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First record of the spiny-cheek crayfish (*Orconectes limosus*) in Slovenia – 300 km upstream from its known distribution in the Drava River

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Abstract – The spiny-cheek crayfish *Orconectes limosus* (Rafinesque, 1817) is one of the most problematic invasive crayfish species in Europe. Here we report the first occurrence of spiny-cheek crayfish in Slovenia, 300 km upstream from the previously known records in the mouth of Drava River in Croatia. The species was not expected to colonize this area for at least two decades. This new isolated population will significantly alter our predictions of the ongoing colonization of the Drava River basin in Austria, Slovenia and Croatia.

Keywords: non-indigenous crayfish / Slovenia / freshwater invasion

Résumé – Premier enregistrement de l'écrevisse américaine (*Orconectes limosus*) en Slovénie – 300 km en amont de sa distribution connue dans la rivière Drava. L'écrevisse américaine *Orconectes limosus* (Rafinesque, 1817) est l'une des espèces d'écrevisses invasives les plus problématiques en Europe. Nous rapportons ici la première occurrence de l'écrevisse américaine en Slovénie, 300 km en amont des sites précédemment connus dans l'embouchure de la Drava en Croatie. L'espèce n'était pas censée coloniser cette zone pendant au moins deux décennies. Cette nouvelle population isolée modifiera considérablement les prédictions de la colonisation en cours du bassin de la Drava en Autriche, en Slovénie et en Croatie.

Mots clés : écrevisse non indigène / Slovénie / invasion

Various crayfish species have been introduced outside their indigenous ranges mainly in the last century. Until very recently, Slovenia was one of the few European countries that had avoided non-indigenous crayfish species' introductions. Before 2000 only indigenous freshwater crayfish species existed in Slovenia: the noble crayfish (*Astacus astacus*), the stone crayfish (*Austropotamobius torrentium*) and the white-clawed crayfish (*Austropotamobius pallipes*). Two non-indigenous species were first discovered during this century: the signal crayfish (*Pacifastacus leniusculus*) and the redclaw crayfish (*Cherax quadricarinatus*). The presence of signal crayfish is considered to be the consequence of its spread from Austria (Pöckl, 1999). It has also been confirmed as a crayfish plague carrier (Kušar *et al.*, 2013; Maguire *et al.*, 2016). A local redclaw aquaculture is most likely the origin of the redclaw population (Jaklič and Vrezec, 2011). Due to the distribution of other non-indigenous crayfish species in neighbouring countries (Maguire *et al.*, 2011; Kouba *et al.*, 2014) and their colonization speed, we also predict the arrival of the red swamp crayfish (*Procambarus clarkii*) in the near future in western parts of Slovenia, near to the Italian border.

The spread of non-indigenous spiny-cheek crayfish in Europe has been very fast. This species has been reported from 22 European territories so far (Kouba *et al.*, 2014). After quickly spreading downstream along the Danube River spiny-cheek crayfish started to spread much slower into its tributary, the Drava River (Hudina *et al.*, 2009). Puky and Schád (2006) expected that upstream sections of the Drava River in Hungary will be colonised by spiny-cheek crayfish within 5–10 years. The rate of upstream dispersal in the Drava River is less than 2.5 km yr^{-1} (Hudina *et al.*, 2009). Lipták and Vitázková (2014) in their analysis of dispersal trends did not include Slovenia in maps of expected distribution in forthcoming years. As upstream spread of the crayfish can be halted by different barriers (Rosewarne *et al.*, 2013), further expansion of its distribution area towards Slovenia is also expected to be limited due to presence of three large dams in this part of the Drava River. The arrival of spiny-cheek crayfish, that was recently confirmed as a crayfish plague carrier also in Croatia (Maguire *et al.*, 2016), was not expected in Slovenia for at least another two decades.

