



Distribution and Characteristics of the Invasive Alien Species *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) in the Republic of Moldova

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Abstract: The invasive alien bivalve species *Sinanodonta woodiana* has been reported for the first time from the Republic of Moldova in 2003. In the study period 2008–2017, this species was recorded at six sampling stations in the Prut River basin: Leova, Goteşti, Cahul, Lake Manta, Lake Beleu, and Cişliţa-Prut, which basin part belongs to the Wetland Danube River Area of international importance. The most numerous size group was represented by specimens with a shell length of 8–12 cm. The highest density of *S. woodiana* was 40 ind./m², while the highest biomass was 750 g/m². The largest measured shell had a length of 240 mm. The smallest mature specimen had a shell length of 55 mm. Our results show that this mussel species has successfully established population in the R. Moldova, spreading upstream in the Prut River basin with estimated rate of 15 km per year. We discuss certain competitive advantages of *S. woodiana*, such as phenotypic plasticity, regeneration capacity, early maturation, high density and biomass, and tolerance to a wide range of environmental factors, which may pose a high risk to the native unionid bivalves in the Lower Prut River basin.

Key words: Chinese pond mussel, distribution, density, biomass, morphology, Moldova.

Introduction

The Eastern Asiatic freshwater species, the Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) (Bivalvia, Unionidae), with synonyms: *Symphynota woodiana* Lea, 1834, and *Anodonta magnifica* Lea, 1834 (BOGATOV & SAYENKO 2002), is the largest European representative of the family Unionidae, with a shell width reaching up to 30 cm (POUROVIRA et al. 2009). The native area of this species is Eastern Asia, including the basins of the Amur River, the Yangtze River, and the Primorye, as well as the territories of China, Taiwan, Cambodia, Thailand, and Japan (ZHADIN 1952, ZATRAVKIN & BOGATOV 1987, KRASZEWSKI & ZDANOWSKI 2007).

Sinanodonta woodiana was firstly described in Canton (Guangzhou), in the Pearl River drainage basin (BESPALAYA et al. 2017). According to the DNA barcoding analyses, in spite of the strong differences in the shell shape, only one haplotype of the species has been identified in Europe (GUARNERI et al. 2014). This mussel populates various habitats from slowly running rivers to eutrophic ponds (ZHADIN 1952).

Sinanodonta woodiana has a fragile shell of irregular rhombic shape with clear growth lines and variable colour, from green to brown or blackish, sometimes with a greenish hue. The umbo sculpture has strong concentric wavelike folds (ZHADIN 1952, YURISHINETS & KORNIUSHIN 2001). The species

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becomes sexually mature in the first year of life, when the shell length reaches 3–4 cm. It grows rapidly and can reach 10 cm in length during the 2–4 years of life. The average life span is 12–14 years. Up to 3% of the individuals are hermaphrodite. The males produce mature gonads throughout the year, however, the females come into reproductive stage only during the spring. There is no sexual dimorphism of the shell form (DUDGEON & MORTON 1983). The parasite phase of the life cycle is 5–14 days, depending on the water temperature (KISS 1995).

Most probably, *S. woodiana* has appeared accidentally in Europe, with the herbivorous cyprinid fish, which hosts the glochidia of this species (YURISHINETS & KORNIUSHIN 2001). The first specimens of *S. woodiana* in Europe were collected in 1979 in Romanian fish farms (SÁRKÁNY-KISS 1986). Later, this species has spread rapidly in many other European water bodies, thus, being recorded in Hungary in 1980 (PETRÓ 1984), in France in 1989 (GIRARDI & LEDOUX 1989), in Slovakia in 1995 (KOŠEL 1995), in the Czech Republic in 1997 (BERAN 1997), in Italy, Austria, and Poland in 1998 (MANGANELLI et al. 1998, REISCHÜTZ 1998, BÖHME 1998), in Ukraine in 2001 (YURISHINETS & KORNIUSHIN 2001), in Germany (GLÖER & ZEITTLER 2005) and Bulgaria (HUBENOV 2006) in 2005, in Serbia, Croatia and Sweden in 2006 (PAUNOVIC et al. 2006, VON PROSCHWITZ 2006, LAJTNER & CRNČAN 2011), in Spain in 2009 (POU-ROVIRA et al. 2009), and in Montenegro in 2013 (TOMOVIĆ et al. 2013). The species has appeared also in other parts of the world in such countries as Indonesia, the Dominican Republic, Costa Rica (WATTERS 1997), as well as in North America (BOGAN et al. 2011). It is important to note, that specimens from different countries have been found for the first time in anthropogenically transformed water bodies, such as: fish farms in Romania and Hungary (SÁRKÁNY-KISS 1986), hydropower station cooling ponds, e.g. warm lakes and canals of the Konin Lakes system (AFANASJEV et al. 2001), and other heavily modified and artificial habitats (PAUNOVIC et al. 2006).

