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Research Article

Distribution of Asian clams *Corbicula fluminea* (Müller, 1774) and *C. fluminalis* (Müller, 1774) in Serbia

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Abstract

Among numerous recently introduced species in Serbian waters, two new mussel taxa were detected. The aim of this paper is to present the current distribution of two morphotypes of the Asiatic clam - *Corbicula fluminea* (Müller, 1774) and *C. fluminalis* (Müller, 1774), in order to discuss pathways of dispersal and reasons for successful adaptation. According to our results, the morphotype *C. fluminea* is better adapted to local environmental conditions, while *C. fluminalis* has rarely been found in Serbia. At present, Asiatic clams are widespread within potamon-type rivers that are under the influence of hydro-morphological alterations and exposed to intensive ship traffic. The distribution of *Corbicula*, as well as some other alien aquatic invertebrate taxa (*Branchiura sowerbyi*, *Anodonta woodiana*, *Orconectes limosus*), indicate that heavily modified waterways are suitable recipient areas for species introduction and adaptation. *Corbicula* gen. sp. is a characteristic taxa for Pleistocene interglacial deposits in the Pannonian Plain. The comparison between Pleistocene and recent taxa is necessary in order to categorize *Corbicula* as either introduced or reintroduced taxa.

Key words: aquatic invasive species, *Corbicula*, Danube River, southern invasion corridor

Introduction

In this paper we present the distribution of two mussel taxa, *Corbicula fluminea* (Müller, 1774) and *C. fluminalis* (Müller, 1774) (Mollusca: Bivalvia: Veneroida: Corbiculidae) (Asian Clams) in Serbian water. In addition to Serbian waters, this investigation includes trans-boundary rivers i.e. sectors of the Danube which are shared with Croatia and Romania, as well as bordering regions with Hungary - the Danube and the Tisza River.

As ship traffic has been underlined as one of the major factors in the dispersal of species beyond their natural range, waterways are under particular pressure (Galil et al. 2007). High pressure of invasions has been already documented for the Danube (Cakic et al. 2004, Simonovic et al. 2001 2006, Berneth et al. 2002, Paunovic et al. 2004, 2005, Pavlovic et al. 2006), the Sava (Paunovic 2004), and the Tisza (Csányi 2002) Rivers.

Study area, Materials and Methods

Within macroinvertebrate investigations, performed in Serbian waters during the period 1998-2006, special attention was focused on the distribution of Asian clams. These investigations were intensive from 2004-2006, during implementation programmes for the EU Water Framework Directive (WFD 2000) in Serbia. We sampled 351 sampling sites in running and standing

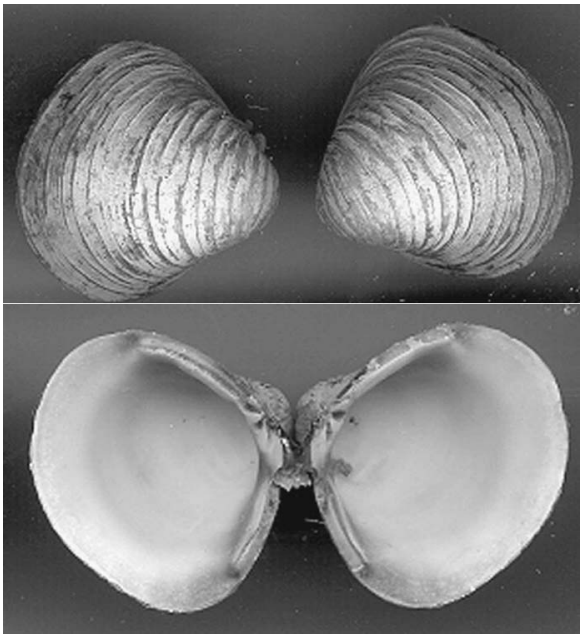

Figure 1. *Corbicula fluminea* from the Danube River, site Stara Palanka (Photo by Bela Csányi).