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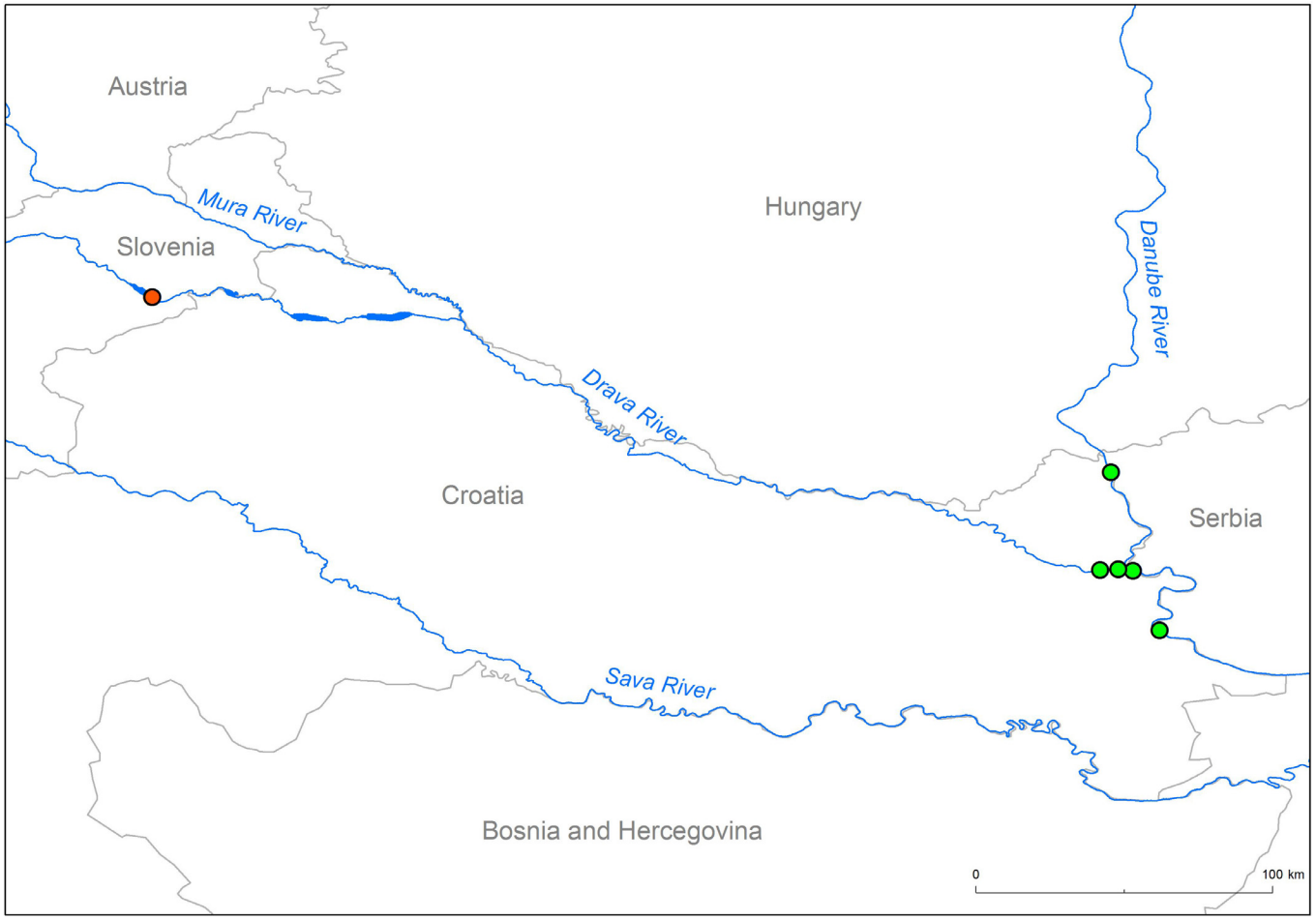

Fig. 1. Location of the newly discovered spiny-cheek crayfish (*Orconectes limosus*) population (red dot) in Slovenia and the previously known localities (green dots).

The Drava River is the fourth largest and longest tributary of the Danube River. Run-off hydroelectric stations were built in Austria and upper Slovenia. In lowland parts of Slovenia and Croatia relatively large and not-very-deep reservoirs were built, whereas hydroelectric power stations have been constructed on side channels (Bonacci *et al.*, 1992). That completely altered the hydrological and ecological regime of the Drava River.

