ethanol are deposited in the author‘s collection.

Fig. 2. Jankovića buk waterfall (loc. 1) is the border between the brackish and the freshwater sections of the Zrmanja River. Photo: Luboš Beran

RESULTS

MOLLUSC ASSEMBLAGES

In total, 33 freshwater mollusc species were found in the rivers Zrmanja and Krupa with their tributaries and springs: 24 gastropods and 9 bivalves (Appendix 2: Tables 1–5). The Zrmanja River harbours 29 species. Only 17 species were recorded in the upper section of the Zrmanja River upstream of the inflow of the Krupa River (Zrmanja III, loc. 27–42), while downstream the assemblages included 25 (Zrmanja II, loc. 12–26) and 22 (Zrmanja I, loc. 1–11) species (Fig. 8, Appendix 2: Tables 1–3). Twenty six species were recorded in the Krupa River (loc. 43–53) and the same number was found in the various small tributaries and springs in the environs of these two rivers (Fig. 8, Appendix 2: Tables 4–5). The middle section of the Zrmanja and the Krupa Rivers were the richest in molluscs. *Theodoxus fluviatilis*, *Sadleriana fluminensis*, *Bithynia tentaculata*, *Valvata piscinalis*, *Stagnicola fuscus*, *Radix ampla*, *Planorbis carinatus*, *Unio elongatulus*, *Pisidium amnicum* and *P. subtruncatum* were most frequent in these sections. The assemblages of the upper section of the Zrmanja River were significantly poorer and also different from those inhabiting the remaining sections and the Krupa River. *Radix labiata* and *Planorbis planorbis* occurred only in the upper section, instead of *R. ampla* and *P. carinatus* which were found in the middle and lower sections of the Zrmanja and in the Krupa Rivers. *Pyrgula annulata*, *Dalmatinella fluviatilis*, *Radomaniola curta*, *Tanousia zrmanjae*, *V. piscinalis*, *Acroloxus lacustris*, *Hippeutis complanatus*, as well as *U. elongatulus* and *Anodonta exulcerata* were not recorded in the upper section, while *B. tentaculata*, *Emmericia patula* and *S. fuscus* were found in only one or two lowest-situated localities of the upper section. *Gyraulus parvus* was the only species with the occurrence limited to the upper section of the Zrmanja River. *Sphaerium corneum* was found only in the Krupa River and its tributary the Krnjeza Brook. A total of 26 species were found in the various small tributaries and springs. *Islamia zermanica* occurred in only one spring (loc. 59). A list of the studied sites and the species found at particular localities are shown in Fig. 1 and in Appendices 1 and 2 (Appendix 2: Tables 1–5).

ZOOGEOGRAPHICAL REMARKS

A third of the recorded species (11 species) have Cosmopolitan, Holarctic or Palaearctic distribution ranges (Fig. 8). Nearly as many (9 species) are distributed in Euro-Siberia or Europe. Most (12) of the recorded species are narrowly distributed. According to current knowledge, *P. annulata*, *S. fluminensis*, *E. patula*, *U. elongatulus* and *A. exulcerata* occur predominantly in the Adriatic Sea basin while the distribu-

Fig. 3. The Zrmanja River upstream of the Berberov buk waterfall (loc. 13) inhabited by the population of *Dalmatinella fluviatilis*. Photo: LUBOŠ BERAN

tion of *Belgrandiella kusceri*, *H. sketi*, *Kerkia* sp. and *R. curta* is limited to different-sized parts of Croatia with an overlap with the adjacent countries in the case of some species. However, the taxonomic status of some of the above-mentioned taxa is still uncertain and it cannot be ruled out that further studies using molecular genetic methods may reveal new endemic species. *D. fluviatilis*, *T. zrmanjae* and *I. zermanica* are endemic to the Zrmanja River catchment area. *Corbicula fluminea* (O. F. Müller, 1774) is an invasive non-native species, originally from Asia.

The upper section of the Zrmanja River (Zrmanja III) has the smallest proportion of narrowly distributed species (Fig. 8) while the middle section (Zrmanja II) has the largest proportion of such species. Species endemic to the Zrmanja River catchment area inhabit only its lower and middle sections and one isolated spring (see below).

ENDEMIC, THREATENED AND RARE MOLLUSCS

Most of the recorded species are common, listed in the current version of the IUCN Red List (IUCN 2020) under the category Least Concern. Only a few are listed as Critically Endangered (*T. zrmanjae*, *I. zermanica*), Endangered (*D. fluviatilis*) and Vulnerable (*H. sketi*). The remaining species (*B. kusceri*, *Kerkia* sp., *U. elongatulus*, *A. exulcerata*) are listed under Data Deficient or not listed due to their recently revised or uncertain taxonomic status. For notes on their distribution, habitats and taxonomic status see below. Their distribution in the studied area is shown in Figs 9 and 10.

Tanousia zrmanjae

It is probably the last surviving species of the genus (Beran et al. 2015). Only two populations were found during the recent survey, at loc. 18 and 19 (Beran 2017). The population at loc. 18 (Fig. 4) was found only in 2012, 2013 and 2014; no live snails were observed in 2016 and 2019 (Beran 2017 and this study). Empty shells (Fig. 11) were found only in the freshwater section of the Zrmanja River, between the Jankovića buk waterfalls and the inflow of the Krupa River. Neither live specimens nor shells were recorded in the Krupa River or in the Zrmanja River upstream of the Krupa inflow (Beran 2017 and this study). Live specimens were recorded at the depths of 0.2 to 4.5 m within a discontinious area of a few square metres (Beran 2017).

Fig. 4. The Zrmanja River in its middle section (loc. 18). Photo: Luboš Beran

Dalmatinella fluviatilis

D. fluviatilis was described from the middle part of the Zrmanja River in 1973 (RADOMAN 1973). The species was also mentioned from the lowest section of the Neretva River between Kula and Opuzen (RADOMAN 1983). Considering the distance between the Zrmanja and the Neretva Rivers, exceeding 200 km, without any records inbetween, FALNIOWSKI & SZAROWSKA (2013) expressed doubts if the same species of *Dalmatinella* could be present at both localities. Current research confirmed this assumption and a new species, *D. simonae* Beran et Rysiewska, 2021, found in the Cetina and Neretva Rivers including Bačina lakes, was described (BERAN et al. 2021, own unpublished results). BERAN (2011) found only a few specimens on stones at loc. 8 (loc. 19 in this study). FALNIOWSKI & SZAROWSKA (2013) found this species at the Jankovića buk waterfalls (loc. 1 in this study). I found several specimens also at loc. 1. More abundant and more continuous occurrence was found at a less than 300 m long section of the Zrmanja River (loc. 13 and 14, Fig. 3). *D. fluviatilis* was found in shallow places on stones at loc. 1, 19 while at loc. 13 and 14 it occurred mostly on the vegetation at the depths ranging from 0.5 to 2 m.

Islamia zermanica

Islamia is a genus of minute freshwater snails of the family Hydrobiidae. *I. zermanica* was described from the freshwater section of the Zrmanja River (RADOMAN 1973). The species was found by A. Falniowski and M. Szarowska at the Jankovića buk waterfalls (BERAN et al. 2016, loc. 1 in this study) and by myself in a small spring at Berberi (loc. 59). The species is regarded as endemic to the Zrmanja River catchment area (RADOMAN 1983, BERAN et al. 2016).