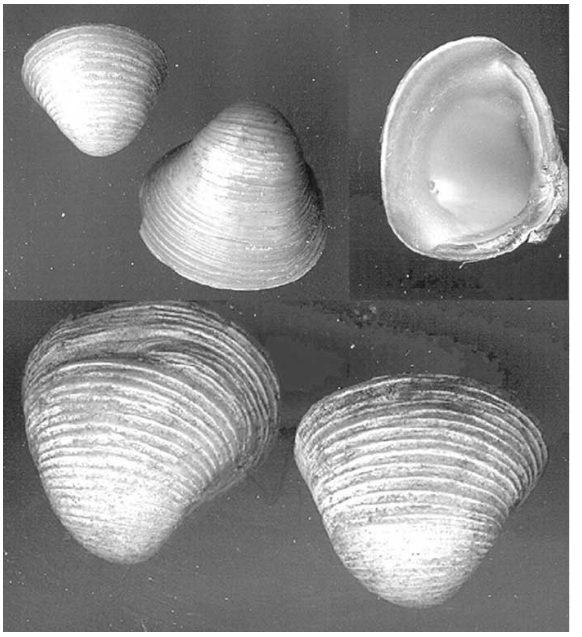

Figure 2. *Corbicula fluminalis* from the Danube River, site Stara Palanka (Photo by Bela Csányi).

Table 1. Relative abundance description sheet.

Description	No. of individuals per sample* or per m^2**	Relative abundance
Single record	1-2	1
Low abundance	3-4	2
Medium abundance	4-20	3
Abundant	20-100	4
Very abundant	>100	5
UN	-	unknown

*In the case of semi-quantitative sampling; one sample cover area of approx. one m^2;
**In the case of quantitative sampling

waters, likely to give us an adequate description of the range of Asian clams through-out Serbia.

Benthic samples were collected by various techniques – benthic hand nets (semi-quantitative technique), dredging, hydraulic polyp sampler (qualitative techniques), Van Veen and Eckman grabs (quantitative sampling). Diving was also performed to collect the mussels. During the diving, the evaluation of abundance was performed, by using quadrates ($0.25m^2$). In areas where the Asian clams could be expected (larger rivers and reservoirs), the bank area (shallow water and flooding zone) was inspected by detailed examination of available habitats. In addition, we checked zones of dredged gravel and cobbles, by visual examination of dredged material, in order to find empty shells of Asian clams as proof of past or current presence in a particular area. Relative abundance was evaluated according to scale presented in the Table 1.

The coordinates (latitude and longitude) of the sampling points were measured by "Garmin eTrex" GPS and mapped by using ArcMap software.

Results

Two representatives of the genus *Corbicula* (Mollusca: Bivalvia: Corbiculidae) have been found in Serbian waters (Figures 1 and 2).

In spring 1998, numerous empty shells of *C. fluminea* were found in the Danube River at Oresac (Site 1; Annex and Figure 3.). The shells were collected accidentally, by fishermen nets. In autumn of the same year, the first live specimen was collected at the same location. This was the first time *C. fluminea* was recorded in Serbian waters.

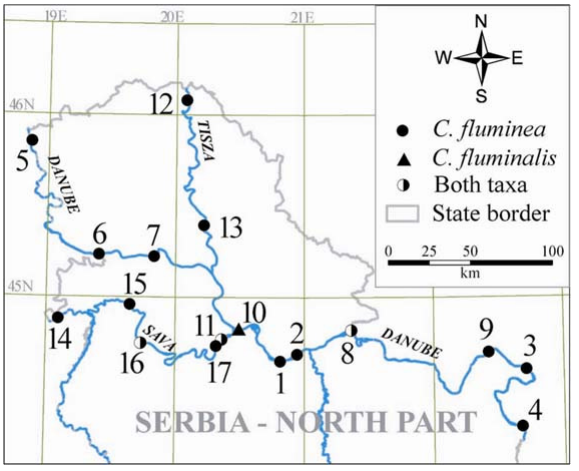

Figure 3. Distribution of *C. fluminea* and *C. fluminalis* in Serbia – site numbers as in the Annex.