In the Republic of Moldova, the first two empty shells of *S. woodiana* (with a length of 10.4–14.3 cm and age of 4–7 years) were recorded in the partly anthropogenically transformed water bodies of Lake Manta in 2003 (MUNJIU & SHUBERNETSKI 2008), while the first living individuals of the same species were recorded in Lake Beleu in 2008 (MUNJIU & SHUBERNETSKI 2008). Both Manta and Beleu lakes are part of the Prut River basin. Part of the Moldavian water bodies such as the Lower Prut and its lake system belong to the Wetland Danube River Area

– the lower part of the so called Southern Invasion Corridor (GALIL et al. 2008). One of the factors which has contributed to the spread of this species is the construction of the Giurgiulesti International Free Port in the Danube part of R. Moldova in 2006 (MUNJIU & SHUBERNETSKI 2010).

In this study we aimed to investigate the distribution and some qualitative and quantitative characteristics of *S. woodiana* on the territory of the Republic of Moldova.

Materials and Methods

Study area

The Prut River is the second largest river in the Republic of Moldova and the most eastern largest left tributary of the Danube River, its confluence being at 174 rkm from the Black Sea. The total length of the Prut River is 963 km, 695 km of which crosses the territory of R. Moldova; its catchment represents about 24% of the territory of the country. The Danube River flows through the territory of R. Moldova over an area of 480 m only.

Lake Beleu is situated in Southern Moldova near the Danube Delta on the territory of the ‘Prutul de Jos’ Protected Wetland Area (since 1991) and the Lower Prut Lakes Ramsar Site (No 1029; 19,152 ha; N 45°42’, E 028°11’). Lake Beleu is a shallow relict lake, approximately 5,000–6,000 years old. It is the largest natural lake of R. Moldova, connected with the Prut River by four natural arms. The lake has high quantity of suspended matter and a muddy bottom (MUNJIU et al. 2016). It has a surface area of 6.26–9.50 km², an average length of 5 km, a width of 2 km, and a depth range from 0.5 to 3 m depending on hydrological situation in the Danube and Prut rivers (BEJAN et al. 2016).

The complex lake system of Manta is situated in the southern part of the R. Moldova near the Danube Delta and consists of three lakes: Badelnic (1,443 km²), Dracele (2,774 km²), and Rotunda (2,329 km²).

Collection and processing of samples

During the investigation period 2008–2017, the sampling was regularly performed on the territory of the Republic of Moldova, in the main rivers Dniester and Prut, with annual, seasonal and monthly frequency.

The sampling was done at 14 sampling stations in the Dniester River basin and at 17 sampling stations in the Prut River basin.

Since *S. woodiana* can burrow deeply into the substrate at depths up to 30–40 cm (BASTIN et al. 2014), the sampling was done by hand and

other standard methods for collection of benthic invertebrates, such as the Petersen and Ekman grabs with a capture area of 1/40 m², nets, bottom scrapers, and a dredge with an area of capture of 8 m² (ABAKUMOV 1983, AQEM CONSORTIUM 2002). The mussels were gathered also by hand from an area of 1–5 m². Near the river banks the samples were collected from a depth of 0.3–1.5 m, while in the lakes from a depth of 0.3–1.0 m. All specimens were collected in the riverbed only in places in which there is slow (0.2–0.7 m/s) or no current, in backwaters and in the lakes with clay soft sediments.

The samples were preserved in 37% formalin or 96% ethanol solutions. For more detailed shell analysis and measurements live mussels were transported to the laboratory and placed in containers with water. The shell dimensions (length, width, and height) were determined by using an optic micrometer for mature glochidia and vernier calipers for large specimens. The weight was measured with an analytical balance ABS 80-4 Kern to 0.0001 g and an ISOLAB balance to 0.01 g precision.

The mussels were determined by standard identification keys for freshwater invertebrates (ZHADIN 1952, TSALOLIHIN 2004). The identification was done using stereomicroscopes M8C-9, upright Jenaval (Zeiss), SteREO Discovery.V8 (Zeiss), and an upright microscope Axio Imager A.2 (Zeiss).

The density and biomass of *S. woodiana* was estimated and converted into ind./m² and g/m², respectively. The age of mussels was determined by counting the annual growth rings. Part of the collected mussels, namely 43 live specimens, was used for the morphometric measurements of the shells. For morphometric purposes, the mussels were divided into length classes according to AFANASJEV et al. (2001).

