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The Spiny-cheek Crayfish *Faxonius limosus* (Rafinesque, 1817) (Decapoda: Cambaridae) Invades New Areas in Serbian Inland Waters

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Abstract: *Faxonius limosus* (formerly known as *Orconectes limosus* in the literature) is an invasive alien crayfish species with the largest distribution range in Europe. The first record of this species from the Danube River in Serbia was near Apatin in 2002, and since then it has expanded its range along the entire Serbian section. The presence of *F. limosus* was studied during a twelve-year period (2007–2019), covering different types of water bodies in Serbia (rivers, canals, lakes, reservoirs and ponds). The species was detected at seven new localities along the main course of the Danube River, denoting that its colonisation has developed in two directions, upstream and downstream, respectively. Along with its expansion in the Danube River, the occurrence of *F. limosus* has been recorded in all main tributaries – the rivers Sava, Tisa and Velika Morava, as well as the Danube–Tisa–Danube Canal (DTD Canal). Due to its rapid dispersal rate and negative effect on native crayfish species, urgent measures are needed to monitor and prevent further spread of this invasive alien species in the Serbian inland waters and the Danube River Basin.

Key words: Spiny-cheek crayfish, invasive alien species, Danube River Basin, range expansion.

Introduction

The North American spiny-cheek crayfish, *Faxonius limosus* (Rafinesque, 1817), representative of the family Cambaridae, is a non-indigenous crayfish species with the largest distribution range in Europe (SOUTY-GROSSET et al. 2006), registered in 22 countries (KOUBA et al. 2014). Since its first observation in the Danube River near Budapest in 1985 (THURÁNSZKY & FORRÓ 1987), this species has colonised the entire course of the river reaching the Lower Danube with the most downstream

finding near the village of Dubova at 970 river km (PÂRVULESCU et al. 2015).

A detailed overview of the invasion history of *F. limosus* and its colonisation of the Danube River Basin is given in LIPTÁK & VITÁZKOVÁ (2014) and TODOROV et al. (2020). This species has rapidly increased its distribution area, establishing populations in Hungary (LUDÁNYI et al. 2016), Croatia (MAGUIRE et al. 2018), Romania (PÂRVULESCU et al. 2015), and Bulgaria (TODOROV et al. 2020), but with no records for the R. Northern Macedonia, Bosnia and Herzegovina, Montenegro and Albania.

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Numerous biological characteristics, e. g. the rapid growth, trophic position (PACIOGLU et al. 2019), facultative parthenogenesis (BUŘIČ et al. 2011, 2013), and plasticity in fecundity (BUŘIČ et al. 2013, PÂRVULESCU et al. 2015) contribute to the high invasive potential of *F. limosus* and its successful invasion in Europe (SOUTY-GROSSET et al. 2006, HOLDICH et al. 2009). Due to its high tolerance to a wide range of environmental conditions, its ability to inhabit diverse water bodies (rivers, ponds, lakes, side arms, and canals) with different water qualities (AKLEHNOVICH & RAZLUTSKIJ 2013), its omnivorous feeding and aggressive behaviour (HOLDICH & BLACK 2007, LELE & PÂRVULESCU 2017), *F. limosus* is more competitive than the native crayfish species. LUCIĆ et al. (2012) reveal that the invasive crayfish have better condition indices than the native species, which is another feature that enables *F. limosus* to invade new areas faster and to compete with native species. Moreover, *F. limosus* is resistant to the crayfish plague, a fungal disease caused by the oomycete *Aphanomyces astaci* Schikora, 1906, which is lethal to the European crayfish (PEAY & FÜREDER 2011, HATCHER et al. 2012). Transmission of the pathogen to non-native crayfish species has been proven in cases of population overlap (MAGUIRE et al. 2016, PANTELEIT et al. 2018).