In the period of follow-up investigations (1999-2006), sampling methods indicated that *C. fluminea* became more frequent and abundant in the Danube River. Thus, several new sites for *C. fluminea* were recorded during 2000, from the lower Serbian Danube (Figure 3): Smederevo (Site 2), Mala Vrbica (Site 3) and Radujevac (Site 4) (VITUKI 2000). During an investigation of the Serbian sector of the Danube River (2001, river km 1429-926) (JDS-ITR National Report 2002), *C. fluminea* was recorded at six sites within habitats where bottom substrate consisted mostly of fine sand (mineral substrate classification according to Verdonschot 1999: grains are visibly perceptible; 0.125-0.5 mm); Bezdan/ Batina (Site 5); Backa Palanka (Site 6); Novi Sad (Site 7), Stara Palanka/Ram (Site 8), Tekija/Orsava (Site 9) and Mala Vrbica/Simijan (Site 3).

Paunovic (2004) reported *C. fluminea* from the lowest section of the Sava River (Site 11). During the 2006 River Sava Survey, *C. fluminea* was recorded at four additional sites; Jamena (Site 14); Sremska Mitrovica (Site 15); Sabac (Site 16) and Ostruznica (Site 17).

A substrate examination of the Sava River showed that *C. fluminea* was abundant in benthos dominated by fine sand, comparable to this species' habitat in the Danube River. In the Sava River, *C. fluminea* was recorded with relative abundance percentages of up to 34 % of the total benthic community.

In addition, *Corbicula fluminea* and *C. fluminea* have been reported from the Tisza River - at Site 12 (Kanjiza - JDS-ITR National Tisza Report 2002) and at Site 13 (Zabalj bridge). The Tisza River specimens were collected from the same habitat type as in the Danube and the Sava Rivers, but with a lower population density (up to 0.43% of total benthic community).

Our investigation showed that *C. fluminea* is particularly abundant at two sites in the Danube River (Sites 1 and 8), and one in the Sava River (Site 16), with relative abundance up to 27, 26, and 28 % of the total macroinvertebrate community, respectively. Substrates at Sites 8 and 16 (Figure 2) are predominantly composed of fine sand. The dense population at Oresac (Site 1) was observed in the side-channel, in the region of slow current, with a higher ratio of silt-clay and very find sand (mineral substrate classification according to Verdonschot 1999: grains not visibly perceptible; <0.125 mm), than within the other sites of distribution.

The other morphotype, *C. fluminalis* was recorded in the Danube River - Stara Palanka/ Ram (Site 8; 0.2 % of total macroinvertebrate abundance), Belgrade/Pancevo bridge (Site 10; two specimens), as well as from the Sava River – Makis (Site 11) and Sabac (Site 16). According to available data, the abundance of *C. fluminalis* is lower than of *C. fluminea* within the co-existing habitats (Annex). The specimens of *C. fluminalis* were collected in the same habitat type as *C. fluminea*.

The fast dispersal of Asian clams along the investigated area confirmed the theory that waterways are suitable recipient areas for bio-invasions. Asian clams were not found in any investigated sites other than those listed in the Annex.

Discussion

Two morphotypes of Asian clams occurred in investigated waters: *C. fluminea* (Figure 1) and *C. fluminalis* (Figure 2). The taxonomic status of those taxa is still unclear (Korniushin 2004), so we consider them as morphotypes, rather than as individual species.

During the study, *C. fluminea* was found at 16 sites, while *C. fluminalis* was observed at 4 sites (Figure 3). The morphotype *C. fluminea* is widely distributed along the entire Serbian stretch of the Danube and the Sava River. *C. fluminea* has been also found at two sites at the Tisza River.

C. fluminea appears to be well adapted to particular aquatic ecosystems. According to our investigations, it was limited to large, potamon-

type Rivers – the Danube, the Tisza and the Sava and it was not found elsewhere in Serbia. Those watercourses are characterized as heavily modified, influenced by hydro-morphological changes and organic pollution and exposed to intensive ship traffic (SCG ICPDR National Report 2004). *C. fluminea* was frequently present in samples, sometimes with a high population density.

C. fluminalis was rare in terms of Serbian distribution. According to the present data, *C. fluminalis* is found only at two sites at the Danube River, as well as two in the Sava River. Both taxa were found within habitats where the substrate consisted mostly of fine sand.

The distribution of *Corbicula*, as well as some other invertebrate taxa, *Branchiura sowerbyi* (Paunovic et al. 2005), *Anodonta woodiana* (Paunovic et al. 2006) and *Orconectes limosus* (Pavlovic et al. 2006), indicated that heavily modified navigational waterways are suitable recipient areas for the introduction and adaptation of invasive species.