The statistical analysis was performed using Statistica V.10, Excel 2007 and 2010 (Microsoft Office) software.

Results

Distribution, density and biomass

The results of our investigation during 2008–2017 revealed 210 live specimens of *S. woodiana* from a total of 296 quantitative and qualitative samples of benthic macroinvertebrates at six sampling stations of the Prut River basin: Leova, Gotești, Cahul, Lake Manta, Lake Beleu, and Cîșlița-Prut (Fig. 1, Table 1). Of them 143 specimens were used in the analyses (Table 1).

The highest density and biomass by hand sampling were recorded at Cîșlița-Prut at the

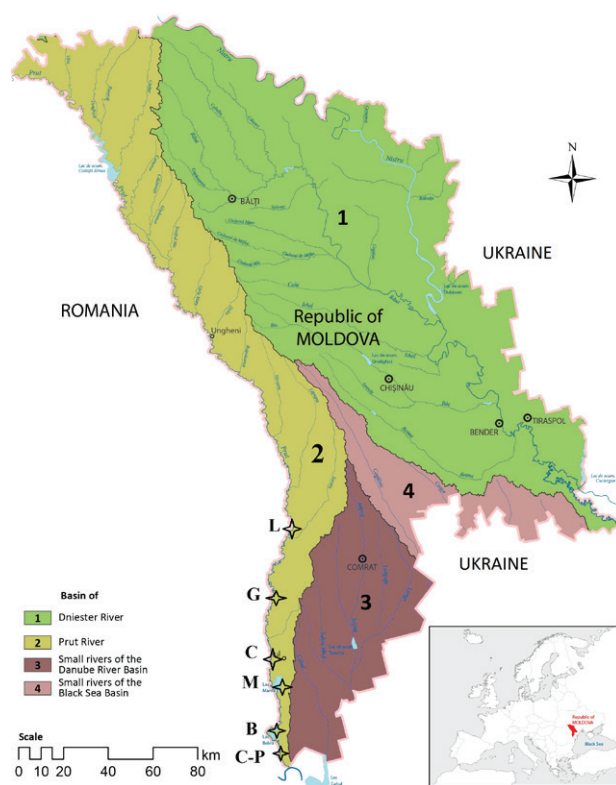


Fig. 1. Map of water basins of the Republic of Moldova and sampling stations where *Sinanodonta woodiana* was recorded during 2008–2017 in the Prut River basin (marked). From North to South: L: Leova, G: Gotești, C: Cahul, M: Lake Manta, B: Lake Beleu, and C-P: Cîșlița-Prut.

amount of 5 ind./m² and 750 g/m², respectively. The highest density and biomass by grabs sampling were recorded at Lake Beleu, 40 ind./m² and 720 g/m², respectively. The highest mean density and biomass were detected at the sampling point of Cîșlița-Prut, 1.92±1.24 ind./m² and 214.20 ±70.96 g/m², respectively (Table 1).

Considering the first registered live specimen of *S. woodiana* in Lake Beleu (MUNJIU & SHUBERNETSKI 2008) in 2008 and the found empty shells in 2015 and living specimens in 2016 at the Leova sampling station, as well as knowing the distance of 100 km from Lake Beleu to Leova, it was estimated that the rate of spreading of this invasive alien species on the territory of R. Moldova is approximately 15 km per year. However, additional field data are required to prove this estimation.

Shell size variation

According to the results obtained, the length of the shells ranged from 3.60 cm to 18.70 for the living specimens and up to 24.00 cm for the largest empty shell. The most numerous groups were IInd and IIIrd classes (of small and medium size), consisting of 12 and 24 specimens, respectively. The IVth class had

Table 1. Locations of *Sinanodonta woodiana* with mean density and biomass in the Prut River basin during 2008–2017 on the territory of the Republic of Moldova.

Location	Latitude/ Longitude	Date of the first record	Number of specimens	Number of samples	Density Mean ± std ind./m ²	Biomass Mean±std g/m ²
Leova	46°28'13"/ 28°14'44"	23.03.2016	1	64	–	–
Goteşti	46°10'37"/ 28°8'39"	30.05.2014	1	31	–	–
Cahul	45°55'16"/ 28°7'33"	10.08.2011	16	82	1.55 ± 1.30	104.45 ± 41.51
Cişliţa-Prut	45°32'57"/ 28°9'60"	5.11.2010	52	82	1.92 ± 1.24	214.20 ± 70.96
Lake Manta	45°49'52"/ 28°10'12"	2008	25	15	0.74 ± 0.58	101.83 ± 71.94
Lake Beleu	45°35'9"/ 28°8'53"	2008	48	22	0.83 ± 0.50	124.53 ± 88.25

Table 2. Morphometric measurements of the shells (cm) of *Sinanodonta woodiana* collected from the different sampling stations of the Prut River basin during 2008–2017 on the territory of the Republic of Moldova. N – number of specimens measured; L – total length; H – wing height (the line of the most distant points); W – width; Min – minimal value; Max – maximal value; Mean – mean value; and SD – standard deviation.

