First records of *Corbicula fluminea* (O.F. Müller, 1774) (Mollusca: Bivalvia) from the Lower Don

LYUBOV A. ZHIVOGLYADOVA¹*, NIKOLAI K. REVKOV²

¹ Azov Research Institute of Fisheries, 344002, Rostov-on-Don, Russia
² A.O. Kovalevsky Institute of Marine Biological Research of RAS, 299011, 2 Nakhimov ave., Sevastopol, Russia.

*Corresponding author: l.zhivoglyadova@mail.ru

Received 10 March 2018  │  Accepted by V. Pešić: 2 April 2018  │  Published online 9 April 2018.

Abstract

The bivalve *Corbicula fluminea* (O. F. Müller, 1774) were considered as new alien species for the first time registered in the River Don. One alive specimen was found in the Teplyj Kanal (Warm Channel) near the Novocherkassk hydroelectric power station, and two specimens were observed in the Don main riverbed near the mouth of the Teplyj Kanal. We have considered extended expansion of this species after its first finding in fresh waters of France, Portugal and Germany throughout the European continent towards the area where it was found in the Lower Don.

Key words: alien species, biological invasion, Bivalvia, *Corbicula fluminea*, Lower Don.

Introduction

*Corbicula fluminea* (OF Müller, 1774) is the Eastern Asian clam, with a typical habitat in Guangzhou (China) [Araujo et al., 1993] and a native areal in the fresh waters of southeast Asia, including Russia, Thailand, Philippines, China, Taiwan, Korea and Japan, Australia and Africa [Zhadin, 1952; Morton, 1986; DAISIE, 2009]. In countries of Southeast Asia, it is an object of aquaculture; its annual output in China amounts to more than 12 million tons per year [Chen et al., 2013]. Mollusk meat is valued for nutritional properties, and is used in pharmacology [Chijimatsu et al., 2013; Liao et al., 2013]. In modern history, outside the natural habitats, it was first discovered in the river system of North America in 1924 (dead valves) [Counts, 1981] and in 1938 (alive mollusks) [Burch, 1944]. This species is believed to be accidentally brought to Europe with ballast water discharged by ships from North America [Kinzelbach, 1991]. Regarding the time of its first detection, there are three distanced regions of primary introduction of the Asian clam into the fresh waters of the European continent, in particular, such rivers as the Dordogne (south of France, 1980), the Tagus (Portugal, 1980) [Mouthon, 1981] and the Weser (Germany, 1983) [Kinzelbach, 1991]. The results of more than 25 year-old expansion have served as a basis for the inclusion of *C. fluminea* in the group of 100 most dangerous invasive species in Europe [DAISIE, 2009].
Material and Methods

The results are based on the materials of benthic survey performed in January 2017 in the Teplyj Kanal (Warm Channel) of the Novocherkasskaya hydroelectric power station and in the river Don near the mouth of the Warm Channel along the grid of stations (fig. 1). Macrozoobenthos samples were taken in two replicates by Petersen grab-corer with a capture area of 0.025 m². Fixation of the material was carried out with 70% ethanol supplemented with 4% formalin.

During the further treatment of benthic samples, there were found three alive specimens and several empty mollusk shells of the genus *Corbicula*, earlier not registered in the fresh waters of the European part of Russia [Key…, 2004]. The length, height and width of shells were measured (large shells with a callipers and small ones under the binocular) to within 0.1 mm. The wet weight of mollusks without mantle liquid was determined to accuracy of 0.001 g by the electronic balance of Shimadzu AX-120 after preliminary drying on filter paper.

Mollusks were found in the Warm Channel at a depth of 1.2–2.0 m where the bottom substrate was represented by silty crushed stone, in the Don riverbed the bottom was covered by silted shells with sand. According to the data of our Institute’s Laboratory of Hydrology, the total mineralization of water at the sampling points was 290–310 mg/dm³, the pH value was 7.7–7.9, the bottom water temperature at the stations in the Warm Channel was 14.6–15.4 °C; near the right bank of the Don where the currents were mixing the temperature fluctuated within 5.2 to 8.6 °C, while upriver it was 1.9–3.5 °C.

Results of the study

The Bivalves found in the basin of the river Don were identified by us as *Corbicula fluminea* (O. F. Müller, 1774). According to [Zhadin, 1952; Korniushin, 2007; Son, 2007; Hubenov et al., 2013; Kamburska et al., 2013] *C. fluminea* has an oval triangular, asymmetric, thick-walled shell with coarse radial ridges (~ 10 well defined ridges per 10 mm). The umbo is slightly swollen, prozogial, slightly shifted toward the anterior margin (fig. 2). Each valve has 3 cardinal teeth. Lateral teeth are long, lamellar, with transverse strokes, reaching the middle of the height of the shell. Muscle scars are almost equal. Mantle line is without sinus. The ratio of shell length to height is 1.0–1.2. The inner surface of the shell is whitish. Periostracum is
The largest found specimen had the length of its shell equal to 25.5 mm, with height and width amounted, respectively, to 24.6 mm and 17.0 mm, the wet weight of the mollusk was 6.453 g. The dimension and weight characteristics of the second mollusk were 8.1, 7.2, 4.9 mm and 0.141 g, respectively, and of the third one they constituted 1.9, 1.5, 1.1 mm and 0.011 g. The frequency of occurrence of the *Corbicula* in the investigated area was 27%. The maximum abundance and biomass of mollusks reached to 20 ind./m² and 129.1 g/m², the corresponding average values were 6 ind./m² and 12.0 g/m². No *C. fluminea* were found along the stretch from the town Semikarakorsk to the mouth of the river including the delta, when a large-scale (60 stations) survey of the Don River was conducted in 2016.