Freshwater bivalves of the genus *Corbicula* are autochthonous fauna in tropical and subtropical regions of Africa, Asia, the Malaysian Archipelago, the Philippines, New Guinea and Eastern Australia (Morton 1986).

During the 20th century, the clams were introduced to Europe (Mouthon 1981, Bij de Vaate and Greijdanus- Klaas 1990, Bij de Vaate 1991, Swinnen et al. 1998, Arujo et al. 1993, Csányi 1999, Berneth et al. 2002, Paunovic 2004) and to America (Ituarte 1981, Counts 1986).

If we consider the introduction of Asian clams into the Danube Basin, *Corbicula fluminea* was first reported in 1991 from the Rhine (Kinzelbach 1991). Further, during the investigation of the Hungarian sector of the Danube River, Csányi (1999) reported *C. fluminea* together with *C. fluminalis* in the vicinity of the nuclear power plant at Paks. Several new sites of *C. fluminea* in the Danube River were revealed in 2000 during the Bioindicator Study (VITUKI 2000) from the lower Serbian Danube: Smederevo (river km 1115), Mala Vrbica (river km 924) and Radujevac (river km 849). This invasive species proved to be more wide spread on the lower Danube section during the JDS survey (Berneth et al. 2002).

The history of the Asian clam invasion, vectors of introduction and dispersal, as well as consequences of invasion are well discussed for the United States (Counts 1986), since it was first observed a long time ago, during the first quarter of the 20th century (Burch 1944, Counts 1986). Counts (1986) reviewed the dispersal mechanisms of the clam, which include transport by birds, accidental transport with sand or gravel, and release as bait or as aquarium specimens.

The introduction and spread of Asiatic clams along the Danube River seems to be connected with shipping, primarily via exchange of ballast water, as well as with the introduction of fish species from Asia. The connection between the introduction of Chinese fish species and other mussel species (Chinese pond mussel, *Anodonta woodiana*) has already been indicated (Paunovic et al. 2006).

Our results, together with previous investigations (Csányi 1999, 2002, VITUKI 2000, Berneth et al. 2002), indicate that *C. fluminea* is rapidly spreading along the Danube River. Bearing in mind that previous investigations did not report *Corbicula* in Serbian waters (Arambasic 1994), and taking into account the fact that a dense population was observed when *C. fluminea* was first recorded, then the period between 1980 and 1995 could be considered as the time of introduction. This time scale is supported by the first report of *C. fluminea* in neighbouring Hungary in 1998 (Csányi 1999).

The results presented confirm that the Danube River is one of the most important invasion corridors – the Southern Invasion Corridor, as indicated by Galil et al. (2007).

If we consider the negative impacts concerning the appearance of Asian clams in inland waters, it has been documented that the most prominent effect of the introduction of the Asian clams is bio-fouling of power plant and industrial water systems (Isom 1986, Williams and McMahon 1986). The mass occurrence of *Corbicula* could also cause problems in irrigation canals and pipes (Prokopovich and Hebert 1965, Devick 1991), as well as in drinking water supply facilities (Ingram 1959, Smith et al. 1979, Clarke 1981). At the time of writing, similar biofouling problems have not been reported from Serbia.

The other aspect of the appearance of Asian clams is impact to recipient ecosystems. The introduction of Asian clams could alter benthic substrate (Sickel 1986), and create competition with native species for limited resources (Devick 1991). Potential ecological problems deserve attention and further investigations on Asian clams in the region are required.

In NW Europe, *Corbicula* has been known from the Lower Pleistocene but is absent from the Cromerian Complex, occurring again in the three interglacials following the Anglian/ Elsterian. It appears to be unknown from the last interglacial, except as derived fossils (Meijer and Preece 2000). *Corbicula* gen. sp. is a characteristic taxa for lower Pleistocene interglacial deposits in Pannonian Plain. Clams that have been usually identified as *C. fluminalis* are among most well-known interglacial molluscs in the region of the Pannonian Plain. The importance of Asian clams in the Pleistocene can be illustrated by the fact that part of Pleistocene layer (middle Pleistocene – Mindel-Riss Interglacial Periods) is named the *Corbicula* deposit (Laskarev 1951, Stevanovic 1977).