In Serbian waters, three native crayfish species have been identified, namely the stone crayfish *Austropotamobius torrentium* (von Paula Schrank, 1803), noble crayfish *Astacus astacus* (Linnaeus, 1758) and narrow-clawed crayfish *Pontastacus leptodactylus* Eschscholtz, 1823. The first record of *F. limosus* in Serbia was in the Danube River near Apatin in 2002 (KARAMAN & MACHINO 2004). Two years later, 13 individuals, 10 females and three males, were detected near Smederevo (PAVLOVIĆ et al. 2006). During the period 2003–2006, new records were reported from the Danube River near Veliko Gradište, Donji Milanovac and in Đerdap Gorge (SIMIĆ et al. 2008).

This paper presents an updated overview of the occurrence of the invasive alien crayfish species *F. limosus* in the territory of Serbia, as part of the Danube River Basin.

Materials and Methods

The presence of *F. limosus* was investigated during a twelve-year period (2007–2019), covering different types of water bodies in Serbia (rivers, canals, lakes, reservoirs and ponds). The crayfish were sampled using the kick and sweep multihabitat sampling procedure with a standard benthological net (500

µm mesh size) or by hand. Moreover, in the period 2017–2018, additional field investigations were performed in order to detect the presence of native crayfish species in Serbia and to evaluate their population status. During this study, baited LiNi traps were used to attract the animals. The crayfish were also caught by hand in the vegetation, and by turning stones and checking holes in the river bank. Data were obtained also from ichthyologists and fishermen when crayfish were caught using fish nets or by electrofishing. After identification using the Atlas of Crayfish in Europe (HOLDICH et al. 2006) all individuals caught were removed from the water, frozen, and then disposed off.

Results

Based on our investigations, the findings of *F. limosus* are presented in Table 1 and Fig. 1. Along the main course of the Danube River the species was detected at seven new localities: Bogojevo, Bačka Palanka, Slankamen, Belgrade (upstream of the Sava River confluence), Pančevo, Banatska Palanka, and Kladovo. Along with the localities in the Danube River, the occurrence of *F. limosus* was detected in

Table 1. Localities of the new records of the spiny-cheek crayfish *Faxonius limosus* in Serbia.

Locality	Geographic coordinates	Date	River
Banatska Palanka	N 44.8257° E 21.3429°	19.10.2007	Danube
Titel	N 45.2068° E 20.3121°	07.11.2010	Tisa
Ostružnica	N 44.7187° E 20.3085°	12.09.2011	Sava
Slankamen	N 45.1427° E 20.2590°	17.07.2013	Danube
Bogojevo	N 45.5247° E 19.0908°	01.08.2013	Danube
Bačka Palanka	N 45.2363° E 19.4275°	14.10.2013	Danube
Pančevo	N 44.8565° E 20.6088°	20.06.2014	Danube
Bagrdan	N 44.0785° E 21.1919°	06.09.2017	Velika Morava
Belgrade	N 44.8338° E 20.4459°	05.02.2018	Danube
Kladovo	N 44.6111° E 22.6215°	03.05.2018	Danube
Melenci	N 45.5427° E 20.3376°	12.06.2019	DTD Canal
Ljubičevski Most	N 44.5858° E 21.1305°	13.08.2019	Velika Morava



Fig. 1. Map of the new findings of the spiny-cheek crayfish *Faxonius limosus* in Serbia. Localities: 1. Banatska Palanka, 2. Titel, 3. Ostružnica, 4. Slanakamen, 5. Bogojevo, 6. Bačka Palanka, 7. Pančevo, 8. Bagrdan, 9. Belgrade, 10. Kladovo, 11. Melenci, and 12. Ljubičevski Most.

all main tributaries – the rivers Sava, Tisa and Velika Morava, as well as the Danube–Tisa–Danube Canal (DTD Canal).

Discussion

Our results show that after the first findings of *F. limosus* in 2002 and 2004 (KARAMAN & MACHINO 2004, PAVLOVIĆ et al. 2006) and several new records reported from 2003–2006 (SIMIĆ et al. 2008) the species has established along the entire Serbian section of the Danube River.

