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Original scientific paper

DIVERSITY AND ECOLOGY OF THE FRESHWATER CRAYFISH IN THE NORTHWEST OF THE REPUBLIC OF SRPSKA

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Abstract: The existence of three autochthonous crayfish species is confirmed in the northwest of the Republic of Srpska: *Astacus astacus*, *Pontastacus leptodactylus* and *Austropotamobius torrentium*. There is a lack of information on the European crayfish population status in the Republic of Srpska comparing to other European countries. Our aim is to generate the latest information on crayfish distribution and population status, and make it the basis for managing and preserving natural population. The present study was implemented in the period from April 2018 until September 2019. Mostly distributed crayfish species in the Republic of Srpska is *A. torrentium* registered in 12 locations at altitude ranging from 201 to 846 m in the Vrbas river basin, but it is also present in the tributary streams of the Sana river, in ecologically-like habitats, in particular in relatively clear waters with low quantity of organic substances (I and II water category). *A. astacus* is mainly present in the Crna river basin, forming both river and lake population (a great number thereof is present in the Balkana lake) – waters with oxygen concentration over 8 g.O₂.m⁻³ and with BOD₅ values below 0.5 g.O₂.m⁻³. *P. leptodactylus* was found only in two locations: the Matura river (in Srbac) and the Vrbas river (upstream from Razboj), in the I-III category waters. The identified possible threats for autochthonous crayfish in fresh water ecosystems of the Republic of Srpska require urgent water management and preservation actions.

Key words: freshwater crayfish, Astacidae, Republic of Srpska.

INTRODUCTION

Basis for any astacological study of certain area fauna is gaining knowledge on population of living organisms in that area, specifically crayfish, and collecting relevant information on the presence of certain species, their number and possible endanger thereof.

More information is available on distribution and zoogeography of European crayfish species than of other species of aquatic invertebrate; the situation is not the same in all parts of Balkan Peninsula. Crayfish information is quite well available in Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, Kosovo and Metochia (Simić *et al.*, 2008; Trožić-Borovac, 2011; Rajković, 2012; Živić *et al.*, 2014). Partial information is available for other places in the Balkan Peninsula, and practically no published scientific information is available for the Republic of Srpska.

Local species are differently distributed in the European countries. The existence of four autochthonous species from the Astacidae family was reported: *Astacus astacus*, *Pontastacus leptodactylus*, *Austropotamobius torrentium* and *Austropotamobius pallipes* which are typical for the Balkan Peninsula (Obradović, 1984; Maguire and Gottstein-Matočec., 2004; Karaman, 1976; Bedjanic, 2004; Simić *et al.*, 2008; Rajković, 2007; Trožić-Borovac, 2011; Živić, 2014). Globally, the *A. astacus*, *A. pallipes* and *A. torrentium* species are so pruned and threatened, and thus included in the international list of threatened species (IUCN Red List), and their habitats included in the Habitat Directive. The *A. astacus* species is classified as species at risk (VU) on the International Red List, *A. pallipes* as threatened species (EN) and the *A. torrentium* is classified as insufficiently known species (DD). Given the different levels of this species' endanger and their habitats, a special conservation approach is required in many parts of their distribution.

This study paper is intended for confirming the presence of the Astacidae family species on the northwest of the Republic of Srpska, and making contribution to knowledge on their distribution and status of their population.

MATERIALS AND METHODS

Observation of physical and chemical water features in researched locations and collection of crayfish samples was performed once a week in the period from April 9th, 2018 until August 23st, 2019.

In line with crayfish sampling, the Institute for Public Health of the Republic of Srpska conducted studies of physical and chemical water parameters in selected areas for the purpose of this study. A portion of selected results was taken over from biological and ecological studies carried out by Crnogorac *et al.* (2013) and Lolić *et al.* (2017) to compare new results with results obtained from previous studies.