Groups	N=43	L (cm)	H (cm)	W (cm)	Ratio L/H	Ratio L/W
Class I Min – Max	2	3.60–4.60	3.00–3.60	1.50–1.60	1.20–1.28	2.40–2.88
Class II Mean±SD	12	8.02±1.45	5.44±0.93	3.07±0.65	1.49±0.24	2.65±0.26
Min – Max		5.70–9.80	4.20–6.90	1.80–3.80	1.23–1.96	2.22–3.17
Class III Mean±SD	24	12.08±1.37	7.99±0.96	4.49±0.68	1.52±0.09	2.72±0.33
Min – Max		10.40–14.60	7.00–10.50	3.10–6.40	1.33–1.66	2.08–3.55
Class IV Mean±SD	5	17.68±1.23	11.10±1.13	6.94±1.67	1.60±0.09	2.63±0.47
Min – Max		16.60–19.30	9.60–12.20	5.20–9.20	1.50–1.73	2.03–3.19

five specimens, while the 1st class was represented only by two specimens (Table 2). The largest empty shell we found, which also is the largest shell ever found in the R. Moldova, had a length of 24.00 cm, height of 16.20 cm, and a width of 9.20 cm. The largest living specimen recorded had a weight of 610 g and shell dimensions of 18.70 x 12.20 x 9.20 cm, while the smallest one was only 14 g, and had dimensions of 3.60 x 3.00 x 1.50 cm, respectively; both specimens were found in Lake Beleu.

The analysis of the morphometric measurements showed that the wing height (H) fluctuated between 3.00 cm and 16.20 cm. The ratio of the total length and wing height L/H reflects the more rounded or more elongated shape of the shells. In our study this ratio varied between 1.20 and 1.96, while the L/W ratio varied from 2.03 to 3.55 (Table 2).

All young specimens of *S. woodiana* had rounded shells (Fig. 2a), while the adult specimens

had both rounded and elongated shells, with prevalence of the latter (Fig. 2b). Despite of the shell shape or length classes, the specific umbo sculpture was kept in all specimens. The young specimens with flattened, fragile shells also had a specific clear umbo sculpture (Fig 2c).

Two specimens of different phenotypic form were found in Lake Beleu. They had very strong shells, in contrast with the fragile shells of the majority of *S. woodiana*.

Two mature individuals with glochidia in gills (Fig. 3a) were recorded in Lake Beleu on 27 April 2011, including the smallest mature specimen with a length of 5.5 cm and a weight of 18 g. Later, in May 2014, a mature specimen (length of 13.5 cm, weight of 228 g) with glochidia in gills was found also at the Goteşti sampling station.

We observed a high capacity of *S. woodiana* to regenerate its damaged shells. The species not only

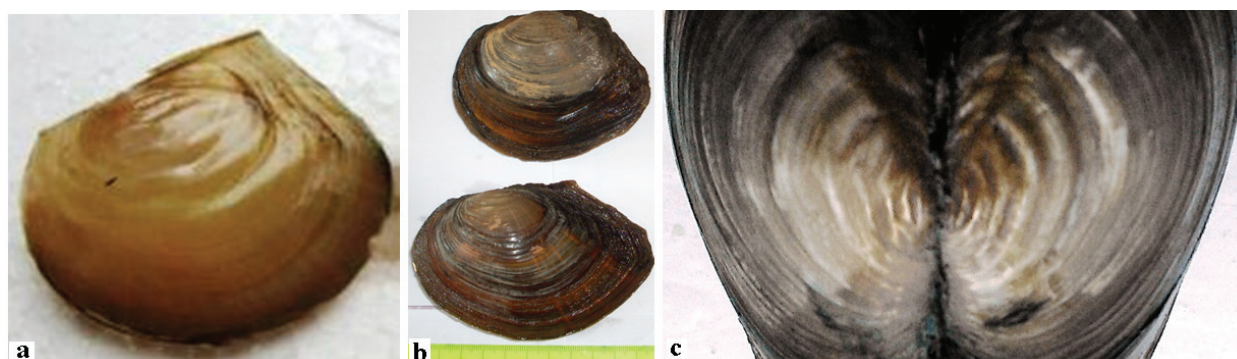


Fig. 2. Morphological characteristics of *Sinanodonta woodiana*: 2a) the smallest specimen recorded (L=3.60 cm); 2b) elongated and rounded shell forms of adult specimens; 2c) umbo sculpture with concentric wavelike folds (Photos: Oxana Munjiu).