Hadziella sketi

H. sketi is a small gastropod living in karstic groundwaters and was described from a cave near Obrovac (BOLE 1961). Its description was based exclusively on shells and its distribution is not well known yet. BILANDZIJA & JALZIC (2011) mentioned its occurrence from the Krka National Park. *H. sketi* was found in springs in the upper section of the Krupa River. Many old and fresh shells were found at loc. 53 and 65 while only old shells were recorded at loc. 51, 52, 64.

Kerkia sp.

Kerkia is a genus of minute valvatiform gastropods living in karstic groundwaters. Fresh shells were found only in the source of the tributary of the Krupa River (loc. 65), while only old shells were collected at loc. 53, 54, 61. Due to the fact that only shells were found during this study the taxonomic status is uncertain because more species of the genus are known from this part of Croatia. *K. kareli* Beran, Bodon et Cianfanelli, 2014 was described from Pag

Fig. 5. The Zrmanja River in its upper section, of a torrential character nearly without travertine cascades and waterfalls (loc. 36). Photo: LUBOŠ BERAN

Island (BERAN et al. 2014) while *K. jadertina* (Kuščer, 1933) is known from more sites in the Split region (BERAN et al. 2014). The nearest site with the occurrence of live specimens is Ljubač near Pag Island, ca. 50 km to the northwest. The population in Ljubač may represent a still undescribed species (RYSIEWSKA et al. 2017).

Belgrandiella kusceri

RADOMAN (1973) described two species of the genus *Belgrandiella* from the Zrmanja River catchment area: *B. krupensis* from the source of the Krupa River and *B. zermanica* from the Zrmanja River above the Jankovića buk waterfalls. However, it has to be noted that the distinctness of these species is doubtful and both should be synonymised with *B. kusceri* (FALNIOWSKI & BERAN 2015, OSIKOWSKI et al. 2018). *B. kusceri* was found at loc. 19, 29, 41, 50–53, 56, 60, 66, 70, 71. The shell morphology of the specimens from loc. 60 corresponds to *B. zermanica* while the remaining ones – to *B. krupensis*.

Unio elongatulus

The range of *U. elongatulus* extends from north of the Apennines in Italy to coastal Croatia (FROUFE et al. 2017) and probably even further south (M. LOPES-LIMA, pers. comm.). The species has not been assessed by the IUCN since it has only recently been recognised and distinguished from *U. mancus* Lamarck, 1819 which is listed in the last version of the IUCN Red List as Near Threatened (LOPES-LIMA & SEDDON 2014). It is among the most common species in the Zrmanja and Krupa rivers and was found at 33 of the studied sites (Fig. 10, Appendix 2: Tables 1–4). Very abundant populations of this bivalve were found in most of the studied sites in the lower and middle sections of the Zrmanja River (Zrmanja I, II), including the Razovac dam reservoir and the Krupa River. Due to the heterogeneous river bed the occurrence was irregular, but in suitable places the density exceeded several hundred individuals per square metre and in many sites the species constituted the dominant component of molluscan biomass together with the other dominant molluscs such as *T. fluviatilis* or *B. tentaculata*.

Anodonta exulcerata

A. exulcerata appears to be endemic to the region ranging from the Italian Peninsula to Croatia and to the west of the Dinaric Alps (FROUFE et al. 2017). It has not been assessed by the IUCN since it has only recently been recognised as a distinct species; according to FROUFE et al. (2017) more research is needed for a precise assessment of its conservation

Fig. 6. Travertine cascades and waterfalls are frequent in the lower section of the Krupa River (loc. 44). Photo: LUBOŠ BERAN

status. A scattered or rare occurrence was observed in the lower and middle sections of the Zrmanja River (Zrmanja I, II) including the Razovac dam reservoir, in the Krupa River and in the Dabarnica Brook (loc. 55) (Fig. 10, Tables 1–5). Usually only a few specimens per site were found compared to tens or hundreds (thousands) of individuals of *U. elongatulus*.

NON-NATIVE SPECIES

One non-native species was recored. *C. fluminea* was found at loc. 1 (Fig. 2) for the first time in 2019 and its occurrence was confirmed in 2020 (Beran 2020). Only two young individuals (less than 10 mm) were found in 2019, while a more abundant occurrence was documented in 2020. A scattered occurrence of live individuals was observed there, except the place where *C. fluminea* was found in 2019. In all, 42 specimens were found within an area of 1 m^2 in the sediment at a shallow place (50–70 cm) near the river bank. Smaller specimens dominated (Beran 2020). No empty shells were found during the 2019 and 2020 surveys. The same site was visited also in 2013 and 2015 and *C. fluminea* was not found there (Beran 2020).

DISCUSSION

MOLLUSC ASSEMBLAGES

Rich mollusc assemblages inhabit the rivers Zrmanja and Krupa. They include both rheophilous species (e.g. *T. fluviatilis*, *S. fluminea*, *E. patula*, *R. ampla*, *A. fluviatilis*) and species preferring stagnant or slow-flowing waters (e.g. *A. lacustris*, *S. fuscus*, *P. planorbis*). The reason is the character of both rivers, where slow-flowing parts are interspersed with waterfalls and fast-flowing sections. The assemblages of the middle and lower sections of the Zrmanja River are more similar to those of the Krupa River than the assemblages from the upper section of the Zrmanja River. These assemblages are poorer, with fewer endemic or threatened species. The occurrence of two pairs of related species is also notable. *R. la-*

Fig. 7. The Krupa River in its upper section (loc. 51). Photo: Luboš Beran

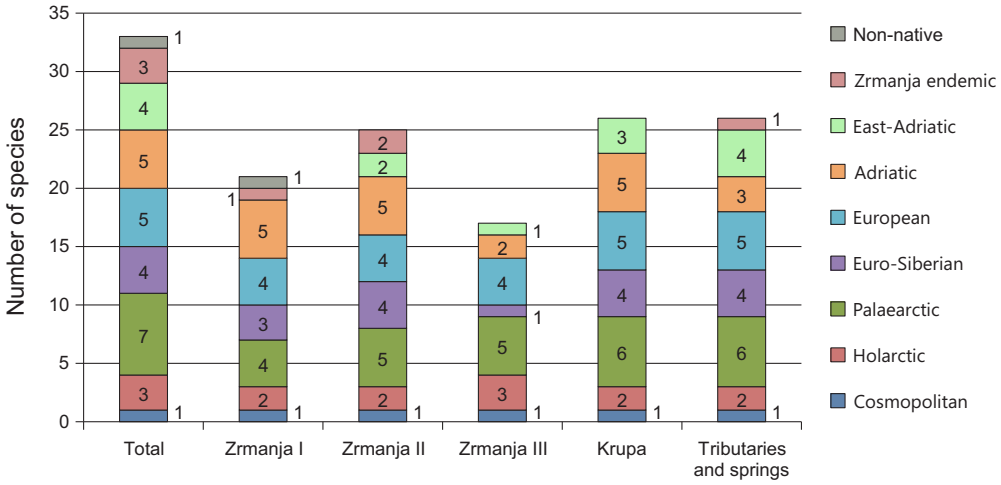

Fig. 8. Number of species recorded in particular sections and zoogeographical analysis of aquatic molluscs found in the Zrmanja River and its tributaries

biata and *P. planorbis* inhabit only the upper section of the Zrmanja upstream of the confluence of both rivers, while *R. ampla* and *P. carinatus* occur in the Krupa River and in the middle and lower sections of the Zrmanja River. The probable reason for this difference is the character of the upper section of the Zrmanja River. The upper course has a torrential character nearly devoid of travertine cascades and waterfalls (Fig. 5) and occasionally dries up, while natural barriers (travertine cascades and waterfalls), which cause the alternation of shallow torrents with deeper, slow-lowing sections exist in the Krupa River (Fig. 6) and in the middle (Figs 3, 4) and lower (Fig. 2) courses of the Zrmanja River.