Crayfish samples were collected manually, LiNi trap with baits and nets. Traps were placed by the watercourse edge, under stones and roots of the littoral vegetation and left overnight. Fresh crayfish were observed, both in the field and laboratory. Afterwards, all collected organisms were classified up to the species level by applying illustrated guidance for identification of European crayfish from the Astacidae family (Maguire, 2010). Morphometric features were measured by a vernier scale. Weighing was carried out by weighing scale produced by Kern PFB, Version 2.2 with maximum weight of 1200 g and accuracy of 0.01 g.

RESULTS

In the northwest of the Republic of Srpska the existence of three European crayfish species from the Astacidae family was reported: *A. astacus*, *P. leptodactylus* and *A. torrentium* (Figure No. 1). Observations were performed on the Crna, Rudnička, Sokočnica, Vijaka, Stanikova, Mlinska, Korana rivers and on the Marjanovića, Matica, Dževerov, Zelenikovac, Ponor, Dobraš, Šargovački, Ledenac streams. Downstream of the Matura and Vrbas rivers was observed, as well as the Malo lake of the Balkana lake and Veliko lake of the Balkana lake.

Table 1. Finding locations of crayfish on northwest of the Republic of Srpska

Locality	Number of individuals	Species	Geographical coordinates	Elevation (m)	Date
Balkana	58	<i>A. astacus</i>	44.41547°N 17.04797°E	787	03.08.2018.
Crna river	26	<i>A. astacus</i>	44.41792°N 17.04739°E	754	03.08.2018.
Rudnička river	3	<i>A. astacus</i>	44.82929°N 17.09777°E	262	10.09.2018.
Sokočnica	1	<i>A. astacus</i>	44.27234°N 17.05662°E	467	31.03.2019.
Vijaka	1	<i>A. astacus</i>	44.80849°N 17.61730°E	165	22.08.2019.
Matura	24	<i>P. leptodactylus</i>	45.12330°N 17.43471°E	90	30.05.2019.
Vrbas	35	<i>P. leptodactylus</i>	45.06337°N 17.45603°E	92	31.05.2019.
Stanikova river	1	<i>A. torrentium</i>	44.73713°N 17.46004°E	328	09.04.2018.
Mlinska river	31	<i>A. torrentium</i>	44.75088°N 17.46322°E	267	22.08.2018.
Rudnička river	24	<i>A. torrentium</i>	44.82929°N 17.09777°E	262	10.09.2018.
Marjanovića stream	67	<i>A. torrentium</i>	44.71530°N 17.29464°E	310	21.10.2018.
Korana	46	<i>A. torrentium</i>	44.316525°N 16.93559°E	637	11.11.2018.
Matica stream	11	<i>A. torrentium</i>	44.88761°N 17.22211°E	233	12.11.2018.
Dževerov stream	1	<i>A. torrentium</i>	44.41230°N 16.98980°E	767	30.03.2019.
Zelenikovac	31	<i>A. torrentium</i>	44.394331°N 16.97244°E	846	30.03.2019.
Ponor	1	<i>A. torrentium</i>	44.28353°N 16.58584°E	680	30.03.2019.
Dobraš	7	<i>A. torrentium</i>	44.87569°N 17.24475°E	253	31.03.2019.
Šargovački stream	1	<i>A. torrentium</i>	44.82323°N 17.16140°E	201	29.06.2019.
Ledenac	1	<i>A. torrentium</i>	44.61569°N 16.99916°E	841	23.08.2019.

