

## DISTRIBUTION OF NATIVE AND ALIEN GAMMARIDS (CRUSTACEA: AMPHIPODA) ALONG THE COURSE OF THE UNA RIVER

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Records of five native and one alien gammarid species are reported from fifteen sites along the entire course of the Una River. Samples of gammarids were collected at ten sites in the main course, and at four sites in small left tributaries of the Una River during field studies conducted from 2005 to 2009. Two endemic species formerly known only from the Adriatic Sea drainage area, *Echinogammarus acarinatus* and *Fontogammarus dalmatinus*, were collected for the first time in the Black Sea drainage area at the main spring and in the upper course of the Una River. All three *Gammarus* species that occur in Croatia have been found in the Una River. Only *G. balcanicus* was recorded at the upper course, while both *G. fossarum* and *G. roeseli* were found in the middle and lower river course. With five gammarid species recorded, the Una River has the highest freshwater gammarid species richness among all of the Croatian watercourses. The new record of the invasive Ponto-Caspian gammarid, *Dikerogammarus haemobaphes*, in the Sava River at the mouth of the Una River is also reported and discussed.

**Key words:** Amphipoda, Gammaridae, Pontogammaridae, endemic, invasive species, distribution, Una River

Žganec, K., Gottstein, S. & Đurić, P.: Rasprostranjenost autohtonih i stranih rakušaca (Crustacea: Amphipoda) duž toka rijeke Une. *Nat. Croat.*, Vol. 19, No. 1, 141–150, 2010, Zagreb.

Ovim radom utvrđena je rasprostranjenost rakušaca duž toka rijeke Une i u Savi na ušću Une. Zabilježeno je pet autohtonih i jedna strana vrsta rakušaca iz porodica Gammaridae i Pontogammaridae. Prikupljanje uzoraka provedeno je bentos-mrežom na ukupno petnaest postaja, na deset postaja duž glavnog toka rijeke Une i na četiri postaje na manjim lijevim pritocima te u Savi na ušću Une tijekom terenskih istraživanja u razdoblju od 2005. do 2009. godine. Ovim istraživanjima su na području izvorskog i gornjeg dijela toka po prvi put u Uni zabilježene dvije endemske vrste rakušaca, *Echinogammarus acarinatus* i *Fontogammarus dalmatinus*, koje su do sada zabilježene samo u rijekama Jadranskog slijeva, te su ovi nalazi ujedno i prvi nalazi ovih vrsta u Crnomorskom

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slijevu. U rijeci Uni zabilježene su i sve tri vrste roda *Gammarus* koje su rasprostranjene na području Hrvatske, od kojih vrsta *G. balcanicus* dolazi u gornjem toku i u pritoku Klokot, dok su vrste *G. fossarum* i *G. roeseli* zabilježene zajedno u srednjem i donjem dijelu toka. S ukupno pet zabilježenih autohtonih vrsta rakušaca, rijeka Una je od svih vodotoka u Hrvatskoj rijeka s najvećim brojem vrsta nadzemnih, slatkovodnih rakušaca. Zabilježen je i novi nalaz invazivne ponto-kaspijske vrste *Dikergammarus haemobaphes* u Savi na ušću Une.

**Ključne riječi:** Amphipoda, Gammaridae, Pontogammaridae, endemi, invazivne vrste, rasprostranjenost, rijeka Una

## INTRODUCTION

Gammarids are small crustaceans (Amphipoda: Gammaroidea) that inhabit a great variety of different freshwater, brackish and marine habitats. They are omnipresent members of benthic invertebrate communities in running waters in Croatia, where they often dominate in terms of both abundance and/or biomass (ŽGANEC, 2009). Although most gammarids are omnivorous and many have predatory appetite, their main food source is dead organic matter, i.e. detritus (MACNEIL *et al.*, 1997). Since many fish species rely on gammarids as food (MACNEIL *et al.*, 1999), they represent an important link between detritus and secondary production in running waters.