A comparison between Pleistocene and recent taxa is needed and those results could help in the identification of the evolutionary status of the two recently identified morphotypes with regard to native fauna. Pleistocene Asian clams lived in associations with many other mollusc species that are components of recent native fauna - *Fagotia esperi* (Ferussac), *Theodoxus danubialis* (Pfeiffer), *Amphimelania holandri* (Ferussac), *Lithoglyphus naticoides* (Müller). The results between the comparison of Pleistocene and recent *Corbicula*, as well as an analysis of Pleistocene and recent molluscs fauna in the region, could give rise to a discussion on how to treat the European population of Asian clams – as an introduction, or as natural process of reintroduction, accelerated by human activity.

Conclusions

Two morphotypes belonging to the genus *Corbicula* – *C. fluminea* and *C. fluminalis* have been established in Serbian waters. Our results, together with previous investigations, show that *C. fluminea* rapidly spreads along large potamon-type rivers. Both taxa are established within the habitats where the substrate consists mostly of fine sand.

Results indicate that Asian clams are limited to heavily-modified potamon-type rivers. Although negative effects of the introduction of Asian clams on industrial facilities have been documented for other recipient areas, such problems with *Corbicula* have not been reported for Serbia and adjacent areas.

Further investigation on invasive species in regional aquatic ecosystems, as well as on further spread of Asian clams in particular, is essential in order to determine possible effects to native biotopes.

A joint research effort between hydrobiologists and paleontologists, aimed to compare recent clams with taxa belonging to Pleistocene, is necessary to determine the status of Asian clams in the region, with regard to aligning them as either introduced or reintroduced taxa.

The data presented confirmed that the Danube River is one of the most important invasive corridors in the Palearctic – Southern Invasion Corridor.

Acknowledgements

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Supplementary material

The following supplementary material is available for this article:

Annex. Records of *C. fluminea* and *C. fluminalis* in Serbia.

Annex. Records of *C. fluminea* and *C. fluminalis* in Serbia

Site No. (Map Ref.)	Location (River, site name, river-kilometer	Record coordinates		Record date	Relative abundance of *C. fluminea*	Relative abundance of *C. fluminalis*	Collector
		Latitude, °N	Longitude, °E				
1	Danube, Oresac, 1126	44°39'41"	20°48'05"	1998	4		Simić
2	Danube, Smederevo, 1117	44°40'01"	20°55'19"	2000/2001	1		Csányi
3	Danube, Mala Vrbica, 926	44°36'20"	22°42'11"	2000	2		Csányi/Paunović
4	Danube, Radujevac, 849	44°15'04"	22°41'19"	2000	UN		Csányi
5	Danube, Bezdan, 1429	45°52'26"	18°49'58"	2001	1		Csányi/Paunović
6	Danube, Backa Palanka, 1300	45°13'52"	19°21'42"	2001	1		Csányi/Paunović
7	Danube, Novi Sad, 1252	45°15'40"	19°53'09"	2001	2		Csányi/Paunović
8	Danube, Stara Palanka, 1077	44°49'17"	21°20'00"	2001	4	1	Csányi/Paunović
9	Danube, Tekija, 954	44°41'59"	22°24'47"	2001	3		Csányi/Paunović
10	Danube, Pancevo bridge, 1166	44°49'54"	20°29'38"	2002		UN	Knežević/Nenadić
11	Sava, Makis, 15	44°46'21"	20°21'05"	2002	1	UN	Paunović
12	Tisza, Kanjiza, 148	46°04'26"	20°03'36"	2001	2		Csányi/Paunović
13	Tisza, Zabalj bridge, 38	45°23'53"	20°12'39"	2003	2		Paunović
14	Sava, Jamena 195	44°52'21"	20°21'05"	2006	3		Paunović
15	Sava, S. Mitrovica, 136	44°57'55"	19°36'01"	2006	3		Paunović
16	Sava, Sabac, 104	44°46'17"	19°42'15"	2006	4	1	Paunović
17	Sava, Ostruznica, 17	44°43'19"	20°18'15"	2006	2		Paunović