The Krka River is the nearest bigger river in the Adriatic part of Croatia. During the Pleistocene, the Zrmanja River flowed southward, to join the Krka. The mollusc assemblages of the Krka River have been studied recently (Vučković 2013, Beran 2016). Altogether 18, mostly common and widespread, freshwater species inhabit both rivers. The bivalve assemblages of the two rivers are very similar. Gastropods preferring slow-flowing waters, including *A. vorticulus*, an endangered species listed in the EU Habitats Directive, are more frequent in the Krka River. The probable reason is the existence of the extensive Visovac Lake and other lakes and pools created by travertine cascades. On the other hand, the Krka River (main current) is significantly poorer in small hydrobiids while small springs in the Krka catchment area harbour several endemic species, for example *Lanzaia skradinensis* Bole, 1992.

HOTSPOT

The Zrmanja River catchment area is regarded as one of the European or global hotspots of freshwater gastropod diversity (Strong et al. 2008, Falniowski & Beran 2015) but this statement probably does not correspond to reality and is rather due to the lack of data from other areas. Although several endemic species and also very rich mollusc assemblages occur there, there are other areas of similar character, with high diversity of endemic freshwater molluscs (mostly gastropods), especially in the Adriatic part of Croatia and adjacent countries (e.g. Radoman 1983) or in the whole Balkan region. This area, with its hundreds of endemic species of freshwater molluscs, mainly small hydrobiids, is thus a much more appropriate candidate for an important part of the Balkans, and is ranked as a hotspot of global biodiversity (Griffith et al. 2004, Strong et al. 2008) and also as the part of Dalmatia which is one of the most important hotspots of hydrobiid diversity (Miller et al. 2018).

THREATS, NOTES ON CONSERVATION STATUS OF THREATENED SPECIES

Although the Zrmanja River and its tributaries are situated in the Velebit Nature Park, there are many anthropogenic factors that threaten its freshwater molluscs. The reversible hydroelectric power plant Velebit (RHEPP Velebit), operating since 1985, and located in the lower section of the river, has caused changes in the hydrological regime (Bonacci & Roja-Bonacci 2015b) and flooded a ca 1.5 km long section of the Zrmanja River with two waterfalls. Construction of another three new dams and hydro-power plants is planned in the middle and upper sections of the Zrmanja (Bjedov 1995). The construction of new dams would significantly affect the river's mollusc assemblages and might lead to extinction of some species. Both rivers are located in a sparsely populated and little exploited area. However, especially in the environs of the Berberov

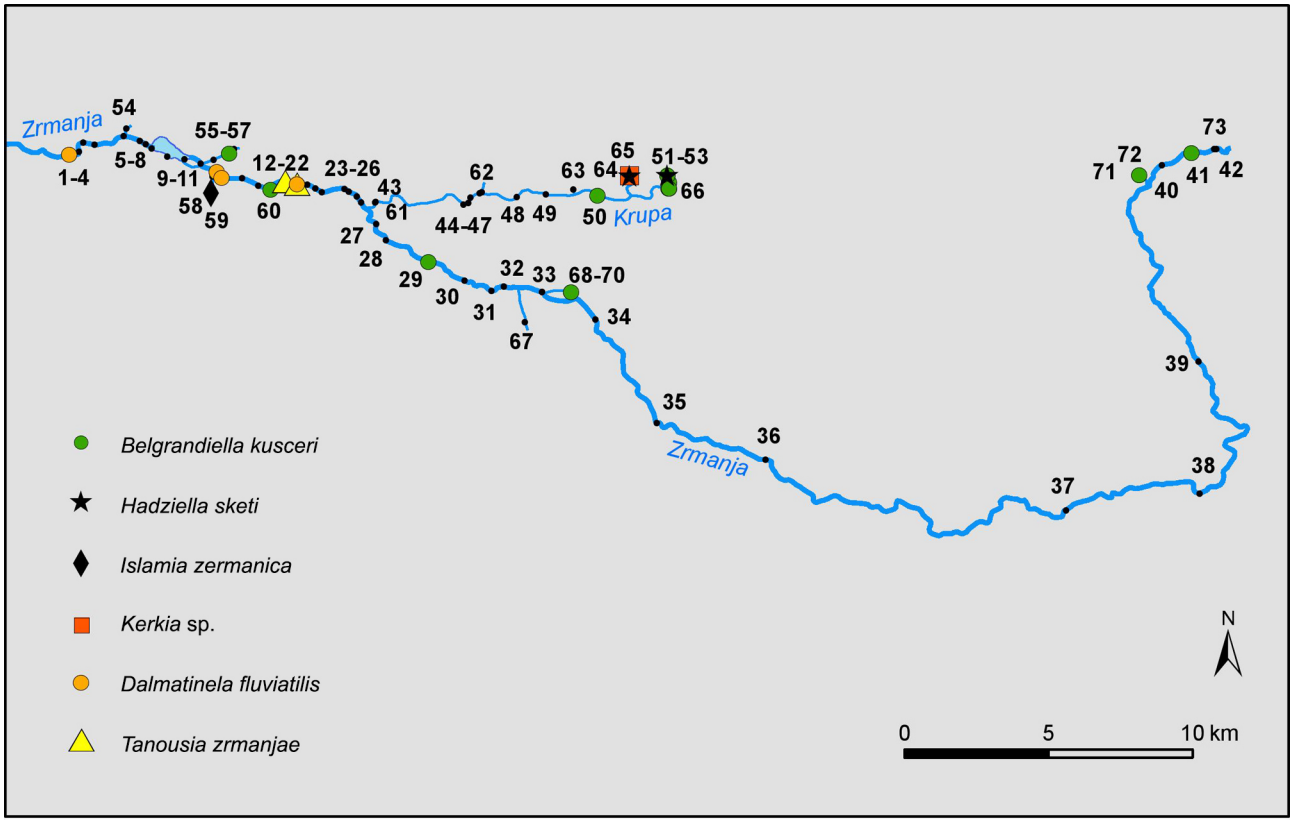

Fig. 9. Map showing the distribution of threatened and endemic gastropods. Drawing H. MEDKOVÁ