Gammarid fauna of the Una River has never been systematically studied. In the previous studies (MATONIČKIN & PAVLETIĆ, 1959; 1964b) only *Gammarus balcanicus* (which was mistakenly identified as *Gammarus pulex* in the paper from 1959) was recorded on travertine barriers from Martin Brod (site U3 in Fig. 1) to Ripač (downstream – site U5 in Fig. 1).

More than a half of species from the genera *Gammarus* and *Echinogammarus*, two largest European genera of the family Gammaridae, have restricted distribution with centres of endemism at Iberian, Apennine and Balkan Peninsulas. The karstic rivers of Balkan Peninsula are well known by their endemic gammarid fauna (KARAMAN & PINKSTER, 1977a, b, 1987; PINKSTER, 1993). Endemic species are easily affected by adverse human impacts upon running water systems due to their restricted distributions (ŽGANEC & GOTTSTEIN, 2009), so this is a strong argument for studying their distribution. Further distribution studies of endemic species, as well as other more widespread native and alien gammarid species in Croatian watercourses, are needed as distribution data in the literature are scarce and scattered. Recent records of alien and invasive amphipods in the Sava River (ŽGANEC *et al.*, 2009) imply that those species could also be present at the mouth and in the lower course of the Una River, and that possibility should be checked with further research.

The present study's aim is to give an overview of all available data on the distribution of gammarids along the whole courses of the Una River as a contribution to the knowledge of gammarids in Croatian and neighbouring watercourses.

## MATERIALS AND METHODS

Samples of gammarids together with other benthic invertebrates were collected during different field studies made between 2005 and 2009. Invertebrates were collected from fifteen sites altogether. Ten sites were located at the main course of the

Una River, four sites were located at small left tributaries, and one site was on the Sava River; at its confluence with the Una River (Fig. 1). Different (qualitative and quantitative) methods of sampling were conducted using benthos hand-nets (mostly 25×25 cm rectangular net with 0.5 mm mesh size). Samples were fixed with 96% alcohol. In the laboratory amphipods were separated from the sediment, organic detritus and other invertebrates and stored in 75% alcohol for later identification.

Amphipods were identified using the keys of CĂRĂUȘU *et al.* (1955), KARAMAN & PINKSTER (1977a, b; 1987), PINKSTER (1993) and EGGERS & MARTENS (2001). A GPS receiver was used for the geocoding of field observations on the spot, and Gauss-Krüger coordinates were determined for each site. Data were mapped using ArcMap in ArcGIS 9.2 program packet (1999-2006 ESRI Inc.).