Spiny-cheek crayfish were first found in Slovenia on 25.8.2015 (Fig. 1). They were found by chance during an electrofishing survey in an area of small abandoned gravel pits and oxbow lakes in the floodplain of the Drava River south east of Ptuj (Lat: 46° 22′ 31.50″, Lon: 15° 56′ 43.81″). In a 15 ha area, there are 3 gravel pits (0.1–0.2 ha) and 4 oxbow lakes (0.1–0.5 ha). All of them are situated within 200 m of the main river edge; the nearest waterbody is less than 20 m from the main river (Fig. 2). Additional investigations were undertaken using baited traps which were set at all seven waterbodies. Due to inaccessibility manual trapping using a pond net was only possible at one-gravel pit (Tab. 1). All crayfishes were measured (CL – carapace length) and sexed.

A total of 122 crayfish were caught at 4 waterbodies (Tab. 1, Fig. 2). Most of them were caught in one-gravel pit. Specimens ranging from 28 to 49 mm CL were caught during electrofishing, 20–52 mm CL were caught in the traps, while manual search yielded specimens of 20–45 mm CL (Tab. 1, Fig. 3). Catch per unit effort (CPUE – number of crayfish caught per trap per night) varied between water bodies (0.75–3.58). Trap catches were dominated by adult males, which correspond to the findings of Holdich and Black (2007).

The occurrence of the spiny-cheek crayfish in Slovenia is most probably the result of deliberate introductions. All currently known sites of spiny-cheek crayfish are significantly outside of Slovenia (Kouba *et al.*, 2014) and 300 km downstream in the Drava River (Maguire *et al.*, 2011), so the question about its arrival to the country stays open. After Slovenia joined the EU in 2004, it has also opened the possibility of a cross-border online trading of crayfish, which has virtually no control. The area is not generally known as a destination for angling, although it is possible to run into some locals fishing here. There is no guidance information about the use of crayfish as live baits. In Slovenia only earthworms and waxworms can be legally used as live baits for fishing in lakes and rivers. Traditionally live fish, lampreys and mussels were used, but not crayfish. The place where spiny-cheek crayfish were found is easily accessible. I speculate that spiny-cheek crayfish may be present in some other private fishponds, from where it was translocated and introduced into the gravel pit complex next to the Drava River.