Fig. 3. *Sinanodonta woodiana* findings in the Prut River basin: 3a) a specimen with glochidia in gills; 3b) normal shell and regenerated damaged shell; 3c) shells with teratogenic features from Lake Beleu (Photos: Oxana Munjiu).

recovered its shells but also increased its weight with approximately 50% or up to 25.57 g in healthy shells and 59.12 g in damaged shells (Fig. 3b). More than 40% of the *S. woodiana* specimens collected near the shore in Lake Beleu had teratogenic features (Fig. 3c).

Discussion

Invasive species have many competitive advantages that contribute to their establishment and active spread in a new region (ALIMOV & BOGUTSKAYA 2004). Some of the advantages of *S. woodiana* are their phenotypic plasticity and regeneration capacity. The large phenotypic variability of *S. woodiana*, such as rounded and elongated shells and shells with teratogenic features collected in the Prut River basin, reflects the capacity of this mollusc to adapt to various environmental conditions in its habitats. Some researchers report that river specimens have more rounded shells than lake specimens (GUARNERI et al. 2014). However, in our study such relation was not observed, probably due to the fact that Lake Manta and Lake Beleu have areas with slow-flowing current, with conditions similar to the Prut River. Furthermore, our results showed that over 40% of the *S. woodiana* specimens collected near the lake shore

in Lake Beleu had teratogenic features. One of the reasons may be that local people use the lake shore as a pasture for cows. The animals are damaging the shells of *S. woodiana* but the species can recover the damaged shell and survive. The high regeneration capacity of *S. woodiana* in its native area in China is used for economic purposes to produce pearls (RAHAYU et al. 2013). In areas as the lower sector of the Prut River, *S. woodiana* may threaten the native population of bivalves where there is a big native molluscan diversity (MUNJIU et al. 2016) without a high regeneration capacity.

Another competitive advantages of *S. woodiana* are its capacity to reproduce 2–3 times per year, while compared to the native species which reproduce only once per year, and also to reach its sexual maturity already in the first year of life (DUDGEON & MORTON 1983). The early maturation or reproducing females with small sizes was observed in the smallest mature specimens with length of 5.5 cm from Lake Beleu, and it can be comparable with the growth rate in its native region (DUDGEON & MORTON 1983) and even in the European cooling water (LABECKA & DOMAGALA 2018). However, it is important to mention that Lake Beleu is a natural lake without any influence of a hydropower station.

Sinanodonta woodiana reaches large density and biomass, being more competitive as resources, than the native species. In a previous study (2012–2013), the invasive mussels *Corbicula fluminea* (Muller, 1774) and *S. woodiana* have constituted a significant proportion of macrobenthos in terms of density and biomass at the Cîşliţa-Prut station (MUNJIU et al. 2014). Thus, *C. fluminea* has formed about 40% (200 ind./m²) of the total density of molluscs, while *S. woodiana* has formed more than 70% (260 g/m²) of the total biomass of malacofauna (MUNJIU et al. 2014). In the Cris River in Romania, *S. woodiana* represents 75% of the unionid biomass (POPA & POPA 2006). The density and biomass of *S. woodiana* at the adjacent territory of the Ukrainian Danube Delta are 0.5–5 ind./m² and 61–910 g/m², respectively (PAVLYUCHENKO et al. 2007), and 20–30 ind./m² (SON 2007). These results are similar to the outcomes of our study at the territory of the R. Moldova: density of 1–40 ind./m² and biomass of 130–750 g/m².

Along with the competitive advantages mentioned above, it shall be also taken into consideration that *S. woodiana* is more tolerant to pollution than the native Unionidae (SÎRBU et al. 2005), as well as to a wide range of environmental factors, such as eutrophication or low trophicity, and temperature disturbance (CORSI et al. 2007, BERAN 2008, DEMAYO et al. 2012, BENKO-KISS et al. 2013). The ecosystem of the Low Prut River is affected by the aridisation; the average annual temperature of the water has increased up to 11.1°C, compared to 10.2°C during the period 1989–1999 (BEJAN et al. 2016). Such climate conditions could be favourable for the spread of *S. woodiana*, which prefers the temperature range of 10–30°C (KRASZEWSKI & ZDANOWSKI 2007). In Poland, the maximum density and biomass of *S. woodiana* population has reached 60 ind./m² and 25 kg/m², respectively, in the heated lakes and channels of the Konin Lake system (KRASZEWSKI & ZDANOWSKI 2007).

