

Distribution of the invasive bivalve *Sinanodonta woodiana* (Lea, 1834) in Croatia

Jasna Lajtner* and Petar Crnčan

Department of Zoology, Division of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, HR-10000 Zagreb, Croatia

E-mail: jlajtn@zg.biol.pmf.hr (JL), petar.crnčan@gmail.com (PC)

*Corresponding author

Received: 7 June 2011 / Accepted: 29 September 2011 / Published online: 12 October 2011

Abstract

The Chinese pond mussel *Sinanodonta woodiana* is an invasive bivalve species present in the flowing and standing waters of most of Europe. Field research conducted from 2007 to 2011 indicated that this species has colonised the entire eastern part of Croatia, and that its spread westward is continuing. During our study, *S. woodiana* was recorded at 54 localities.

Key words: Chinese pond mussel, *Sinanodonta woodiana*, Unionidae, invasive species, Croatia

Introduction

The Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) is a species native to East and South–East Asia. Some authors have placed this species within the order *Anodonta* though newer taxonomic research has placed it in the order *Sinanodonta* (Bogatov and Sayenko 2002). In Europe it was first discovered in Romanian fish farms at Cefa-Oradea in 1979 (Sàrkàny-Kiss 1986). In Hungary *S. woodiana* was recorded in 1980 (Petró 1984). In the meantime, this species has been discovered in a number of European countries: France (Girardi and Ledoux 1989), Slovakia (Košel 1995), Czech Republic (Beran 1997), Austria (Reischutz 1998), Poland (Bohme 1998), Ukraine (Urishients and Korniuushin 2001), Italy (Manganelli et al. 1998), Germany (Glöer and Zeittler 2005), Serbia (Paunovic et al. 2006) and Sweden (von Proschwitz 2006). The spread of *S. woodiana* has continued and it has since been reported on several Indonesian islands, the Dominican Republic and Costa Rica (Watters 1997). In these countries, the species has succeeded in establishing stable populations, and continuing its spread. In the meantime, it has also been discovered in Moldova (Munjiu and Shubernetski 2008), Spain (Pou-Rovira et al.

2009), and most recently in the United States (Bogan et al. 2011).

It is believed that the primary pathway of introduction of this species to Europe was with Asian fish species, such as silver carp (*Hypophthalmichthys molitrix* Valenciennes, 1844), bighead carp (*Aristichthys nobilis* Ricardson, 1844) and grass carp (*Ctenopharyngodon idella* Valenciennes, 1844), primarily introduced to regulate aquatic vegetation in fish ponds (Paunovic et al. 2006). Many of these fish carried bivalve larvae in their gills or fins that were not noticed due to their small size. In the Republic of Croatia, these fish were introduced to fish ponds in the 1960s (Bojčić and Bunjevac 1982).

The first data on the distribution of *S. woodiana* in Croatia were reported by Paunovic et al. (2006). These data were for the Danube River, which forms the border between Croatia and Serbia. International research was conducted on the Danube in 2007 and also confirmed the presence of this bivalve species in the Croatian part of the Danube (Graf et al. 2008). Its distribution in Croatia outside of the Danube River was unknown until now. Therefore, the primary objective of this paper was to determine actual distribution of *S. woodiana* throughout Croatia.