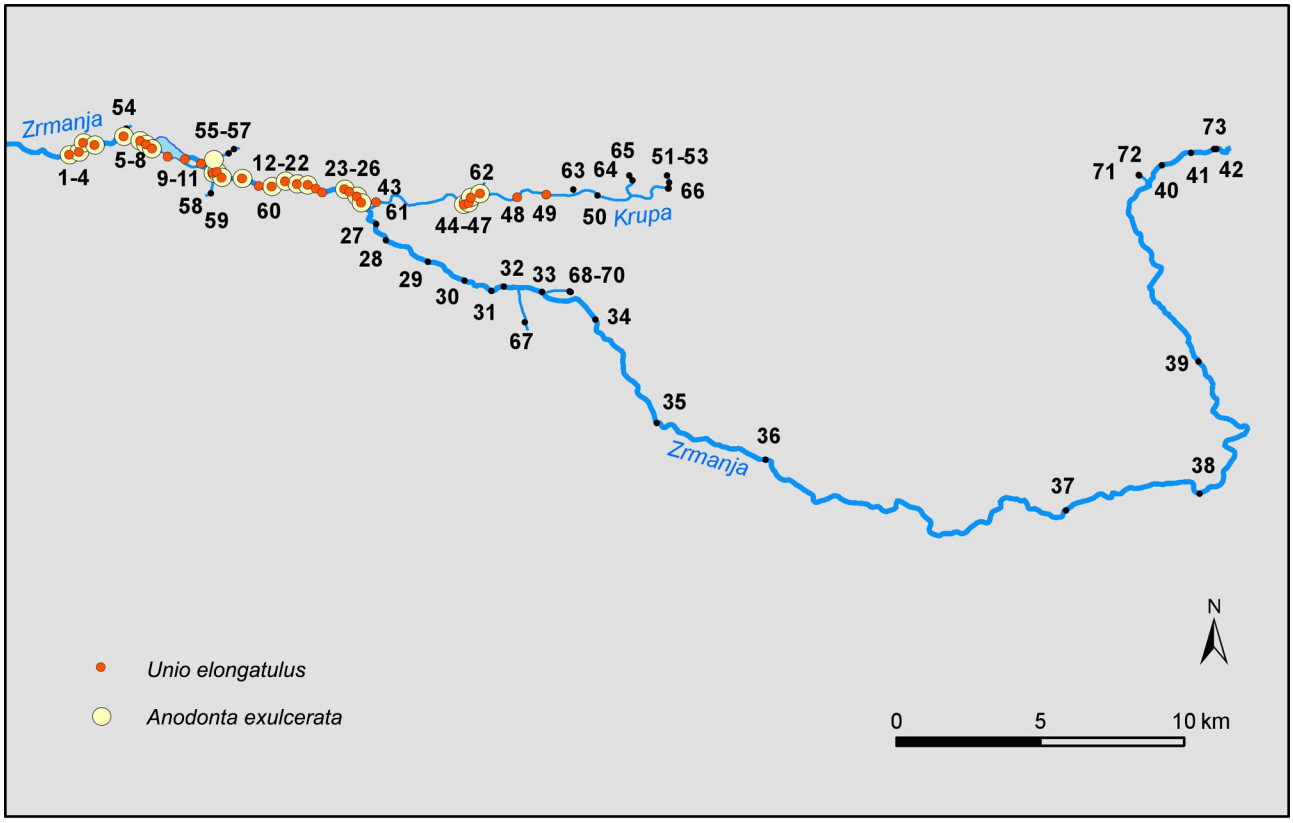

Fig. 10. Map showing the distribution of *Unio elongatulus* and *Anodonta exulcerata*. Drawing H. MEDKOVÁ

buk waterfall, there is currently a development of recreational facilities (camps, restaurants). This trend may cause undesirable eutrophication of the Zrmanja River. In contrast, individual recreational activities (swimming, kayaking, rafting, sport fishing) probably have a minimal impact on the mollusc assemblages. Introduction or acceleration of invasion of non-native species (BERAN 2020) is an exception. The mollusc assemblages of the Zrmanja River are affected by one non-native species. *C. fluminea* was recorded for the first time in 2019 and its further expansion is expected (BERAN 2020). The invasion, together with high abundance, could have a negative effect, especially on bivalves. Invasion of other non-native species can be expected in the future. *Physa acuta* (Draparnaud, 1805) is common and widespread also in the Adriatic part of Croatia (ŽGANEC et al. 2020, BERAN unpublished records) and occurs for example in the Krka River catchment area (BERAN 2016). The Razovac dam reservoir is used for sport fishing; another non-native mollusc, *Sinanodonta woodiana* (Lea, 1834), can be introduced there with infected fish. Invasion of this species might have a negative effect on the autochthonous unionids (*U. elongatulus, A. exulcerata*).

The degree of threat is in some cases correlated with the distribution range. Three species endemic to the Zrmanja River catchment area are currently the most threatened molluscs. Only two area-limited sites with the occurrence of *T. zrmanjae* were found in the middle section of the Zrmanja River; a probable extinction or at least a significant decline in one of these two known sites was observed during the last ten years (BERAN 2017). The reasons for the decline are still unknown (BERAN 2017). Despite intensive searches, no live individuals were found anywhere else. *T. zrmanjae* should be regarded as critically endangered, with a high probability of extinction in the following years or decades (BERAN 2017). *D. fluviatilis* was found in the middle and lower sections of the Zrmanja. Only few individuals were found at loc. 1 and 19 in 2013 and 2010, respectively. Repeated searches of these sites in the following years were unsuccessful, but due to its small size the species is likely to have been overlooked and may be found there or at some new sites in the future. A more abundant population was found at a less than 300 m long section (loc. 13 and 14). *D. fluviatilis* can be regarded as endemic to the freshwater part of the Zrmanja River (see Results). Although the situation of this species is slightly better than in the case of *T. zrmanjae*, in view of the above facts it is desirable that in the further version of the IUCN Red List the species be reclassified from Endangered to Critically Endangered. At present, the distribution of the two species (*T. zrmanjae, D. fluviatilis*) is limited to a very short section of the Zrmanja River, whereas in the past their occurrence and also the occurrence of other freshwater molluscs may have been much wider because in the last Ice Age the sea level was more than 135 m lower, the Zrmanja River was significantly longer and flowed into the palaeo Po River. This is supported by the fact that fossil shells of *T. zrmanjae* were also found in the brackish section of the Zrmanja River near Obrovac (SCHLICKUM & SCHÜTT 1971). *I. zermanica* is also regarded as endemic to the Zrmanja River catchment area. It was found in the Zrmanja River (BERAN et al. 2016, loc. 1 in this study) and in an isolated spring (loc. 59). In spite of intensive searches during the survey, it was not found in other sites. Due to its small size it may have been overlooked and may be also found in some springs in this area. Nevertheless, its status remains unsatisfactory and *I. zermanica* should be treated as a critically endangered species facing the threat of extinction.

Fig. 11. Shell of *Tanousia zrmanjae*, the most threatened mollusc of the Zrmanja River. Photo: M. HORSÁK

The situation of other spring-dwelling molluscs (e.g. *B. krupensis*) is somewhat better in comparison with the rivers. Most of the springs have not yet undergone any drastic modifications. The probable reason is that water from the rivers is used for irriga-

tion or as a source of drinking water more than water from small springs. In contrast, in areas without major watercourses, springs are the only sources of water (drinking or for irrigation) and they have often been drastically modified, which has significantly affected or destroyed their malacofauna (RADOMAN 1983, SZAROWSKA 2006, own observations from the environs of Zadar).