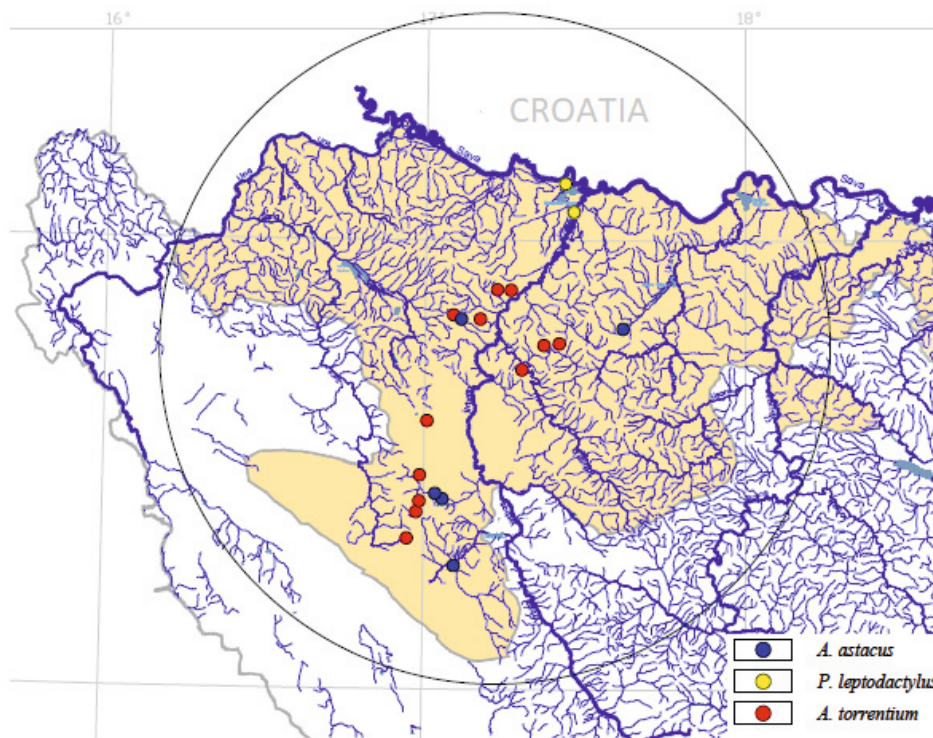


Figure 1. Distribution of *A. astacus*, *P. leptodactylus* and *A. torrentium* in the northwest of the Republic of Srpska

The European crayfish *A. astacus* is distributed in the north and the west of the Republic of Srpska in the downstream of the Crna, Rudnička, Sokočnica and Vijaka rivers and the Balkana lake. The observed aquatic habitats are located in highland area with altitude ranging from 165 to 787 m (Table 1). The water temperature in the part of the Rudnička river upstream is relatively low (12.8°C). While observing, the water temperature in the Crna river is higher (16.6°C). In all observed habitats the water was subcaline (pH value ranges from 7.2 to 8.22). In all observed habitats, oxygen saturation was over 80%. Increased concentration of BOD₅ was registered on the Crna river with 3.54 gO₂m⁻³ and BOD₅ value on the upstream of the Rudnička river and Balkana lake was below 0.5 gO₂m⁻³. Analyzed parameters for the most observed aquatic habitats meet values anticipated under the Regulation referring to the first category of surface waters, implying to satisfactory water quality.

The Danube crayfish *P. leptodactylus* is distributed in the northern part of the Republic of Srpska, in the Matura river downstream and in the Vrbas river upstream in Srbac. Given its distribution, this species was observed on an altitude ranging from 90 to 92 m (Table 1). Waters in these watercourses with the Danube crayfish present, has relatively high values of diluted oxygen (> 8 gO₂m⁻³) and BOD₅ value which is rather low >1.92 gO₂m⁻³. Temperature measured in the sampling period fluctuated from 8 to 18°C. In the subsequent studies, females (*P. leptodactylus*) with eggs were registered in the Vrbas location, referring to the successful existence of relatively stable population distributed on the surface of 13 km of the Vrbas river watercourse (from Razboj) all the way to the Sava river mouth (up to Srbac).