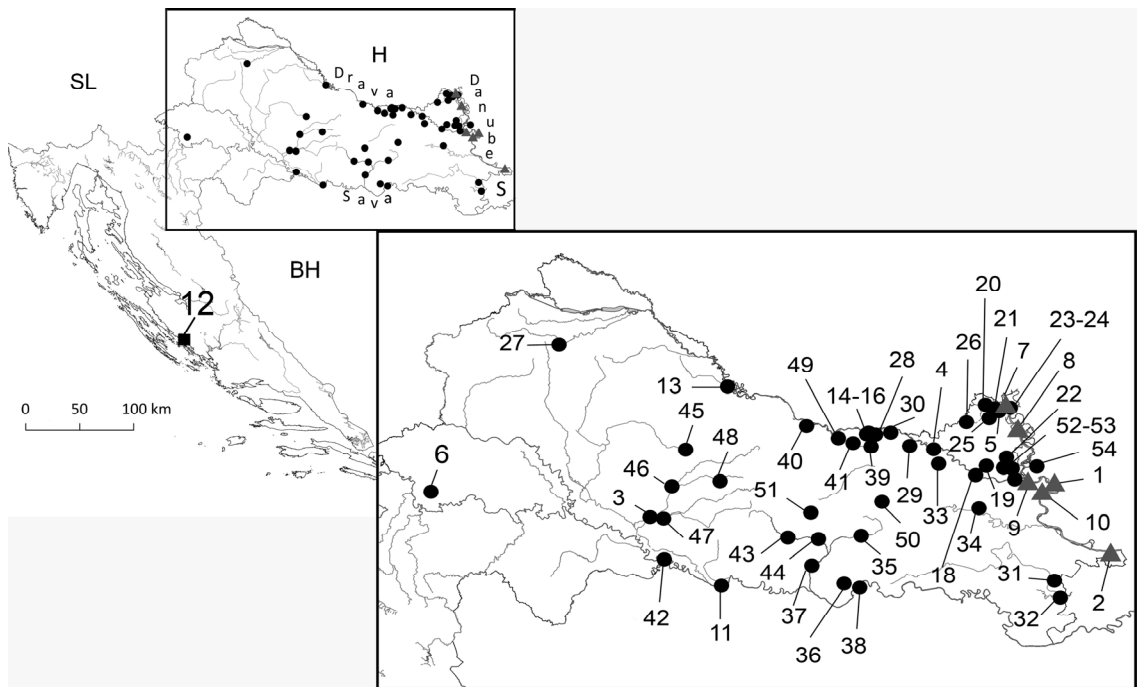


Figure 1. Distribution of *Sinanodonta woodiana* in Croatia (site numbers as in the Appendix; BH - Bosnia and Herzegovina, H - Hungary, S - Serbia, SL - Slovenia, triangle - literature data, circle - our investigation, quadrate (Record No. 12) - questionable finding).

Materials and methods

Study site

Research was conducted on natural watercourses such as rivers, lakes, backwaters and artificial habitats such as channels and fish ponds throughout Croatia (Pannonian-Peripannonian, Dinarid and Mediterranean geographical units). Watercourses in Croatia belong to two basins: the Adriatic and Black Sea basins.

Data collection

Research on the species *Sinanodonta woodiana* was conducted in the period 2007 to 2011. Bivalves were collected using a benthos net and by diving at some sites.

Results

The species *Sinanodonta woodiana* was confirmed at 54 localities (Figure 1; Appendix 1) mostly within the Pannonian-Peripannonian region (the Danube, Black Sea Basin). Only one case of introduction has been confirmed for the

Mediterranean region – the Vrana Lake (Appendix 1, Record No. 12). It was not detected in the Dinarid Region of Croatia.

The first report of this species in Croatia was for the Danube River in September 2001 at the localities Ilok and Erdut (Paunović et al. 2006). The next report (2006) confirms its presence in the Ilova River near Kutina (Appendix 1, Record No. 3). Confirmation that this was in fact *Sinanodonta woodiana* was obtained in 2011 when the collected material was examined as part of another project.

The largest specimen of this species found in Croatia to date was found in the Mali Strug Channel near Stara Gradiška (Figure 2; Appendix 1, Record No. 10). The adult individual was 25.10 cm long, 14.29 cm tall and 9.72 cm wide, with a wet mass of 1.335 kg.

This species is mostly present in lowland rivers, manmade canals, wetlands and fishponds (Appendix 1), particularly in places with a silt-clay substrate. The following native bivalve species from the Unionidae family were also found together with *Sinanodonta woodiana*: *Anodonta cygnea* (Linnaeus, 1758), *A. anatina*

Figure 2. *Sinanodonta woodiana* from river channel Mali Strug, Nature Park Lonjsko polje.



Figure 3. Empty shell of *Sinanodonta woodiana* on banks of channel Hulovo, Nature Park Kopački rit.



(Linnaeus, 1758), *Pseudanodonta complanata* (Rossmässler, 1835), *Unio crassus* (Philipsson, 1788), *U. pictorum* (Linnaeus, 1758) and *U. tumidus* (Philipsson, 1788).

It is of particular concern that these individuals have been found within two Nature Parks: Lonjsko Polje (Figure 2; Appendix 1, Record No. 10) and Kopački Rit (Figure 3; Appendix 1, Records No. 52, 53, 54). Both of these parks represent important wetland habitats at the European level. Kopački Rit is connected to the Drava and Danube Rivers by channels, while Lonjsko Polje is situated alongside the Sava River.

Discussion

As mentioned in the introduction, the primary pathway of introduction of this species to Europe is thought to be the introduction of Asian fish species (Paunovic et al. 2006). The first find of this species in Croatian watercourses was made by scientists investigating the Danube River, which forms the border between Serbia and Croatia (Paunovic et al. 2006; Graf et al. 2008).