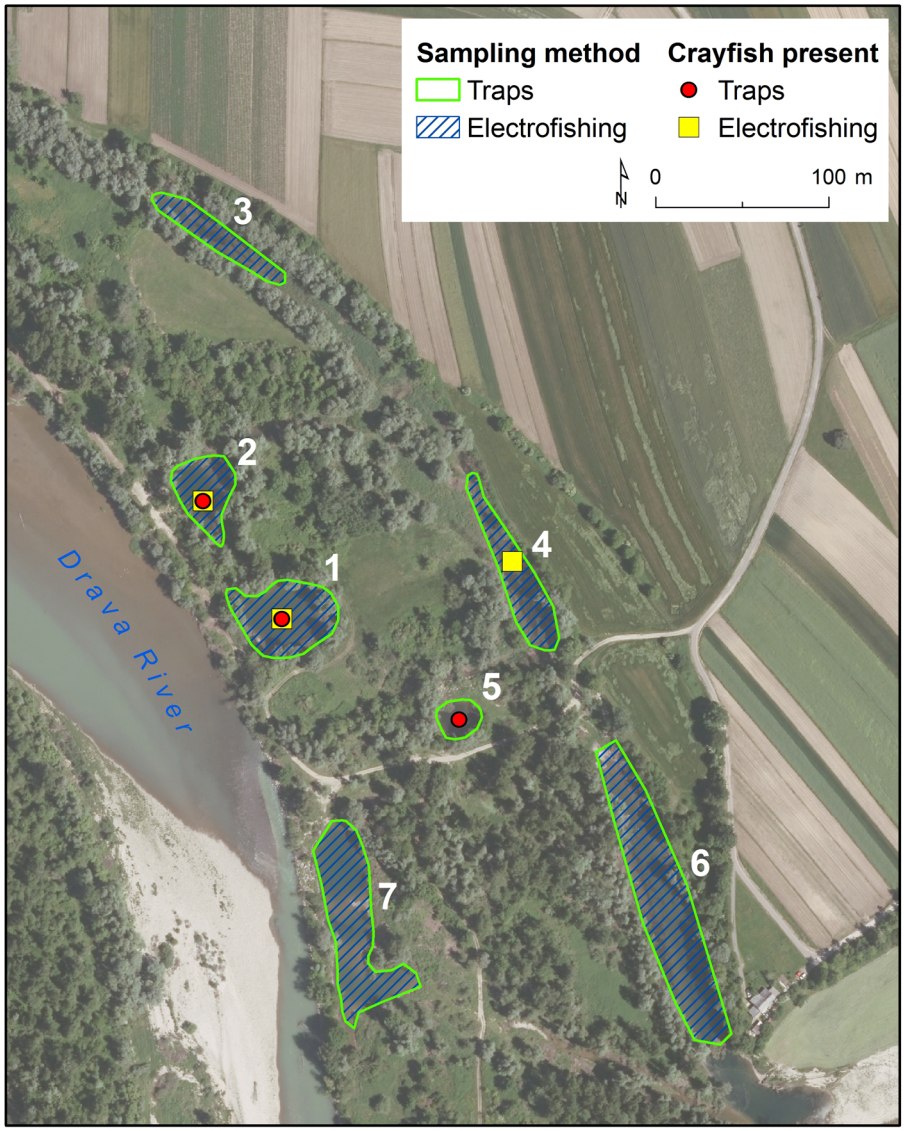

Fig. 2. Detailed map of the area with newly discovered spiny-cheek crayfish (*Orconectes limosus*) population in Slovenia.

In the stretch of the Drava River where spiny-cheek crayfish were found, the hydrological regime is controlled by man-made structures. The discharge is set at 20 m^3 s^{-1} during the summer and 10 m^3 s^{-1} during the winter. There is no water level oscillation after regular rainy days and there are quite stable conditions in the riparian zone of the Drava River. The distance between all examined water bodies and the main Drava River channel is short (Fig. 2) so crayfish can move actively between them. Overland dispersal is a common phenomenon in crayfish and has also been observed in spiny-cheek crayfish (Puky, 2014). During significant flood events all the gravel pits and oxbow lakes in the riparian zone are flooded. Water level oscillation is fast and high. The flood period takes only a few days, but this is the time when spiny-cheek crayfish can more actively disperse between the Drava River channel, oxbow lakes and gravel pits in the flood zone, especially if floods occur during the mating season (Buřič *et al.*, 2009). Floods also increase the probability of crayfish drift downstream in the main river. The newly discovered spiny-cheek crayfish population will have an immediate significant impact downstream and it has altered the predicted spread of this species in the Drava River basin to be much faster than it would have been if colonization occurred by natural upstream dispersal. As this species prefers slow-flowing, larger and warmer rivers (Pöckl, 1999; Petrusek *et al.*, 2006) and shallow parts of lakes (Hirsch *et al.*, 2016) it is expected to spread downstream into the accumulation lakes of the Drava River hydroelectric power plants, where it has the potential to reach high population densities.

The spread of the spiny-cheek crayfish will also affect indigenous crayfish. As spiny-cheek crayfish is a potential vector of crayfish plague, a disease that has devastating effects on indigenous crayfish, thus its presence in the Drava River could lead to the complete elimination of native crayfish populations in the basin. The Noble crayfish and the narrow-clawed crayfish (*Astacus leptodactylus*) are present downstream in the Drava River in Croatia (Maguire *et al.*, 2011). Interestingly in past two years Croatian researchers did not

Table 1. Results of electrofishing, trapping and manual searching of spiny-cheek crayfish (*Orconectes limosus*) (water body type: GP – gravel pit, O – oxbow, sex ratio (male:female), CPUE – number of crayfish caught per trap per night, CL range – carapace length (mm) range).