The existence of stone crayfish *A. torrentium* was reported on numerous locations in the Stanikova, Mlinska, Rudnička and Korana rivers and the Marjanovića, Matica, Dževerov, Zelenikovac, Ponor, Dobraš, Šargovački, Ledenac streams. Observed streams run through the highlands at altitude from 201 to 846 m (Table 1). Most locations have relatively small number of populations reported, and the biggest number was reported in the Marjanovića stream (in Čelinac) with 67 analyzed specimens. Presence of female with eggs was reported in the population found in the Marjanovića stream. Water temperature in all observed

locations fluctuated from 11.5 to 15.5°C. Measurement results of diluted oxygen showed no big difference in concentration between observed locations and fluctuated from 5.17 to 10.12g·m⁻³. In all observed locations the water saturation with oxygen was always over 80%. Given the pH value, all observed locations are situated in subalkaline area. The values of pH were ranging from 7.15 to 8.28. Increased BOD₅ values were registered in the Ponor area with 2.99 g·O₂·m⁻³, and in other locations was below 0.5, in particular 0.6 g·O₂·m⁻³.

Morphometric analysis was carried out on the European crayfish samples from the Balkana lake, the Danube crayfish from the Vrbas river and stone crayfish from the Marjanovića stream. According to the results, the longest body of the European crayfish was 114.87 mm, and the heaviest one was 55.9 g. The length of the Danube crayfish varied from 73.22 to 135.36 mm, with weight from 13.9 to 64.3 g. Smaller size, characteristic for stone crayfish, was measured and reached maximum of 117.9 mm with weight of 46 g (Table 2).

Table 2. Values of morphometric features of the Astacidae representative specimens from the northwest of the Republic of Srpska

A. astacus (Balkana)								
Males (N=38)					Females (N=20)			
	Mean	Min	Max	St.dev.	Mean	Min	Max	St.dev.
TBL	107.74	100.8	114.4	5.13	88.03	71.23	105.6	13.55
W	42.68	31.9	55.9	8.69	21.86	9.7	45.6	13.81
P. leptodactylus (Vrbas)								
Males (N=22)					Females (N=13)			
	Mean	Min	Max	St.dev.	Mean	Min	Max	St.dev.
TBL	103.91	79.3	135.36	15.92	89.61	73.22	112.73	14.73
W	30.82	20.9	64.3	11.98	20.8	13.9	39	8.31
A. torrentium (Marjanovića stream)								
Males (N=33)					Females (N=34)			
	Mean	Min	Max	St.dev.	Mean	Min	Max	St.dev.
TBL	104.01	82.64	117.9	8.86	93.47	69.48	114.37	8.12
W	28	12	46	6.95	16.67	6.6	28.6	4.85

Analyzing sex structure, we may notice the male majority, being presumably consequence of the period when female were laying eggs and were less active (Streissl and Hodl, 2002; Maguire *et al.*, 2002; Rajković, 2012).

DISCUSSION

The new records presented in this study paper include three species. Number of registered species was fairly uniform in comparison to information on registered species in Slovenia (three species - Bertok *et al.*, 2003, 2004), Croatia (four species - Maguire and Gottstein Matočec, 2004), Srbiji (three species – Simić *et al.*, 2008) and Montenegro (three species - Rajković, 2012).

The existence of the *A. astacus* species was reported in Europe at altitude ranging from 100 to 1600 m (Subchev and Stanimirova, 1998), and from 165 to 787 m in the northwest of the Republic of Srpska, although this species was found in Bosnia and Herzegovina and lowlands at altitude of 98 m, and high moun-

tains up to altitude of 1128 m (Trožić-Borovac, 2011). Machino and Füreder (1998) states that upper height limit of the European crayfish distribution in Austria is at altitude of 1516 m (Prebersee). Rajković (2012) believes that this species population significantly decreased in Europe mostly due to plague and habitat degradation. According to studies, this species appeared along with *A. pallipes* in Europe, in France (Souty-Grosset *et al.*, 2006). During 2002 the presence of this species along with white-clawed crayfish *A. pallipes* were reported in the Boracko lake, as well as in the location of Mostarsko blato (Šanda and Petrušek, 2008). Results of general ecological conditions where the European crayfish lives in Europe, somewhat match the conditions found in the Republic of Srpska. This species inhabits waters with lower temperature (around 14.8 °C) and high oxygen percentage (over 80%). Further, individual ecology studies of the European crayfish were carried out in the region (Maguire, 2010; Rajković, 2012; Trožić-Borovac, 2012). It is stated that ideal habitats for *A. astacus* are clear streams with low water temperature (optimal from 12 to 14 °C), good oxygen saturation, loamy, rocky or gravel layer and abundance of water vegetation (Obradović, 1988).