Paunovic et al. (2006) made the assumption that the Danube is an important watercourse for the spread of this species eastwards into the Serbian watercourses. A similar conclusion was

reached in this study, which confirmed the widespread presence of this species in Croatia. The species has spread from the Danube into its large tributaries, the Drava and Sava Rivers, and their tributaries.

On the other hand, we assumed that the record of this species in fish ponds indicates a second possible pathway of spread in Croatia. The transport of carrier fish and/or water from one fish pond or water course to another has also enabled the wider transport of this species. Furthermore, if the fish ponds are equipped with flowing water, bivalves can enter into the tributaries and rivers. This is a somewhat slower, though significant pathway of invasion for this species.

The find of empty shells of the species *S. woodiana* in Nature Park Vrana Lake in the Mediterranean region is likely the consequence of the introduction of individuals of this species from continental parts of Croatia. Vrana Lake is known for its rich fish fauna as an important destination for sports fishermen from continental Croatia, particularly during the summer vacation period. Fishermen bring bivalves with them for use as bait. Research of the malacofauna of this lake is ongoing and the presence of this species has not been confirmed. It can be assumed that any live bivalves that may have been released into the lake likely did not survive, due to stress caused by increased salinity as this lake is connected to the sea by a manmade channel.

This species is known to seriously threaten the native population of bivalves from the family Unionidae. Fabbri and Landi (1999) stated that the native species *A. anatina* had been completely replaced by *S. woodiana* in several channels with a soft substrate and high trophic level. The Chinese pond mussel is a direct competitor for food and space with native species, while another important factor is competition for fish hosts (Rashleigh 1995; Fabbri and Landi 1999) as the larvae of these species develop on the gills and fins of fish. Dudgeon and Morton (1983) stated that this species reproduces two to three times per year, unlike the native species, which typically reproduce only once per year. The same authors also stated that *S. woodiana* becomes sexually mature in the first year of life at a shell length of 3 to 4 cm, and individuals have an average life span of 12 to 14 years. The parasite phase of the life cycle lasts 5–15 days, depending on the water temperature. Research has shown that this species is not selective with regards to the fish

host, which is a significant advantage (Douda et al. 2011). The species also has a much higher rate of increase and better tolerance of hypoxia and pollution than native species (Sîrbu et al. 2005). Due to the above mentioned invasive characteristics of *S. woodiana*, it can be expected that all the native bivalve species in Croatia will be threatened.

Research conducted in the channels of Miedzyodrze in Poland indicated that this species is resistant to unfavourable habitat conditions, and was found in waters that partially freeze in winter (Domagala et al. 2007). The same applies for watercourses in Croatia, as during winter, the air temperature drops below freezing and shallow sections of rivers and lakes also freeze.

The shell length of individuals found in Croatian waters indicates that this species has long been present here, and finds of individuals of varying size indicates that the biotic and abiotic conditions of these habitats are favourable. In other words, the species has established stable populations capable of reproducing.

In Croatia, three additional invasive mollusc species have been confirmed to date: the bivalves *Dreissena polymorpha* (Pallas, 1771), *Corbicula fluminea* (O. F. Müller, 1774) and the snail *Potamopyrgus antipodarum* (Gray, 1843) (Lajtner et al. 2004; Gottstein et al. 2009). These species are known in central and eastern Croatia, indicating that the main pathway of entry and spread of invasive mollusc species are the large lowland rivers, and that the species are spreading upstream and into the tributaries. *S. woodiana* has not yet been found in the rivers of the Adriatic basin. There are two possible reasons for this: the Dinarid mountain range forms a geographic barrier, making contact between these two basins impossible. On the other hand, in the lower courses of the Adriatic rivers where the substrate is suitable, i.e. silty-sandy, the water is brackish.

It can be assumed that the process of expansion of this species in Croatia will continue and that this species will enter into the tributaries of the large rivers in central Croatia where both the physicochemical parameters and substrate type are suitable. It can also be expected to spread into southwestern Croatia, primarily into the fish ponds and reservoirs. In areas where it is already present, it can be expected to form dense populations. For the above reasons, regular monitoring of this species is required.

Acknowledgements

This study was supported by the Ministry of Science, Education and Sports of the Republic Croatia (project No. 119-11930801231). We would like to thank to Ivan Darko Grlica, Ivan Katanović, Mladen Kerovec and Krešimir Žganec for sample collection. We are also grateful to reviewers for their critical remarks on the manuscript. Publication of this paper was supported by the European Commission 7th Framework Programme through the *enviroGRIDS* project (Grant Agreement n° 226740).