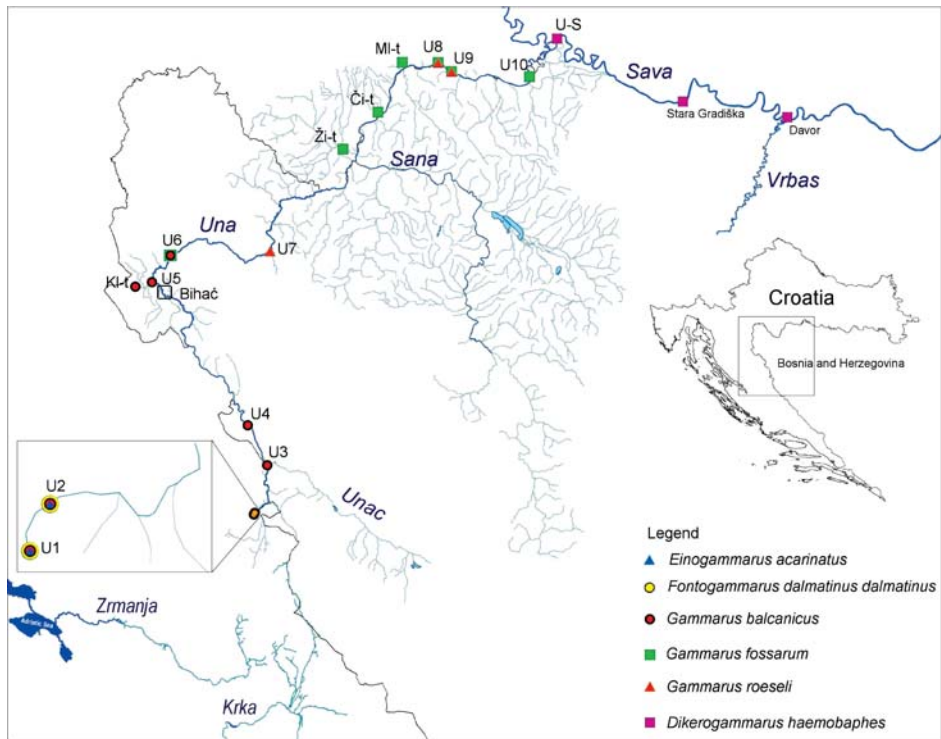
## RESULTS AND DISCUSSION

Five native gammarid species were found in the main course of the Una River which is the highest known number of native gammarid species sharing a location for Croatian watercourses in the Black Sea drainage area.

Two endemic species, *Echinogammarus acarinatus* (S. Karaman, 1931) and *Fontogammarus dalmatinus* S. Karaman, 1931, were found in headwaters of the Una River – at the main spring (U1) and on the site U2, about 0.35 km downstream (Fig. 1, Tab. 1). At both sites, species were accompanied with the more widespread *Gammarus balcanicus* Schäferna, 1922. These two endemic species were formerly known only from the Adriatic Sea drainage area, and this is the first recorded presence of these species not only for the Una River, but also for the Black Sea drainage area. The species *E. acarinatus* was known to occur in the watersheds of the Krka and Neretva rivers, as well as in some other small rivers and streams within the Adriatic Sea drainage area as far south as the Bay of Kotor in Montenegro (KARAMAN S., 1931; KARAMAN G., 1970; PINKSTER, 1993). The species *F. dalmatinus* (Croatian endemic genus) was recorded only in the Krka and Zrmanja river basins where its two subspecies with disjunctive distribution occur: *F. dalmatinus dalmatinus* in the Zrmanja River basin and *F. dalmatinus krkensis* in the Krka River basin (KARAMAN S., 1931; MATONIČKIN & PAVLETIĆ, 1964a; KARAMAN G., 1965). The main spring of the Zrmanja River is located about 20 km SE from the Una's main spring whilst the main spring of the Krka River is located about 40 km S (but the upper course of Krka's tributary, the Butižnica Stream, is located only about 12 km SE from the Una's main spring). Interestingly, collected specimens at the headwaters of the Una River belong to the subspecies *F. dalmatinus dalmatinus*, previously known only from the Zrmanja River basin where it coexists only with *G. balcanicus*, whilst other subspecies *F. dalmatinus krkensis* coexists in the Krka River basin with *E. acarinatus* and *G. balcanicus* according to the previously mentioned authors. We confirmed these findings with our own studies of gammarids in watersheds of the Zrmanja and Krka rivers (GOTTSTEIN *et al.*, 2007; ĐURIĆ, 2009; ŽGANEC, 2009). Thus, in the upper course of the Una River new combination of the subspecies *F. dalmatinus dalmatinus* with *E. acarinatus* and *G. balcanicus* was recorded. According to Slišković (1995) the recent water divide between the Black Sea and the Adriatic Sea basins of the West Bosnia and Herzegovina represents a wide »zonal« watershed due to the fact that some water overflows from the Black Sea basin into Adriatic Sea basin and

vice versa during the strong pluvial events. This supports assumption on epigeal connections between paleoriver systems of West Bosnia and Herzegovina (including Una River system) with the paleorivers of Dalmatia (eg. Krka and Zrmanja Rivers) which could explain observed distribution patterns of *E. acarinatus* and *F. dalmatinus dalmatinus*.