Based on the analysis of data on the spread of *S. woodiana*, we assume two possible pathways of introduction of this species in the R. Moldova. The first one is an introduction of glochidia with fingerlings of herbivorous fish imported directly from the native region in the 1960–1970s. About one hundred thousand fingerlings of herbivorous fish were imported in the R. Moldova from China in 1961, and from the Amur River basin in 1972–1974. These fingerlings were released in the Dniester and Prut river basins, including Lake Manta and Costeşti-Stînca Reservoir, with the aim to improve fisheries productivity and regulate the aquatic vegetation

(LOBCHENKO 1999). The second possible pathway is an introduction of glochidia of *S. woodiana* with fish hosts from the Danube Delta originating from the Romanian and/or Ukrainian territory. This invasive mussel was recorded in 1998 in Romania (POPA & POPA 2006) and one year later in Ukraine (YURISHINETS & KORNIUSHIN 2001).

Although the herbivorous fish, possible hosts of glochidia, were introduced in the past from the Eastern Asia to the Dniester and Prut river basins (LOBCHENKO 1999), our results show that a stable population of *S. woodiana* has been formed only in the lower Prut River basin. This is most likely due to the specific hydrological regime of the Prut River basin, namely the water intrusion from the Danube River, and the hydromorphological conditions as the shallow lakes with silty-clay substrate and water temperatures up to 32°C, which are suitable habitats of *S. woodiana*.

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References

- ABAKUMOV V. A. 1983. Guidelines on the methods of hydrobiological analysis of surface waters and bottom sediments. Leningrad: Gidrometeoizdat, 239 p. (In Russian).
- AFANASJEV S. A., ZDANOWSKI B. & KRASZEWSKI A. 2001. Growth and population structure of the mussel *Anodonta woodiana* (Lea, 1834) (Bivalvia, Unionidae) in the heated Konin lakes system. Archives of Polish Fisheries 9 (1): 123–131.
- ALIMOV A. F. & BOGUTSKAYA N. G. (Eds.) 2004. Biological invasions in aquatic and terrestrial ecosystems. Moscow – Saint Petersburg: KMK Scientific Press Ltd., 436 p. (In Russian).
- AQEM CONSORTIUM 2002. Manual for the application of the AQEM system. A comprehensive method to assess European streams using benthic macroinvertebrates, developed for the purpose of the Water Framework Directive. Version 1.0, February 2002, 198 p. www.aqem.de
- BASTIN K., MANDORLO G. & CHARLES L. 2014. Discovery of the Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) (Mollusca, Bivalvia, Unionidae) in the Sèvre Nantaise river (Poitou-Charentes, France). MalaCo – Journal électronique de la malacologie continentale Française 10: 2–4.
- BEJAN I., BOBOC N., BACAL P., JELEAPOV A. & ANGHELUŢA V. 2016. The Prut River basin management plan. Cycle I,