References

- Bojčić C, Bunjevac I (1982) 100 godina ribogojstva na tlu Jugoslavije. Ribozajednica, Zagreb, 154 pp
- Beran L (1997) First record of *Sinanodonta woodiana* (Mollusca: Bivalvia) in the Czech Republic. *Acta Societatis Zoologicae Bohemoslovenicae Praha* 61: 1–2
- Bogan AE, Bowers-Altman J, Raley ME (2011) A new threat to conservation of North American freshwater mussels: Chinese Pond Mussel (*Sinanodonta woodiana*) in the United States. *Tentacle* 19: 39–40
- Bogatov VV, Sayenko EM (2002) On the structure and systematic position of the genus *Sinanodonta* (Bivalvia, Unionidae). *The Bulletin of the Russian Far East Malacological Society* 7: 85–93
- Bohme M (1998) Ein neuert Fundort der Chinesischen Teichmuschel (*Sinanodonta woodiana*) in Mitteleuropa. *Heldia* 2: 166
- Domagala J, Labecka AM, Migdalska B, Pilecka-Rapacz M (2007) Colonization of the channels of Miedziodrze (north-western Poland) by *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae). *Polish Journal of Natural Sciences* 22: 679–690, <http://dx.doi.org/10.2478/v10020-007-0058-8>
- Douda K, Vrtilek M, Slavik O, Reichard M (2011) The role of host specificity in explaining the invasion success of the freshwater mussel *Anodonta woodiana* in Europe. *Biological Invasions*, <http://dx.doi.org/10.1007/s10530-011-9989-7>
- Dudgeon D, Morton B (1983) The population dynamics and sexual strategy of *Anodonta woodiana* (Bivalvia: Unionacea) in Plover Cove Reservoir, Hong Kong. *Journal of Zoology (London)* 201: 161–183, <http://dx.doi.org/10.1111/j.1469-7998.1983.tb04268.x>
- Fabbri R, Landi L (1999) Nuove segnalazioni di molluschi, crostacei e pesci esotici in Emilia-Romagna e prima segnalazioni di *Corbicula fluminea* (O. F. Müller, 1774) in Italia (Mollusca Bivalvia, Crustacea Decapoda, Osteichthyes Cypriniformes). *Quaderno di Studi e Notizie di Storia Naturale della Romagna* 12: 9–20
- Girardi H, Ledoux JC (1989) Présence d'*Anodonta woodiana* (Lea) en France (Mollusques, Lamellibranches, Unionidae). *Bulletin Mensuel de la Société Linnéenne de Lyon* 58: 186–290
- Glöer P, Zeittler ML (2005) Kommentierte Artenliste der Süßwassermollusken. *Deutschlands Malakologische Abhandlungen* 23: 3–23
- Gottstein S, Žganec K, Hudina S, Lajtner J, Lucić A, Maguire I (2009) Invasion of large Croatian rivers by alien molluscs and crustaceans. World Conference on Biological Invasion and Ecosystem Functioning. Book of Abstracts, Porto, Portugal, 142
- Graf W, Csány B, Leitner P, Paunovic M, Chiriac G, Stubauer I, Ofenböck T, Wagner F (2008) Macroinvertebrate. In: Liška I, Wagner F, Slobodník J (ed), Joint Danube Survey 2 - Final Scientific Report. ICPDR – International Commission for the Protection of the Danube River, <http://www.icpdr.org> (Accessed 7 September 2009)