The species *G. balcanicus* was found at six sites along the main course of the Una River (U1-U6), and at one site in the main spring of the strong left tributary Klokot (Kl-t) (Fig. 1, Tab. 1). *E. acarinatus* and *F. dalmatinus dalmatinus* were more abundant in qualitative samples gathered at the main spring (U1) and at the site 0.35 km downstream (U2). *G. balcanicus* was the only gammarid found at sites U3-U5. At the site U6 *G. balcanicus* was the only species present in the samples from July 2005, but in samples collected in November 2005 also five specimens of species *Gammarus fossarum* (Koch, 1836) were found. To our present knowledge *G. balcanicus* is continuously distributed in the river reach from the main spring (U1) to the site U6, located about 81 km downstream. This species has its downstream limit of distribution in the Una River between the town of Bihać (i.e. site U6) and the site U7 (107 km). Presence of the species *G. fossarum* at U6 indicates that, at downstream limit of *G. balcanicus* distribution, it coexists with *G. fossarum*.



**Fig. 1.** Distribution of five native gammarid species in the Una River and its four tributaries with three sites in the Sava River where invasive alien gammarid *Dikerogammarus haemobaphes* was recorded.

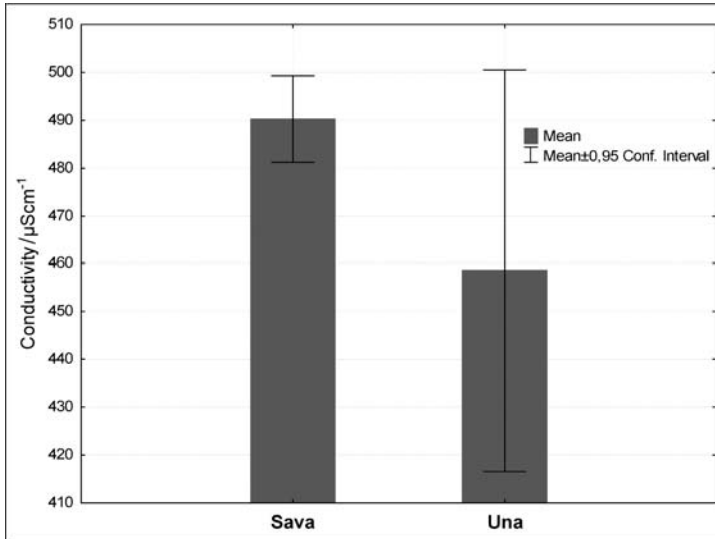
**Tab. 1.** Number of specimens collected for all six gammarid species (five native and one alien, invasive species – *Dikerogammarus haemobaphes*) at all fifteen studied sites, with distance from the source or distance from the Una River for the sites on tributaries (\*). Site abbreviations (shown on map in Fig. 1) and dates of sampling are also shown.

Site	Site code	Distance from the source, km	Fontogammarus dalmatinus ssp. dalmatinus	Echinogammarus acarinatus	Gammarus balcanicus	Gammarus fossarum	Gammarus roeseli	Dikerogammarus haemobaphes	Date of sampling
Una-main spring	U1	0	97	68	52	~	~	~	19.3.2006
Una-upper course	U2	0.35	47	42	16	~	~	~	20.9.2008
Una-Martin Brod	U3	13.6	~	~	119	~	~	~	26.7.2005 3.11.2005
Una-Kulen Vakuf	U4	23.4	~	~	2239	~	~	~	26.7.2005 3.11.2005
Una-Bihać-Kralje	U5	72.5	~	~	56	~	~	~	26.7.2005 3.11.2005
Una-Bihać-Kostela	U6	81.4	~	~	166	5	~	~	26.7.2005 3.11.2005
Klokot-spring tributary	Kl-t	4.4*	~	~	2165	~	~	~	26.7.2005 2.11.2005
Una-Bosanska Otoka	U7	106.8	~	~	~	~	1193	~	26.7.2005 2.11.2005
Una_Hrvatska Kostajnica_1	U8	174.9	~	~	~	6	8	~	4.4.2009
Una_Hrvatska Kostajnica_2	U9	178.4	~	~	~	2	1	~	4.4.2009
Una_Hrvatska Dubica	U10	197.4	~	~	~	2	~	~	28.9.2006
Žirovnica_small tributary	Zi-t	3.8*	~	~	~	10	~	~	13.9.2006
Čitlaj stream-small tributary	Či-t	0.8*	~	~	~	5	~	~	5.4.2009
Milinski Stream_small tributary	Ml-t	2.5*	~	~	~	1465	~	~	13.9.2006
Sava-Jasenovac confluence with Una	U-S	212.0	~	~	~	~	~	16	20.5.2009