In the case of groundwaters, the situation is not very well known. Due to the sparse population and low exploitation it is assumed that there are no significant negative changes. The groundwaters in the upper section of the Krupa River are an important habitat for *H. sketi*. The number of shells found indicates that there still occur numerous populations, while the findings of *Kerkia* sp. are rather rare. *H. sketi* is listed in the current version of the IUCN Red List as Vulnerable (BILANDZIJA & JALZIC 2011). Because its distribution is not well known yet, it would be advisable to reclassify it in the category Data Deficient and it is not excluded that the species is more threatened than currently believed.

CONCLUSIONS

The rivers Zrmanja and Krupa are refuge for endemic species and also host very rich mollusc assemblages which include endangered and rare species. The most important is the middle section of the Zrmanja River with the endemic *T. zrmanjae* and the abundant population of *D. fluviatilis*. However, the situation of the first species is critical and it may become extinct within a few years or decades without the causes of its extinction being identified.

This area is thus a very important part of the Balkan region, which is inhabited by hundreds of endemic freshwater mollusc species, mainly small hydrobiids. Although it is protected, there are still anthropogenic factors that are negatively affecting or may affect the mollusc assemblages. The potential construction of other dam reservoirs is among the most serious threats.

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APPENDIX 1

LIST OF INVESTIGATED SITES

The data in the list are as follows: site number, geographical co-ordinates, name of the nearest settlement, site description, date of investigation. For location of the sites see Fig. 1

ZRMANJA RIVER

Zrmanja I

1 – 44°12'10.6"N, 15°43'19.5"E, Zaton Obrovački, Zrmanja River upstream of Jankovića buk waterfalls, **a)** 16.8.2013, **b)** 28.6.2015, **c)** 11.7.2019, **d)** 5.7.2020;
2 – 44°12'13.8"N, 15°43'30.2"E, Zaton Obrovački, Zrmanja River ca. 400 m upstream of Jankovića buk waterfalls, 28.6.2015;
3 – 44°12'23.8"N, 15°43'35.2"E, Zaton Obrovački, Zrmanja River near ruin of castle St. Obrovac, at destroyed hydro-power station, **a)** 13.8.2009 (Beran 2011), **b)** 30.6.2015;
4 – 44°12'21.4"N, 15°43'47.9"E, Zaton Obrovački, Zrmanja River ca. 200 m upstream of destroyed hydro-power station, 30.6.2015;
5 – 44°12'30.9"N, 15°44'20.6"E, Muškovci, Zrmanja River ca. 500 m downstream of Razovac dam reservoir, 6.7.2017;
6 – 44°12'26"N, 15°44'39"E, Muškovci, Zrmanja River ca. 100 m downstream of Razovac dam reservoir, 6.7.2010 (Beran 2011);
7 – 44°12'21.8"N, 15°44'45.7"E, Muškovci, Zrmanja River ca. 50 m downstream of Razovac dam reservoir, **a)** 12.7.2018, **b)** 6.7.2020;
8 – 44°12'17.3"N, 15°44'52.5"E, Muškovci, SW. shore of Razovac dam reservoir, **a)** 11.7.2018, **b)** 6.7.2020;
9 – 44°12'08.5"N, 15°45'10.1"E, Muškovci, S. shore of Razovac dam reservoir, 10.7.2018;
10 – 44°12'05.6"N, 15°45'29.4"E, Berberi, left arm of Zrmanja River at its inflow to Razovac dam reservoir, 29.6.2015;
11 – 44°12'00.7"N, 15°45'47.4"E, Berberi, right arm of Zrmanja River at its inflow to Razovac dam reservoir, 29.6.2015;

Zrmanja II

12 – 44°11'50"N, 15°46'01.1"E, Berberi, Zrmanja River downstream of Berberov buk waterfall, **a)** 3.7.2014, **b)** 7.7.2016;
13 – 44°11'51.2"N, 15°46'05.4"E, Berberi, Zrmanja River upstream of Berberov buk waterfall, 10.7.2019;
14 – 44°11'44.9"N, 15°46'10.8"E, Berberi, Zrmanja River upstream of bridge near Berberov buk waterfall, **a)** 9.8.2009 and 14.8.2009 (Beran 2011), **b)** 2.8.2012, **c)** 1.7.2015, **d)** 3.7.2016, **e)** 9.7.2018, **f)** 9.7.2019;
15 – 44°11'44.2"N, 15°46'33.9"E, Berberi, Zrmanja River ca. 400 m upstream of Berberov buk waterfall, 4.7.2014;
16 – 44°11'35.7"N, 15°46'52.5"E, Berberi, Zrmanja River ca. 700 m upstream of Berberov buk waterfall, 1.7.2015;
17 – 44°11'35.0"N, 15°47'07.2"E, Dramotiči, Zrmanja River downstream of waterfall, **a)** 14.8.2013, **b)** 3.7.2016;
18 – 44°11'40.7"N, 15°47'22.3"E, Dramotiči, Zrmanja River upstream and downstream of small waterfall, **a)** 30.7.2012, **b)** 11.8.2013, **c)** 9.7.2016, **d)** 9.7.2019;
19 – 44°11'37.7"N, 15°47'35.6"E, Dramotiči, Zrmanja River downstream of waterfall (left bank) at big rock, **a)** 3.7.2010, 4.7.2010, 6.7.2010 (Beran 2011), **b)** 29.6.2014, **c)** 9.7.2019;
20 – 44°11'36.8"N, 15°47'47.4"E, Dramotiči, Zrmanja River between two waterfalls, **a)** 5.7.2016, **b)** 10.7.2019;
21 – 44°11'32.6"N, 15°47'56.5"E, Dramotiči, Zrmanja River ca. 1,300 m downstream of Visoki buk waterfall at small rapids, 11.8.2013;
22 – 44°11'28.2"N, 15°48'03.9"E, Dramotiči, Zrmanja River at small island, 6.7.2016;
23 – 44°11'32"N, 15°48'29"E, Dramotiči, Zrmanja River ca. 600 m downstream of Visoki buk waterfall, 14.7.2010 (Beran 2011);
24 – 44°11'29.1"N, 15°48'34.1"E, Dramotiči, Zrmanja River ca. 500 m downstream of Visoki buk waterfall, 11.8.2013;
25 – 44°11'23.7"N, 15°48'43"E, Dramotiči, Zrmanja River downstream of Visoki buk waterfall, 14.8.2013;
26 – 44°11'16.9"N, 15°48'47.7"E, Dramotiči, Zrmanja River upstream of Visoki buk waterfall, 14.8.2013;

Zrmanja III

27 – 44°10'52.9"N, 15°49'04.9"E, Golubić, Zrmanja River ca. 750 m upstream of inflow of Krupa River, 2.7.2015;