- Košel V (1995) The first record of *Anodonta woodiana* (Mollusca, Bivalvia) in Slovakia. *Acta Zoologica Universitatis Comenianae Bratislava* 39: 3–7
- Lajtner J, Marušić Z, Klobučar GIV, Maguire I, Erben R (2004) Comparative shell morphology of the zebra mussel, *Dreissena polymorpha* in the Drava river (Croatia). *Biologia* 59: 595–600
- Manganelli G, Bodon M, Favilli L, Castagnolo L, Giusti F (1998) Checklist delle specie della fauna d'Italia, molluschi terrestri e d'acqua dolce. Errata and addenda, 1. *Bollettino Malacologico* 33: 151–156
- Munju O, Shubernetki I (2008) First record of *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) in Moldova. *Aquatic Invasions* 3: 441–160, <http://dx.doi.org/10.3391/ai.2006.1.3.10>
- Paunovic M, Csány B, Simic V, Stojanovic B, Cacic P (2006) Distribution of *Anodonta* (*Sinanodonta*) *woodiana* (Lea, 1834) in inland waters of Serbia. *Aquatic Invasions* 1: 154–160, <http://dx.doi.org/10.3391/ai.2006.1.3.10>
- Petró E (1984) Occurrence of *Anodonta woodiana woodiana* (Lea, 1834) in Hungary. *Allatani Közlemények* 71: 189–191
- Pou-Rovira Q, Araujo R, Boix D, Clavero M, Feo C, Ordeix M, Zamora I (2009) Presence of the alien Chinese pond mussel *Anodonta woodiana* (Lea, 1834) (Bivalvia, Unionidae) in the Iberian Peninsula. *Graellsia* 65: 67–70, <http://dx.doi.org/10.3989/graellsia.2009.v65.i1.137>
- Sîrbu I, Sárkány-Kiss A, Sîrbu M, Benedek AM (2005) The Unionidae from Transylvania and neighborhood regions. *Heldia* 6: 183–192
- Rashleigh B (1995) Simulation modelling of competition between freshwater mussels for fish hosts. *Association of Southeastern Biologists Bulletin* 42: 114
- Reischutz PL (1998) Vorschlag für deutsche Namen der in Österreich nachgewiesenen Schnecken- und Muschelarten. *Nachrichtenblatt der ersten orarlberger Malakologischen Gesellschaft* 6: 31–44
- Sárkány-Kiss A (1986) *Anodonta woodiana woodiana* (Lea, 1834) a new species in Romania (Bivalvia: Unionacea). *Travaux du Museum d'Histoire Naturelle "Grigore Antipa"* 28: 15–17
- Urishients VI, Kornushin AV (2001) The new species in the fauna of Ukraine *Sinanodonta woodiana* (Bivalvia, Unionidae), its diagnostics and possible ways of introduction. *Vestnik Zoologii* 35: 79–84
- von Proschwitz T (2006) Faunistic news from the Göteborg Natural History Museum 2005 – snails, slugs and mussels – *Bithynia transsilvanica* (E. A. Bielz) refound in Sweden - *Sinanodonta woodiana* (Lea) - for Sweden new fresh water mussel. *Göteborg Naturhistoriska Museum Årstryck* 2006: 39–70
- Watters GT (1997) A synthesis and review of the expanding range of the Asian freshwater *Anodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae). *Veliger* 40: 152–156