The species *G. fossarum* was found on four sites (U6, U8-U10) in the middle and lower course of the Una River and in three out of four left tributaries studied (Ži-t, Či-t, Ml-t). Interestingly, *Gammarus roeseli* (Gervais, 1835) was the only gammarid species found at site U7 and *G. fossarum* was not found at this site probably due to its low abundance. Further downstream at sites U8 and U9 both species were found together, while at the most downstream site (U10) only *G. fossarum* was found in very low abundance.

An interesting pattern of longitudinal distribution of gammarid species was established along the course of the Una River. Further studies with more intensive sampling and at a larger number of sites are needed for deeper insight into distribution patterns of each recorded species. However, our results indicate that *E. acarinatus* and *F. dalmatinus* are probably restricted to the upper course due either to their adaptation to stable environmental conditions or restricted ability of these species to disperse further downstream or perhaps because of a combination of both of these reasons. The species *G. balcanicus* is the most abundant in »summer-cold« (summer water temperatures <15°C) and »summer-cool« (summer water temp. 15–20°C) watercourses in Croatia, while it is rare in reaches that are warmer during summer (ŽGANEC, 2009). Since the water quality of the Una River has not been significantly affected by the pollution from the town of Bihać (MEŠTROV et al., 1978; KEROVEC et al., 2005), the temperature conditions downstream from the U6 are probably the main factor that limits distribution of *G. balcanicus* further downstream. The presence of only *G. roeseli* at U7 (25 km downstream from Bihać), the species that finds optimal conditions in »summer-warm« watercourses (summer temp. 20–25°C) (PÖCKL, 1993; PÖCKL et al., 2003), indicates that absence of stronger tributaries at this part of the Una River (Fig. 1) probably makes this reach of the river warmer during summer months in comparison with neighbouring sampling sites. Further downstream a strong right tributary, the Sana River, probably cools the Una River during summer months and creates temperature conditions which allow *G. fossarum* and *G. roeseli* to coexist (summer temperature not much higher than 20°C).

We emphasize new record of invasive Ponto-Caspian gammarid species *Dikergammarus haemobaphes* (Eichwald, 1841) in the Sava River at Jasenovac (left bank), at the confluence with the Una River, in May 2009. This new record moves known distribution of *D. haemobaphes* reported in ŽGANEC et al. (2009) about 50 km upstream. This species was not found in the samples collected during July and October 2004 at Jasenovac, but it was present at the first downstream site in the town of Stara Gradiška in all samples collected during four months of 2004. Thus, it can be concluded that in the period between 2004 and 2009 *D. haemobaphes* has managed to spread further upstream in the Sava River, as far as the mouth of the Una River. The nearest sampling site on the Una River (U10) was located about 15 km upstream from the mouth, and therefore we can not be sure that *D. haemobaphes* has not already entered into the Una River. In the case of Polish watercourses GRABOWSKI et al. (2009) present arguments that lower conductivity could be the main factor restricting spread of alien amphipods into tributary rivers, which can provide refuges for native amphipods. Conductivity data were obtained for eleven sites at the reach of the Sava River where *D. haemobaphes* was found (from the mouth of the Una River in Jasenovac to Gunja, see Žganec et al., 2009) and for two sites in the lower



**Fig. 2.** Average values of conductivity ( $\pm 95\%$  confidence interval) at eleven sites in the Sava River (from the mouth of the Una River at Jasenovac to the downstream site at Gunja) where *Dikerogammarus haemobaphes* occurs, and two sites in the lower course of the Una River (at the mouth of the river and at Hrvatska Kostajnica-U9).