ID number (Fig. 2)	1	2	3	4	5	6	7	Sum/total
Water type	GP	GP	O	O	GP	O	O	
Electrofishing	x	x	x	x		x	x	
Number of crayfish	6	2		1				9
Sex ratio								1:2
CL range								28–49
Trapping	x	x	x	x	x	x	x	
Number of crayfish	68	12	0	0	14	0	0	94
CPUE	3.58	0.75			1.56			
Sex ratio	12.6:1	2:1			1:2.5			3.9:1
CL range	20–52	33–50			26–49			20–52
Manual searching	x							
Number of crayfish	19							19
Sex ratio	1.38:1							1.38:1
CL range	20–45							20–45

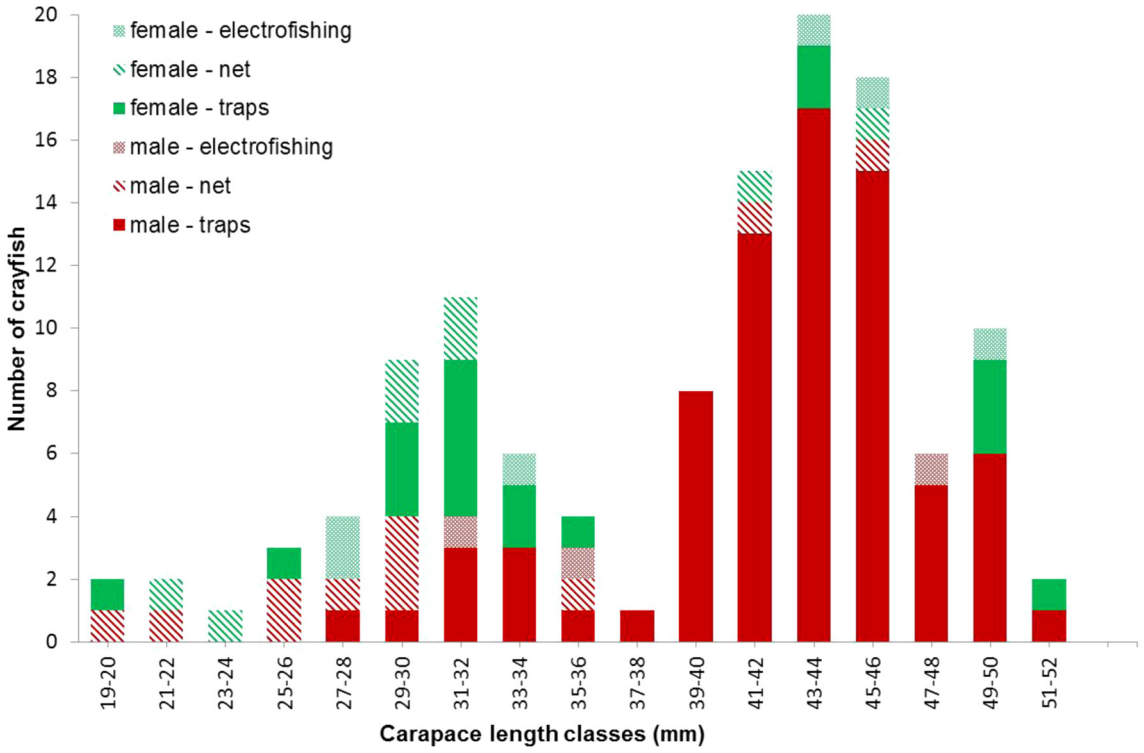

Fig. 3. Carapace length frequency distribution of caught spiny-cheek crayfish (*Orconectes limosus*) in Slovenia.

confirm any noble crayfish 40 km downstream in the Drava River close to Varaždin (Mišel Jelić, pers. comm.). The Stone crayfish populations that are present downstream are also threatened by the spiny-cheek crayfish populations in the tributaries of Drava River in Slovenia and Croatia.

The discovery of this problematic invasive species came as a big surprise. The status and distribution of Slovenia's crayfish populations could soon be impacted detrimentally, due to high dispersal ability of spiny-cheek crayfish in lotic (Buřič *et al.*, 2009) and lentic systems (Hirsch *et al.*, 2016). Eradication options for the introduced spiny-cheek population are being considered. Proposed methods, in particular the use of biocides, are certainly controversial, but have been used effectively elsewhere in the EU to tackle non-indigenous crayfish introductions (Peay *et al.*, 2006). Due to expected spreading there is a need for species monitoring and for careful monitoring of potential contact zones between indigenous and non-indigenous crayfish populations and eliminating the

possibility of their contact. There is international border only twelve kilometres downstream so cooperation between Slovenia and Croatia is necessary in this case. As new population presents a new colonization front, the rate of spread might decrease also by its reduction (Moorhouse and Macdonald, 2011).

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