28 – 44°10'34.7"N, 15°49'15.9"E, Kaštel Žegarski, Zrmanja River next to big rock ca. 5 km downstream of bridge in Kaštel Žegarski, 2.7.2015;
29 – 44°10'10.3"N, 15°50'03.1"E, Kaštel Žegarski, Zrmanja River ca. 3 km downstream of bridge in Kaštel Žegarski, 2.7.2015;
30 – 44°09'49.4"N, 15°50'44.4"E, Kaštel Žegarski, Zrmanja River ca. 700 m downstream of bridge in Kaštel Žegarski, 5.7.2014;
31 – 44°09'37.3"N, 15°51'14.6"E, Kaštel Žegarski, Zrmanja River at Riva rafting centre in Kaštel Žegarski, **a)** 11.7.2019, **b)** 9.7.2020;
32 – 44°09'42.7"N, 15°51'28.5"E, Kaštel Žegarski, Zrmanja River in Kaštel Žegarski, **a)** 9.8.2009 (Beran 2011), **b)** 4.7.2010 (Beran 2011), **c)** 13.7.2018;
33 – 44°09'36.3"N, 15°52'11.3"E, Kaštel Žegarski, Zrmanja River at inflow of small tributary ca. 1 km from bridge in Kaštel Žegarski, 10.7.2017;
34 – 44°09'05.3"N, 15°53'11.4"E, Prndelji, Zrmanja River upstream of bridge in Prndelji, **a)** 8.7.2010 (Beran 2011), **b)** 10.7.2017;
35 – 44°07'09.4"N, 15°54'20.7"E, Vujanići, Zrmanja River W of Vujanići, 11.7.2017;
36 – 44°06'27.9"N, 15°56'22.8"E, Ervenik, Zrmanja River at bridge in Ervenik, **a)** 10.8.2009 (Beran 2011), **b)** 8.7.2010 (Beran 2011), **c)** 11.7.2017;
37 – 44°05'31.1"N, 16°02'01.0"E, Mokro Polje, Zrmanja River in Mokro Polje at bridge, **a)** 10.8.2009 (Beran 2011), **b)** 8.7.2010 (Beran 2011), **c)** 10.7.2018;
38 – 44°05'50.0"N, 16°04'31.2"E, Prevjes, Zrmanja River at bridge, 1.9.2018;
39 – 44°08'18"N, 16°04'30"E, Palanka, Zrmanja River in Palanka at bridge, 10.8.2010 (Beran 2011);
40 – 44°11'59"N, 16°03'49"E, Zrmanja Vrelo, Zrmanja River ca. 2 km downstream of its soure, 8.7.2010 (Beran 2011);
41 – 44°12'12.5"N, 16°04'21.9"E, Zrmanja Vrelo, Zrmanja River in Zrmanja Vrelo ca. 1 km downstream of its source, 8.7.2018;
42 – 44°12'16.7"N, 16°04'49.9"E, Zrmanja Vrelo, Zrmanja River in Zrmanja Vrelo ca. 400 m downstream of its source, 8.7.2018;

Krupa River

43 – 44°11'17.5"N, 15°49'04.6"E, Golubić, Krupa River ca. 450 m upstream of its inflow to Zrmanja River, 2.7.2015;
44 – 44°11'14.8"N, 15°50'43.1"E, Golubić, Krupa River downstream of waterfalls downstream of Kudin most bridge, 2.7.2014;
45 – 44°11'16.5"N, 15°50'48.6"E, Golubić, Krupa River between Kudin most bridge and waterfalls upstream of bridge, **a)** 2.7.2014, **b)** 8.7.2019;
46 – 44°11'22.7"N, 15°50'51.1"E, Golubić, Krupa River upstream of travertine cascades ca. 200 m upstream of Kudin most bridge, 2.7.2014;
47 – 44°11'27.0"N, 15°51'01.5"E, Golubić, Krupa River upstream of inflow of Krnjeza Brook, 8.7.2019;
48 – 44°11'23.0"N, 15°51'43.1"E, Krupa, Krupa River upstream of waterfall ca. 1,500 m upstream of inflow of Krnjeza Brook, 10.7.2019;
49 – 44°11'25.9"N, 15°52'15.8"E, Krupa, Krupa River west of Krupa Monastery, 10.7.2019;
50 – 44°11'24.6"N, 15°53'13.8"E, Krupa, Krupa River near Krupa Monastery, **a)** 4.7.2010 (Beran 2011), **b)** 13.7.2018;
51 – 44°11'32.8"N, 15°54'33.5"E, Krupa, Krupa River in Krupa near bridge, **a)** 14.7.2010 (Beran 2011), **b)** 13.7.2018;
52 – 44°11'39.3"N, 15°54'34.5"E, Krupa, Krupa River and small spring ca. 140 m upstream of bridge in Krupa, 17.8.2013;
53 – 44°11'47.3"N, 15°54'32.3"E, Krupa, source of Krupa River, 17.8.2013;

Small tributaries and springs

54 – 44°12'39.8"N, 15°44'23.6"E, Muškovci, small spring NW of Razovac dam reservoir, 6.7.2017;
55 – 44°12'05"N, 15°46'02"E, Muškovci, Dabarnica Brook ca. 200 m upstream of Razovac dam reservoir, 6.7.2010 (Beran 2011);
56 – 44°12'12.0"N, 15°46'19.2"E, Muškovci, two small springs by path along Dabarnica Brook, 29.6.2014;
57 – 44°12'16.4"N, 15°46'24.7"E, Muškovci, source of left arm of Dabarnica Brook, 29.6.2014;
58 – 44°11'46.3"N, 15°46'00.9"E, Berberi, small tributary (Džebinovac) ca. 20 m upstream of its inflow to Zrmanja River, 9.7.2018;

59 – 44°11'27.3"N, 15°45'58.8"E, Berberi, small spring under rock in small valley south of Berberov buk waterfall, **a)** 3.7.2014, **b)** 1.7.2015;
60 – 44°11'31.3"N, 15°47'06.1"E, Dramotiči, spring by Zrmanja River downstream of waterfalls, **a)** 14.8.2013, **b)** 29.6.2014;
61 – 44°11'16.8"N, 15°49'03.9"E, Golubić, small spring next to Krupa River ca. 450 m upstream of its inflow to Zrmanja River, 2.7.2015;
62 – 44°11'28.7"N, 15°51'03.7"E, Golubić, Krnjeza Brook upstream of its inflow to Krupa River, 8.7.2019;
63 – 44°11'31.4"N, 15°52'46.9"E, Krupa, spring and rivulet W of Krupa Monastery, 10.7.2019;
64 – 44°11'41.6"N, 15°53'53.4"E, Krupa, tributary (Orovača) of Krupa River W of Krupa, 30.6.2014;
65 – 44°11'47.2"N, 15°53'49.4"E, Krupa, source of tributary of Krupa River W of Krupa, 30.6.2014;
66 – 44°11'33"N, 15°54'34"E, Krupa, spring by Krupa River near bridge, **a)** 14.7.2010 (Beran 2011), **b)** 13.7.2018;
67 – 44°09'02.4"N, 15°51'52.3"E, Kaštel Žegarski, spring on E. edge of Kaštel Žegarski, 8.7.2017;
68 – 44°09'36.1"N, 15°52'11.3"E, Kaštel Žegarski, small canal upstream of its inflow to Zrmanja River, 10.7.2017;
69 – 44°09'36.8"N, 15°52'42.5"E, Kaštel Žegarski, rivulet ca. 50 m downstream of spring NE of Kaštel Žegarski, 8.7.2017;
70 – 44°09'36.2"N, 15°52'43.9"E, Kaštel Žegarski, big spring NE of Kaštel Žegarski, 8.7.2017;
71 – 44°11'47.7"N, 16°03'23.1"E, Zrmanja Vrelo, spring near monument in Zrmanja Vrelo, 8.7.2018;
72 – 44°11'47.3"N, 16°03'23.5"E, Zrmanja Vrelo, small tributary near monument in Zrmanja Vrelo, 8.7.2010 (Beran 2011);
73 – 44°12'16.9"N, 16°04'47.5"E, Zrmanja Vrelo, small spring by Zrmanja River ca. 450 m downstream of its source, 8.7.2018.