course of the Una River (U9 and U-S). The difference between average values of conductivity in the Sava River ( $490.2 \mu\text{Scm}^{-1}$ ) and lower course of the Una River ( $458.0 \mu\text{Scm}^{-1}$ ), shown in Fig. 2, was not significant ( $t$ -test,  $p=0.10$ ). Therefore, if only conductivity is considered, it seems that the lower course of the Una River could be suitable for the invasion by *D. haemobaphes*. However, it is possible that an unsuitable temperature regime in the lower course of the Una River disables this alien and invasive species from spreading upstream. Since many studies have showed that alien gammarids can be strong predators on native amphipods and other invertebrate species (DICK & PLATVOET, 2000; MACNEIL & PLATVOET, 2005; KRISP & MAIER, 2005; BERNAUER & JANSEN, 2006) there is a need for long-term detailed studies of gammarids in the lower course of the Una River to check whether this part of the river has been already invaded, and whether this alien species is spreading upstream. Also, studies of other invertebrate fauna in the Una River, which were neglected by researches in the past, should be checked for the presence of rare and threatened species as they could be negatively affected by *D. haemobaphes* invasion.

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benthos community in the Una River on the bilateral project between our department and the Bihać University. We also wish to thank all students and colleagues who helped during the field work.

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## SAŽETAK

### Rasprostranjenost autohtonih i stranih rakušaca (Crustacea: Amphipoda) duž toka rijeke Une

K. Žganec, S. Gottstein & P. Đurić

U rijeci Uni, duž cijelog toka (10 postaja na glavnom toku, četiri na malim lijevim pritocima Une i jednoj u Savi na ušću Une) zabilježeno je pet autohtonih i jedna strana vrsta rakušaca iz porodica Gammaridae i Pontogammaridae. Prikupljanje uzoraka obavljeno je pomoću bentos mreže tijekom terenskih istraživanja u razdoblju 2005.–2009. g.

Ovim istraživanjima su na području izvorskog i gornjeg dijela toka po prvi put u Uni zabilježene dvije endemske vrste rakušaca, *Echinogammarus acarinatus* i *Fontogammarus dalmatinus*, koje su dosada zabilježene samo u rijekama jadranskog slijeva, te su ovi nalazi ujedno i prvi nalazi ovih vrsta na području crnomorskog slijeva. U rijeci Uni zabilježene su i sve tri vrste roda *Gammarus* koje dolaze na području Hrvatske, od kojih vrsta *G. balcanicus* dolazi u gornjem dijelu toka i pritoku Klokot, dok su vrste *G. fossarum* i *G. roeseli* zabilježene zajedno u srednjem i donjem dijelu toka. S ukupno pet zabilježenih autohtonih vrsta porodice Gammaridae, rijeka Una je od svih istraženih vodotoka na teritoriju Hrvatske, rijeka s najvećim brojem vrsta nadzemnih, slatkovodnih rakušaca.

Zanimljiv je novi nalaz invazivne pontokaspijske vrste *Dikergammarus haemobaphes* na lijevoj obali Save na ušću Une u Jasenovcu. Ovim nalazom se poznata granica rasprostranjenosti ove vrste u rijeci Savi (ŽGANEC et al., 2009) pomiče za oko 50 km uzvodno. Utvrđeno je da, s obzirom na električnu provodljivost, nema zapreka za širenje ove invazivne vrste uzvodno u Unu. Naime, u Poljskoj su GRABOWSKI et al. (2009) ustanovili da strane vrste rakušaca nisu kolonizirale pritoke većih rijeka u kojima je električna provodljivost vode značajno niža od glavnog toka rijeke gdje su prisutni u velikom broju. Zbog toga postoji velika vjerojatnost da je ova invazivna vrsta već ušla i na područje donjeg toka rijeke Une. Najbliža postaja u ovim istraživanjima bila je oko 15 km uzvodno od ušća Une u Savu, gdje vrsta *D. haemobaphes* nije zabilježena, te je potrebno provesti daljnja istraživanja kako bi se pouzdano utvrdila prisutnost ove invazivne vrste u rijeci Uni. Također je potrebno provesti detaljna istraživanja ostale faune beskralješnjaka rijeke Une, posebice rijetkih i ugroženih vrsta na koje bi širenje invazivnog rakušca *D. haemobaphes* moglo imati značajan negativan utjecaj.