- 2017–2022. Chişinău: Institute of Ecology and Geography of the Academy of Sciences of Moldova, 42 p.
- BENKO-KISS A., FERINCZ A., KOVÁTS N. & PAULOVITS G. 2013. Spread and distribution pattern of *Sinanodonta woodiana* in Lake Balaton. *Knowledge & Management of Aquatic Ecosystems* 408, 09: 1–7.
- BERAN L. 1997. First record of *Sinanodonta woodiana* (Mollusca: Bivalvia) in the Czech Republic. *Acta Societatis Zoologicae Bohemoslovenicae* 61: 1–2.
- BERAN L. 2008. Expansion of *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) in the Czech Republic. *Aquatic Invasions* 3 (1): 91–94.
- BESPALAYA Y. V., BOLOTOV I. N., AKSENOVA O. V., GOFAROV M. Y., KONDAKOV A. V., VIKHREV I. V. & VINARSKI M. V. 2017. DNA barcoding reveals invasion of two cryptic *Sinanodonta* mussel species (Bivalvia: Unionidae) into the largest Siberian river. *Limnologia* 69: 94–102.
- BOGAN A. E., BOWERS-ALTMAN J. & RALEY M. E. 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 V. V. & SAYENKO E. M. 2002. The history of investigation of Anodontinae and Pseudanodontinae in the Russian Far East. *The Bulletin of the Russian Far East Malacological Society* 6: 102–114. (In Russian).
- BÖHME M. 1998. Ein neuer Fundort der Chinesischen Teichmuschel (*Sinanodonta woodiana*) in Mitteleuropa. *Heldia* 2 (5/6): 166.
- CORSI I., PASTORE A. M., LODDE A., PALMERINI E., CASTAGNOLO L. & FOCARDI S. 2007. Potential role of cholinesterases in the invasive capacity of the freshwater bivalve, *Anodonta woodiana* (Bivalvia: Unionacea): A comparative study with the indigenous species of the genus *Anodonta* sp. *Comparative Biochemistry and Physiology. Part C: Toxicology & Pharmacology* 145 (3): 413–419.
- DEMAYO C. G., CABACABA K. & TORRES M. 2012. Shell shapes of the Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) from Lawis stream in Iligan City and Lake Lanao in Mindanao, Philippines. *Advances in Environmental Biology* 6 (4) 1468–1473.
- 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* 201 (2): 161–183.
- GALIL B. S., NEHRING S. & PANOV V. 2008. Waterways as invasion highways – impact of climate change and globalization. In: NENTWIG W. (Ed.) *Biological Invasions. Ecological Studies (Analysis and Synthesis)*, Vol. 193. Berlin, Heidelberg: Springer, pp. 59–74.
- GIRARDI H. & LEDOUX J. C. 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 M. L. 2005. Kommentierte Artenliste der Süßwassermollusken Deutschlands. *Malakologische Abhandlungen* 23: 3–23.
- GUARNERI I., POPA O. P., GOLA L., KAMBURSKA L., LAUCERI R., LOPES-LIMA M., POPA L. O. & RICCARDI N. 2014. A morphometric and genetic comparison of *Sinanodonta woodiana* (Lea, 1834) populations: does shape really matter? *Aquatic Invasions* 9 (2): 183–194.
- HUBENOV Z. 2006. *Anodonta* (*Sinanodonta*) *woodiana* (Lea, 1834) (Mollusca: Bivalvia: Unionidae) – a new invasive species for the Bulgarian malacofauna. *Acta Zoologica Bulgarica* 58 (1): 35–40.
- KISS A. 1995. The propagation, growth and biomass of the Chinese huge mussel *Anodonta woodiana woodiana* Lea, 1834 (Bivalvia: Unionacea) in Hungary. University of Agricultural Science in Gödöllő, Tropical and Subtropical Department. Private Editions, Second Edition, 33 p.
- KOŠEL V. 1995. The first record of *Anodonta woodiana* (Mollusca, Bivalvia) in Slovakia. *Acta Zoologica Universitatis Comenianae* 39: 3–7.
- KRASZEWSKI A. & ZDANOWSKI B. 2007. *Sinanodonta woodiana* (Lea, 1834) (Mollusca) - a new mussel species in Poland: occurrence and habitat preferences in a heated lake system. *Polish Journal of Ecology* 55 (2): 337–356.
- LABECKA A. M. & DOMAGALA J. 2018. Continuous reproduction of *Sinanodonta woodiana* (Lea, 1824) females: an invasive mussel species in a female-biased population. *Hydrobiologia* 810: 57–76.
- LAJTNER J. & CRNČAN P. 2011. Distribution of the invasive bivalve *Sinanodonta woodiana* (Lea, 1834) in Croatia. *Aquatic Invasions* 6 (1): 119–124.
- LOBCHENKO V. 1999. Introduction, acclimatization and problems of biodiversity of Dniester River. In: Proceedings of the International Conference 'Biodiversity Conservation of the Dniester River Basin', October 7–9, 1999. Chisinau: BIOTICA Ecological Society, pp. 130–131. (in Russian)
- MANGANELLI G., BODON M., FAVILLI L., CASTAGNOLO L. & GIUSTI F. 1998. Checklist of the species of the fauna of Italy, terrestrial and freshwater molluscs. Corrections and additions 1. [Checklist delle specie della fauna d'Italia, molluschi terrestri e d'acqua dolce. Errata and addenda 1.] *Bollettino Malacologico* 33: 151–156. (In Italian).
- MUNJIU O. & SHUBERNETSKI I. 2008. First record of *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) in Moldova. *Aquatic Invasions* 3 (4): 441–442.
- MUNJIU O. & SHUBERNETSKI I. 2010. First record of Asian clam *Corbicula fluminea* (Müller, 1774) in the Republic of Moldova. *Aquatic Invasions* 5, Supplement 1: 67–70.
- MUNJIU O., TODERAS I., ZUBCOV E., BILETCHI L. & SHUBERNETSKI I. 2014. Composition and distribution of benthic macroinvertebrates in the Prut River (2012–2013). *Analele Ştiinţifice ale Universităţii „Alexandru Ioan Cuza” din Iaşi, s. Biologie animală*, 60: 27–34.
- MUNJIU O., SHUBERNETSKI I. & RAILEAN N. 2016. Macroinvertebrates of the Lake Belevu. In: TODERAS I. (Ed.) *Sustainable use, protection of animal world and forest management in the context of climate change. The Materials of International Conference of Zoologists*. Chisinau: Elan Poligraf, pp. 215–217.
- PAUNOVIC M., CSÁNYI B., SIMIC V., STOJANOVIC B. & CAKIC P. 2006. Distribution of *Anodonta* (*Sinanodonta*) *woodiana* (Lea, 1834) in inland waters of Serbia. *Aquatic Invasions* 1 (3): 154–160.
- PAVLYUCHENKO O. V., MELNYCHENKO R. K. & GARBAR V. A. 2007. Shell morphology, distribution and some peculiarities of ecology of *Sinanodonta woodiana* (Mollusca, Bivalvia, Unionidae) in the reservoirs of Danube Delta. *Vestnik Zoologii* 41 (3): 241–250.
- PETRÓ E. 1984. Occurrence of *Anodonta woodiana woodiana* (Lea, 1834) in Hungary. *Állatani Közlemények* 71: 189–191.