APPENDIX 2

Table 1. Zrmanja I – list of freshwater molluscs recorded in the lower section of the Zrmanja River. x – few specimens, xx – scattered occurrence, xxx – abundant occurrence, (x) – old shells only, Σ – number of sites with the occurrence of particular species (number of sites with the occurrence of old shells only in parentheses)

Species	Site no.																	
	1a	1b	1c	1d	2	3a	3b	4	5	6	7a	7b	8a	8b	9	10	11	Σ
Gastropoda																		
Theodoxus fluviatilis (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xx	xxx	xx	x	xxx	x	x	xxx	11
Pyrgula annulata (Linnaeus, 1758)	x															(x)		1(1)
Sadleriana fluminensis (Küster, 1852)				x												(xx)	xxx	2(1)
Dalmatinella fluviatilis Radoman, 1973	x																	1
Tanousia zrmanjae (Brusina, 1866)	(x)	(x)		(x)				(x)								(x)		(5)
Emmericia patula (Brumati, 1838)																(x)	xx	1(1)
Bithynia tentaculata (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xx	xx	x	xxx	xx	x	x	11
Valvata piscinalis (O. F. Müller, 1774)	xxx	xx	x			xx	x	x		xxx	xx	xx	xx	xxx	xx	x	x	9
Acroloxus lacustris (Linnaeus, 1758)			x		x	x				x								4
Stagnicola fuscus (C. Pfeiffer, 1821)	xx	xx	x			xx										(x)	x	3(1)
Radix ampla (Hartmann, 1821)	x	xxx	xx	xx	x				x							(xx)		3(1)
Radix auricularia (Linnaeus, 1758)	x						x		x							x		4
Planorbis carinatus O. F. Müller, 1774	xxx		xx			xx	xx	x								(x)		3(1)
Hippeutis complanatus (Linnaeus, 1758)						x	x			x								2
Ancylus fluviatilis (O. F. Müller, 1774)	x							x										2
Bivalvia																		
Unio elongatulus C. Pfeiffer, 1825	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xx	xxx	x	xx	x	11
Anodonta exulcerata Porro, 1838	xx	x	x	xx	x	x	x	x	x	xx		x	x	x				8
Corbicula fluminea (O. F. Müller, 1774)			x	xx														1
Pisidium amnicum (O. F. Müller, 1774)	xxx	x	xx	xx	x	xx	xx	xx	x	xx		x				x	x	9
Pisidium casertanum Poli, 1791							x	x								x	x	4
Pisidium nitidum Jenyns, 1832	xx		x			x	x	x	x	x		x					x	7
Pisidium subtruncatum Malm, 1855			x	x		x	xx	x	x	xx		x	x				x	8
Number of species	14	8	13	9	7	12	12	11	9	10	4	8	6	5	4	7	11	

Table 2. Zrmanja II – list of freshwater molluscs recorded in the middle section of the Zrmanja River. For explanation see Table 1

Species	Site no.																											
	12a	12b	13	14a	14b	14c	14d	14e	14f	15	16	17a	17b	18a	18b	18c	18d	19a	19b	19c	20a	20b	21	22	23	24	25	26	Σ
Gastropoda																													
Theodoxus fluviatilis (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	15
Pyrgula annulata (Linnaeus, 1758)		x	x	x		x	x	x		x	x	x		xx	xx	x	x	x	x	x	xxx	x		x			x	x	12
Sadleriana fluminensis (Küster, 1852)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	15
Belgrandiella kusceri (Wagner, 1914)																		x										(x)	1(1)
Dalmatinella fluviatilis Radoman, 1973			xx			xx	xx	xx	xx									x											3
Radomaniola curta (Küster, 1852)																		x											1
Tanousia zrmanjae (Brusina, 1866)	(x)	(x)	(x)		(x)	(x)				(x)		(x)		xxx	xx	(x)		x	xxx	x	(x)			(x)		(x)			2(8)
Emmericia patula (Brumati, 1838)	xx		xx	x	xxx	xxx	xxx	xx	xx	xx		x			x		xx	x		x					xxx			8
Bithynia tentaculata (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	15
Valvata piscinalis (O. F. Müller, 1774)	xx		xx	xx	xxx	x	xx	xx	xx	xxx	xx	xxx	xx	xxx	xxx	xx	xx	xx	xx	x	xx	xx	xx	xx		xx	x	xxx	14
Acroloxus lacustris (Linnaeus, 1758)			x			x					x							x						x				5
Galba truncatula (O. F. Müller, 1774)													x																1
Stagnicola fuscus (C. Pfeiffer, 1821)	xx	x	xx	xx	xx	xx	x	xx	xx	x	xx	xx	x	xx	xx		xx	xx	xx	xx	x	xx	xx	xx	xx			xx	13
Radix ampla (Hartmann, 1821)		x	xx	x	xx	xx	x	x	xxx	x	xx	x	xx		xx	xx	xxx	xxx	x	xxx	xx	xx	xx	x	xxx	xxx	x	xx	15
Radix auricularia (Linnaeus, 1758)	x								x			x		x	x		x	xx	x			xx		x		x	x	x	
Planorbis carinatus O. F. Müller, 1774	xx	xx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	15
Hippeutis complanatus (Linnaeus, 1758)	x	x								x	x		x					x							x				6
Ancylus fluviatilis (O. F. Müller, 1774)		x		x		x	xx		x	x		x		xx	x			x		x	x	x	x	xxx	xxx	x	x	x	13
Bivalvia																													
Unio elongatulus C. Pfeiffer, 1825	xxx	xxx	xx	xx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xx	xxx	xx	xx	xxx	xxx	xx	xx	15
Anodonta exulcerata Porro, 1838	x		x	x		x	x	x	x	xx			x	x			x	x	x		x				x		x	x	11
Pisidium amnicum (O. F. Müller, 1774)	x	xxx	xx	xx	xx	xx	xx	xx	xx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx	xx	xxx	xx	xx	xxx	xxx	xxx	xx	xxx	15
Pisidium casertanum Poli, 1791	x		x	x	x	x						xx		xx	xx	x		xx	x		x				x	x	xx	x	11
Pisidium nitidum Jenyns, 1832					x	x	x			x	x			x				x	x		x				x		x	x	9
Pisidium personatum Malm, 1855	x		x	x													x	x											5
Pisidium subtruncatum Malm, 1855	x	x		x	x	x	x	x	x	x	x	xx	x	xxx	xxx	x	xx	xx	xxx	x	xx	x	x	xx	xx	xx	x	xx	14
Number of species	15	12	16	16	13	18	16	14	15	16	14	15	13	16	16	11	15	24	16	14	15	13	11	13	15	13	15	16	

Table 3. Zrmanja III – list of freshwater molluscs recorded in the upper section of the Zrmanja River. For explanation see Table 1