Today's studies in Europe show that the Danube crayfish inhabits lentic and slow-flowing rivers. Habitats are located at altitudes ranging from 0 to 858 m (Trichkova *et al.*, 2013), and from 90 to 92 m in the northwest of the Republic of Srpska. In Bosnia and Herzegovina this species is recently officially registered 2005 (Trožić-Borovac, 2011); today we know that it inhabits the Sava river (the Brčko area) and Miljacka (upstream from Sarajevo). Uncontrolled, scientifically unjustified introduction of the Danube crayfish to numerous European rivers, lakes, ponds, swamps, fishponds, has significantly spread its areal (Zaikov *et al.*, 2009). The *P. leptodactylus* species behaves as invasive species not only in areas where introduced but also in areas where it is native in particular where spread naturally (Maguire and Dakić, 2011; Maguire 2010; Holdich, 2002). Although widespread, a little information is available thereof (Maguire and Dakić, 2011; Trožić-Borovac, 2011).

The existence of the *A. torrentium* species is registered at altitude ranging from 201 m (the Šargovački stream) to 846 m (Zelenikovac). It is mostly distributed in places ranging from 300 to 900 m, rarely below 200 m and over 1200 m (Trichkova *et al.*, 2013). Subchev and Stanimirova (1998) state that it is distributed at altitude ranging from 100 to 200 m, rarely over 1600 m. Bohl (1987) believes that these crayfish were displaced from their natural habitats in lowlands to higher altitudes due to anthropogenic influence to their habitats as confirmed in the Republic of Srpska, because majority of these ecosystems is out of settlements. *A. torrentium* was found along with the European crayfish *A. astacus* in location of the Rudnička river in the village of Motike. According to studies in Bulgaria, this species occurs together with the *A. astacus* and *P. leptodactylus* species. Such cohabitation of the *A. torrentium* species with other crayfish is not usual for the species, and is rarely observed (Todorov *et al.*, 2014). Analysis results of general ecological conditions where stone crayfish lives in Europe partially match conditions in the Republic of Srpska. Trožić-Borovac *et al.* (2007) state that this species is related to highland zone with beech trees. Namely, specimens prefer habitats with high quality degree (I/II), lower temperature (around 13°C) and high oxygen percentage (over 80%). In addition, similar studies were carried out in the region regarding exclusive relationship between water quality and status of the stone crayfish population (Maguire, 2010; Rajković, 2012; Trožić-Borovac *et al.*, 2007). It is emphasized that the ideal habitats for habitation of the *A. torrentium* species are clear flowing waters with low water temperature, rich oxygen saturation, rocky or gravel layer and abundance of aquatic vegetation.

CONCLUSION

This paper presents information on distribution and individual ecology of crayfish in the northwest of the Republic of Srpska. Former studies confirmed an inhabitation of the northwest of the Republic of

Srpska with three autochthonous European species: *A. astacus*, *P. leptodactylus* and *A. torrentium*. Total of 19 locations belonging to Black Sea watershed was observed. The *A. astacus* and *A. torrentium* species inhabit mountain ecosystems, in relatively clear waters with low quantity of organic substances (I and II water category). The altitude where the distribution spot of the *A. astacus* and *A. torrentium* species is present, ranges from 165 to 846 m. Parts of lowlands of the Vrbas river (altitude of 92 m) and the Matura river (altitude of 90 m) were inhabited by specimens of the Danube crayfish *P. leptodactylus*. Former results of studies shows significant astacological values in the northwest of the Republic of Srpska, and thus observation should be continued to a greater extent in the forthcoming years.

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