- POPA O. & POPA L. O. 2006. *Sinanodonta woodiana* (Lea, 1834), *Corbicula fluminea* (O. F. Muller, 1774), *Dreissena bugensis* (Andrusov, 1897) (Mollusca: Bivalvia): alien invasive species in Romanian fauna. *Travaux du Museum National d'Histoire Naturelle* 49: 7–12.
- POU-ROVIRA Q., ARAUJO R., BOIX D., CLAVERO M., FEO C., ORDEIX M. & ZAMORA L. 2009. Presence of the alien Chinese pond mussel *Anodonta woodiana* (Lea, 1834) (Bivalvia, Unionidae) in the Iberian Peninsula. *Graellsia* 65 (1): 67–70.
- RAHAYU S. Y. S., SOLIHIN D. D., MANALU W. & AFFANDI R. 2013. Nucleus pearl coating process of freshwater mussel *Anodonta woodiana* (Unionidae). *HAYATI Journal of Biosciences* 20 (1): 24–30.
- REISCHÜTZ P. L. 1998. Vorschlag für deutsche Namen der in Österreich nachgewiesenen Schnecken- und Muschelarten. *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft* 6: 31–44.
- SÁRKÁNY-KISS A. 1986. *Anodonta woodiana* (Lea, 1834) a new species in Romania (Bivalvia, Unionacea). *Travaux du Museum National d'Histoire Naturelle "Grigore Antipa"* 28: 15–17.
- SÎRBU I., SÁRKÁNY-KISS A., SÎRBU M. & BENEDEK A. M. 2005. The Unionidae from Transylvania and neighborhood regions. *Heldia* 6: 183–192.
- SON M. O. 2007. Invasive molluscs in fresh and brackish waters of the Northern Black Sea Region. Odessa (UA): Druk. 131 p. (In Russian).
- TOMOVIĆ J., ZORIĆ K., SIMIĆ V., KOSTIĆ M., KLJAJIĆ Z., LAJTNER J. & PAUNOVIĆ M. 2013. The first record of the Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) in Montenegro. *Archives of Biological Sciences* 65 (4): 1525–1533.
- TSALOLIHIN S. Y. 2004. Keys to the freshwater invertebrates of Russia and adjacent countries. Vol. 6, 528 p. (In Russian)
- von PROSCHWITZ T. 2006. Faunistical news from the Göteborg Natural History Museum 2005 – snails, slugs and mussels – *Bithynia transsilvanica* (E. A. Bielz) – re-found in Sweden – *Sinanodonta woodiana* (Lea) – for Sweden new fresh water mussel. *Göteborg Naturhistoriska Museum Årstryck*, pp. 39–70.
- WATERS G. T. 1997. A synthesis and review of the expanding range of the Asian freshwater mussel *Anodonta woodiana* (Bivalvia: Unionidae). *Veliger* 40: 152–156.
- YURISHINETS V. I. & KORNIUSHIN A. V. 2001. The new species in the fauna of Ukraine *Sinanodonta woodiana* (Bivalvia: Unionidae), its diagnostics and possible ways of introduction. *Vestnik Zoologii* 35 (1): 79–84. (In Russian).
- ZATRAVKIN M. N. & BOGATOV V. V. 1987. Large bivalve freshwater and brackish water mollusks of the Far East of the U.S.S.R. Vladivostok: AN SSSR. 154 p. (in Russian)
- ZHADIN V. I. 1952. Mollusca of fresh and brackish waters of the USSR. Vol. 43. Moscow – Leningrad: AN SSSR, 346 p. (In Russian).