Species	Site no.																								
	27	28	29	30	31a	31b	32a	32b	32c	33	34a	34b	35	36a	36b	36c	37a	37b	37c	38	39	40	41	42	Σ
Gastropoda																									
Theodoxus fluviatilis (Linnaeus, 1758)	xxx	xx	xx	x	x	x	x	x	x																6
Sadleriana fluminensis (Küster, 1852)	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xx		x					xxx	xxx	xx	xxx	xx	x	xx	xx	14
Belgrandiella kusceri (Wagner, 1914)			xx																				x		2
Emmericia patula (Brumati, 1838)	xxx	xxx																							2
Bithynia tentaculata (Linnaeus, 1758)	xxx	x																							2
Galba truncatula (O. F. Müller, 1774)					x																			xx	2
Stagnicola fuscus (C. Pfeiffer, 1821)	x																								1
Radix auricularia (Linnaeus, 1758)	x	x	x								x														4
Radix labiata (Rossmässler, 1835)	xx	xx		x	x	xx	xxx	xx	xx	xxx	xxx	xx	xxx	xx	x	xxx	xxx	xxx	xxx	xxx	x	xxx			13
Planorbis planorbis (Linnaeus, 1758)	x	xx		x	xx	xxx		xxx	xx	xx	xxx	x	x	x	x		xx	xx	x						10
Gyraulus parvus (Say, 1817)											xx	xx	xx	x		xx	x	x							4
Ancylus fluviatilis (O. F. Müller, 1774)	xxx	xxx			xx	x	x		xx	x	x		xxx				xxx	xx	xx	x	xxx	x	xx	xx	13
Bivalvia																									
Pisidium amnicum (O. F. Müller, 1774)	x	x	x	x	xx	x	xx	xx	xx	x	xx	x					x	x	x	xx	x				11
Pisidium casertanum Poli, 1791		x	x	x	x		x	x	x	x	x	x	x			x	x	x	x						10
Pisidium nitidum Jenyns, 1832									x									x							2
Pisidium personatum Malm, 1855			x			x			x											xx		xx	x	x	7
Pisidium subtruncatum Malm, 1855	xx	x	x	x	xx	xx	x	xx	xx	x	x	x	xx			xx	x		xx	x					12
Number of species	11	11	8	7	9	8	7	7	10	7	8	7	6	3	2	4	8	8	7	6	4	4	4	4	

Table 4. Krupa – list of freshwater molluscs recorded in the river. For explanation see Table 1

Species	Site no.														
	43	44	45a	45b	46	47	48	49	50a	50b	51a	51b	52	53	Σ
Gastropoda															
Theodoxus fluviatilis (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	x		x			9
Pyrgula annulata (Linnaeus, 1758)		xx													1
Sadleriana fluminensis (Küster, 1852)	xx		(x)		(xx)	xx	xx	x	xxx	xxx	xxx	xxx	xxx		7(2)
Belgrandiella kusceri (Wagner, 1914)									x		xx	(x)	xx	xx	4
Hadziella sketi Bole, 1961												(x)	(x)	xxx	1(2)
Kerkia sp. Radoman, 1978														(x)	(1)
Radomaniola curta (Küster, 1852)									xxx	xx	xx	x	xxx	xxx	4
Emmericia patula (Brumati, 1838)	xxx	xxx	xx	x	xx		x		x	x					6
Bithynia tentaculata (Linnaeus, 1758)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx							7
Valvata piscinalis (O. F. Müller, 1774)		xx	x	x	xx	xx									4
Acroloxus lacustris (Linnaeus, 1758)		x	x		x	x	x	x							6
Galba truncatula (O. F. Müller, 1774)		x											x		2
Stagnicola fuscus (C. Pfeiffer, 1821)	xx					x									2
Radix ampla (Hartmann, 1821)	xx			xx		xx									3
Radix auricularia (Linnaeus, 1758)				x	x	xx	x								4
Radix labiata (Rossmässler, 1835)				x	xx	x	x	x		x					6
Planorbis carinatus O. F. Müller, 1774	xxx	xxx	xxx	xxx	xxx	xxx	xx	xx							7
Hippeutis complanatus (Linnaeus, 1758)		x													1
Ancylus fluviatilis (O. F. Müller, 1774)							x	x	x	xx	xxx		xx	xx	6
Bivalvia															
Unio elongatulus C. Pfeiffer, 1825	x	xxx	xxx	xxx	xxx	xxx	xx	xx							7
Anodonta exulcerata Porro, 1838		xx	xx		xx	xx									4
Sphaerium corneum (Linnaeus, 1758)		xx	x	x	x	x	x	x							6
Pisidium amnicum (O. F. Müller, 1774)	xx								x	x	xx	xxx			3
Pisidium casertanum Poli, 1791									xx	x	xx	x			2
Pisidium nitidum Jenyns, 1832		x			x		xx	x							4
Pisidium personatum Malm, 1855									x	x		x		x	3
Pisidium subtruncatum Malm, 1855	x	xx	x	x	x	x				xx		x			7
Number of species	10	14	10	11	13	14	12	10	9	10	6	7	5	5	

Table 5. Small tributaries and springs – list of recorded freshwater molluscs. For explanation see Table 1

Species	Site no.																							
	54	55	56	57	58	59a	59b	60a	60b	61	62	63	64	65	66a	66b	67	68	69	70	71	72	73	Σ
Gastropoda																								
Theodoxus fluviatilis (Linnaeus, 1758)	xxx	xxx			xx			x	x	xxx	xxx													6
Sadleriana fluminensis (Küster, 1852)	xxx	xxx		xxx								x	xxx			xxx			xxx	xxx			xx	9
Belgrandiella kusceri (Wagner, 1914)	(xxx)		xxx					xxx	xxx				(x)	(x)	xxx					xx	xxx			5(3)
Hadziella sketi Bole, 1961													(x)	xx										1(1)
Islamia zermanica Radoman, 1973						x	xx																	1
Kerkia sp. Radoman, 1978	(x)									(x)				x										1(2)
Radomaniola curta (Küster, 1852)			xx										xxx		xx									3
Emmericia patula (Brumati, 1838)	xx	xxx	xxx		xxx			xxx	xxx	xxx	xxx	xx												8
Bithynia tentaculata (Linnaeus, 1758)		xx																						1
Valvata piscinalis (O. F. Müller, 1774)					xx						xx													2
Acroloxus lacustris (Linnaeus, 1758)					x																			1
Galba truncatula (O. F. Müller, 1774)						x	x					x												3
Stagnicola fuscus (C. Pfeiffer, 1821)		xx			x						xx													3
Radix ampla (Hartmann, 1821)		xx									x													2
Radix auricularia (Linnaeus, 1758)												x												1
Radix labiata (Rossmässler, 1835)												xx						xx						2
Planorbis carinatus O. F. Müller, 1774		xx			xx						xxx	xx												4
Hippeutis complanatus (Linnaeus, 1758)											x													1
Ancylus fluviatilis (O. F. Müller, 1774)	xxx	x		xxx		xxx	xxx				xxx	xxx	xxx	xxx					xx		xx	xx	x	12
Bivalvia																								
Anodonta exulcerata Porro, 1838		x																						1
Sphaerium corneum (Linnaeus, 1758)											x													1
Pisidium amnicum (O. F. Müller, 1774)		x																						1
Pisidium casertanum Poli, 1791												xxx					xx		xx		x	xxx		5
Pisidium nitidum Jenyns, 1832		x																						1
Pisidium personatum Malm, 1855				xxx		xx	xx					xx												3
Pisidium subtruncatum Malm, 1855		xx								x	x													3
Number of species	4	12	3	3	6	4	4	3	3	3	10	9	3	3	2	1	1	1	3	2	3	2	2	