Appendix 1. Records of *Sinanodonta woodiana* in Croatia.

No.	Record date	Location	Latitude N	Longitude E	Data
1	01.09.2001.	Danube River, Erdut	45°31.938'	19°04.440'	Lit. data ¹
2	01.09.2001.	Danube River, Ilok	45°13.644'	19°21.726'	Lit. data ¹
3	12.09.2006.	Ilova River, Ilova	45°26.579'	16°50.142'	Present study
4	05.05.2007.	Drava River, Belišeće	45°41.458'	18°25.070'	Present study
5	05.05.2007.	Nameless channel, Draž	45°51.189'	18°45.993'	Present study
6	22.06.2007.	Fishponds Draganići, Draganići	45°33.793'	15°37.612'	Present study
7	01.09.2007.	Danube River, Batina	45°52.158'	18°49.744'	Lit. data ²
8	02.09.2007.	Danube River, upstream of confluence of Drava	45°45.956'	18°53.361'	Lit. data ²
9	02.09.2007.	Drava River	45°32.596'	18°55.673'	Lit. data ²
10	03.09.2007.	Danube River, Dalj	45°29.881'	19°00.204'	Lit. data ²
11	15.09.2007.	Channel Mali Strug, Gornji Varoš	45°08.886'	17°13.083'	Present study
12	10.12.2007.	Vrana Lake, Nature park Vrana lake	43°53.313'	15°33.982'	Present study
13	05.04.2008.	Drava River, bank Jelkuš, Pitomača	45°58.900'	17°17.150'	Present study
14	02.10.2008.	Fishponds Konopljište, Viljevo	45°45.909'	18°02.966'	Present study
15	02.10.2008.	Nameless pond, Viljevo	45°46.217'	18°03.873'	Present study
16	02.10.2008.	Drava River, Kamen	45°46.259'	18°03.631'	Present study
17	08.10.2008.	Drava River, Sarvaš	45°33.084'	18°51.447'	Present study
18	18.06.2009.	Drava River, Višnjevac	45°34.544'	18° 38.619'	Present study
19	21.06.2009.	Armljet Stara Drava Bilje	45°36.773'	18°42.290'	Present study
20	21.06.2009.	Borza River, Topolje	45°52.159'	18°43.011'	Present study
21	21.06.2009.	Bučka River, Gajić	45°50.385'	18°47.415'	Present study
22	21.06.2009.	Channel Mali Dunav, Podunavlje	45°38.578'	18°49.127'	Present study
23	21.06.2009.	Danube River, Batina	45°51.136'	18°51.249'	Present study
24	21.06.2009.	Danube River, Batina	45°51.148'	18°51.221'	Present study
25	21.06.2009.	Karašica River, Podolje	45°48.719'	18°44.038'	Present study
26	21.06.2009.	Nameless channel, Branjin vrh	45°47.983'	18°36.373'	Present study
27	10.07.2009.	Fishpond Bajer, Novi Marof	46°10.349'	16°20.996'	Present study
28	02.08.2009.	Channel Drava – Karašica, Viljevo	45°45.670'	18°05.988'	Present study
29	02.08.2009.	Karašica River, Črnkovići	45°42.528'	18°17.164'	Present study
30	02.08.2009.	Nameless fishpond, Donji Miholjac	45°46.048'	18°11.000'	Present study
31	05.08.2009.	Bosut River, Nijemci	45°07.153'	19°02.814'	Present study
32	05.08.2009.	Spačva River, Lipovac	45°02.807'	19°04.392'	Present study
33	05.08.2009.	Vučica River, Ladimirevci, confluence to Karašica	45°37.725'	18°26.515'	Present study
34	05.08.2009.	Vuka River, Ernestinovo	45°26.183'	18°39.136'	Present study
35	09.08.2009.	Londža River, Čaglin	45°20.368'	17°59.760'	Present study
36	09.08.2009.	Mrsunja River, Brodski Stupnik	45°08.582'	17°53.532'	Present study
37	09.08.2009.	Orljava River, Dragovci	45°13.327'	17°43.121'	Present study
38	09.08.2009.	Sava River, Slavonski Brod	45°07.353'	17°58.612'	Present study
39	12.08.2009.	Karašica River, Kapelna	45°42.717'	18°04.283'	Present study
40	16.08.2009.	Channel Županijski kanal, Kapinci	45°48.463'	17°43.074'	Present study
41	16.08.2009.	Karašica River, Krčenik	45°43.714'	17°58.307'	Present study
42	21.08.2009.	Una River, Uštica, confluence to Sava	45°15.882'	16°54.502'	Present study
43	23.08.2009.	Orljava River, Jaguplije	45°20.486'	17°35.499'	Present study
44	23.08.2009.	Orljava River, Kuzmica	45°19.883'	17°45.637'	Present study
45	30.08.2009.	Česma River, Veliki Grdevac	45°43.288'	17°02.579'	Present study
46	30.08.2009.	Ilova River, Garešnica	45°34.248'	16°57.621'	Present study
47	30.08.2009.	Pakra River, Banova Jaruga	45°26.111'	16°54.642'	Present study
48	30.08.2009.	Toplica River, Daruvar	45°35.237'	17°13.672'	Present study
49	05.12.2009.	Channel Voćin-Drava, Čadavica	45°45.095'	17°53.476'	Present study
50	18.02.2010.	Lake Lapovac, Našice	45°28.792'	18°07.168'	Present study
51	30.08.2010.	Spring Bistra, Kaptol	45°26.604'	17°43.426'	Present study
52	10.10.2010.	Channel Linjov, Nature park Kopački rit	45°36.060'	18°47.977'	Present study
53	10.10.2010.	Channel Hulovo, Nature park Kopački rit	45°35.766'	18°50.783'	Present study
54	10.10.2010.	Kopačevo Lake, Nature park Kopački rit	45°36.035'	18°58.992'	Present study

¹Paunovic M, Csány B, Simic V, Stojanovic B, Cacic P (2006) Distribution of *Anodonta (Sinanodonta) woodiana* (Lea, 1834) in inland waters of Serbia. *Aquatic Invasions* 1: 154–160

²Graf W, Csány B, Leitner P, Paunovic M, Chiriac G, Stubauer I, Ofenböck T, Wagner F (2008) Macroinvertebrate. In: Liška I, Wagner F, Slobodnik J (ed), Joint Danube Survey 2 - Final Scientific Report. ICPDR - International Commission for the Protection of the Danube River