Based on a previous investigation in the region, which demonstrates the fast dispersal rate and high invasive potential of *F. limosus* (LIPTÁK et al. 2013), the results presented herein are easily presumable. The estimated colonisation speed of the species in the Danube River is 84 km/year in Croatia and Serbia (HUDINA et al. 2009), 15 km/year in Romania (PÂRVULESCU et al. 2012), and from 13 to 16 km/year in Hungary (PUKY & SCHÁD 2006). Since its first finding in 2003 in the Kopački Rit Nature Park

(MAGUIRE & KLOBUČAR 2003), by the end of 2016, *F. limosus* has spread to a total of 21 localities in Croatia, with significant expansion of its distribution area during 2014–2016 (MAGUIRE et al. 2011, 2018). In Hungary, the species is widespread along the entire course of the Danube and Tisa rivers, as well as in a large number of tributaries, being present at a total of 90 sites from 39 watercourses (LUDÁNYI et al. 2016). In 2008, *F. limosus* reaches the Romanian Danube River (PÂRVULESCU et al. 2009), as well as the surrounding countries. The species is most recently registered in Bulgaria in 2015, when 14 specimens are found in the Toplovetz River (a Danube tributary) near the town of Vidin (TODOROV et al. 2020). Therefore, we can assume that the expansion routes of *F. limosus* in the Danube River have been established in several directions simultaneously, both upstream and downstream, along the main course, and along its tributaries.

The presence and spread of *F. limosus* in the tributaries of the Danube River has also been expected. Five years ago LIPTÁK & VITÁZKOVÁ (2014) indicated that further dispersal of this species is very likely and suggested that ‘*F. limosus* can invade other Serbian rivers, such as the Sava, Tisa or Velika Morava’. According to our findings, the species spread at the same time to the Sava and Tisa rivers (findings from 2010 and 2011), and it was found at sites not far from the confluence with the Danube River (Ostružnica and Titel). The record from the Tisa River near Titel, however, may also be due to the spread of the species from Hungary where it was deliberately introduced in 2005 (SALLAI & PUKY 2008). The finding of the species in the Velika Morava River near Ljubičevski Most and Bagrdan indicate a secondary introduction from the Danube River. During an investigation in 2010, the presence of six allochthonous macroinvertebrate species has been confirmed at all sites examined, but *F. limosus* was not registered (ZORIC et al. 2013).

In Serbia and its neighbouring countries, the native crayfish species *A. astacus* and *A. torrentium* are protected at the national level and listed as endangered or critically endangered (HUDINA et al. 2009, CHUCHOLL 2013, PÂRVULESCU & ZAHARIA 2013, MARKOVIC et al. 2017). The effects of *F. limosus* on the native crayfish species have been thoroughly studied and documented in Europe. Decrease in the number of native crayfish species has been reported from Austria, Hungary and Croatia (HUDINA et al. 2009, WEINLÄNDER & FÜREDER 2009, GYÖRE et al. 2013). In the eastern part of the territory of Croatia, *F. limosus* has almost displaced *P. leptodactylus* (MAGUIRE et al. 2018). SIMIĆ et

al. (2008) revealed the same pattern in the Serbian section of the Danube River, especially in the area of the *Derdap* reservoirs, with an abundance ratio of 5 *F. limosus* : 2 *P. leptodactylus*. During our study both species were never caught together. A similar outcome was obtained in a study from Belarus (AKLEHNOVICH & RAZLUTSKIJ 2013), and it could be due to the competition between these two species or their slightly different habitat requirements.

Because of the rapid dispersal rate of *F. limosus* we may assume that the invasive range of the species in Serbia is larger than it is documented here and further expansion is probable. Therefore, a scientific survey of crayfish populations in Serbia is needed in order to examine and update the current distribution, population size, and impact. Despite the rapid spread of *F. limosus*, the situation in Serbia is still more favorable than other countries in the region, where the presence of two or more invasive alien crayfish species has been reported. Therefore, particular attention should be paid to the possible entry points.

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