**Figure 2.** *Corbicula fluminea* shell from the lower reaches of the Don River.

**Discussion**

The success of the global expansion of *C. fluminea* on five continents (Eurasia, North and South America, Africa, Australia) can be caused with physiological tolerance and biological features of the species, namely: their high-rated growth, early-age maturation, high fertility, various types of reproduction, availability of planktonic larva, the ability to form high density settlements [McMahon, 2002; Sousa et al., 2008a]. Since their appearance on the European continent in 1980, the process of *C. fluminea* colonization included a series of successive stages of overcoming the isolation space between the basins of large and small rivers and the dispersion of mollusk settlements within already occupied freshwater systems [Bij de Vaate, Greijdanus-Klaas, 1990; Bij de Vaate, 1991; Grabow, Martens, 1995; Tittizer, Taxacher, 1997; Csánya 1998–1999; Brauckmann et al., 1999; Fischer, Schultz, 1999; Howlett, Baker, 1999; Bij de Vaate, Hulea, 2000; Hubenov, 2001; Vincent, Brancotte, 2002; Vrabec et al., 2003; Paunović, 2004; Lyashenko et al., 2005; Beran, 2006; Son, 2007; Alexandrov et al., 2007; Cianfanelli et al., 2007; Paunović et al., 2007; Schmidlin, Baur 2007; Son, 2007; Willing, 2007; Elliott, zu Ermgassen, 2008; Pérez-Quintero, 2008; Morais et al., 2009; Popa, Murariu, 2009; Lois, 2010; Marescaux et al., 2010; Munju, Shubernetski, 2010; Lyashenko, Makovskii, 2011; Bódis et al., 2011, 2012; Lucy et al., 2012; Schmidlin et al., 2012; Kamburska et al., 2013 etc]. As regards the beginning of the colonization and the coverage of the territory, there can be distinguished three main stages of *C. fluminea* distribution across of the European continent. The first stage can be called as continental European one, covering the river systems of most European countries and originating from the first finding of the mollusk in 1980–1983 [Mouthon, 1981; Kinzelbach, 1991]; the second one is the Danube stage, associated with the invasion of mollusks into the extensive basin of the Danube River since the mid-1990s. [Tittizer, Taxacher, 1997; Alexandrov et al., 2007]. The third period is the British one, when colonization began later, namely, in 1998 [Howlett, Baker, 1999; Sweeney, 2009; Caffrey et al., 2011]. Proceeding from the well-known assumption of the penetration of *C. fluminea* into the European river systems with the ballast waters of ships and, accordingly, taking into account the first finds of mollusks in the lower reaches of the navigable rivers (the Tagus in Portugal, the Dordogne in France, the Rhine in the
Netherlands, the Weser in Germany), we can argue that the initial vector of the species distribution throughout the European continent was directed away from the Atlantic coast deep into the continent with subsequent dispersion within the river systems.

The digging of the Main-Danube Canal in 1992 afforded new opportunities for the species spreading out eastwards along the Danube with further access to the Northern Black Sea region. However, it should be noted that the first discovery of *Corbicula fluminea* in the Danube river system occurred in the Ukrainian sector of the delta in 1995 [Alexandrov et al., 2007], and only in 1997 the mollusk was found in the upper reaches and tributaries in Germany [Vincent, Brancotte, 2002]. This fact allowed to suggest the possibility of independent penetration of *Corbicula* into the Danube river system both through the Main-Danube canal and the ports in the lower Danube [Son, 2007]. The spatial expansion rate with which *Corbicula fluminea* spread in the river systems of Europe evidences to support the latter assumption.

The upstream settling speed of mollusks depends on the navigation intensity and is largely determined by human activity (sport fishing, aquaculture, aquaristics, transport of sand and gravel, catch for food, etc.) [Lucy et al., 2012]. Seven years were needed to *Corbicula* to spread over the Rhine, one of the largest navigable rivers of Western Europe; these molluscs were found in the estuary in 1988 [Bij de Vaate, Greijdanus-Klaas, 1990], and in 1995 [Schmidlin, Baur, 2007] this species was observed in the upper reaches of the river near Basel, Switzerland. The average migration rate of the mollusks is about 63 km/year and in some areas the maximal rate was estimated up to 276 km/year [Hubenov et al., 2013].

On the contrary, along the non-navigable sections of the Elbe and the tributaries of the Danube (the Iskar, the Vit, the Yantra and the Osam rivers), the average and maximum rates of *Corbicula* settling speed were much lower and not exceeded 2.4–8 km/year [Beran, 2006; Hubenov et al., 2013]. If *Corbicula* had occupied upstream biotopes of the Danube with the similar settling speed as in the Rhine, it would have taken them at least 10 years since their first detection in the river estuary in 1995.

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The European vector of *Corbicula fluminea* expansion that we are considering lies within the framework of the already known scheme (i.e. its European branch) of exotic species penetration into the Northern Black Sea region [Son, 2007]. According to this scheme, the main way to overcome the distance from the Danube Delta to the site of the first finding of the species in the Lower Don passed throughout the Northern Black Sea Region; undoubtedly, it was facilitated by the navigation in the lower reaches of the Dnieper. However, the vector (and rate) of further possible spread of *Corbicula fluminea* depend from orographic boundaries and drying small meandering out local rivers of the Northern Azov Sea Region. The overcoming of that barrier actually had taken more than 20 years: from the moment of the species appearance in the Lower Danube in 1995 up to its finding in the Lower Don basin in 2017.

No one can deny the possibility of *Corbicula fluminea* appearance in the lower Don River system through the Northern Black Sea along the “corridor of invasion” described above. However, from our point of view the most probable is another way, i.e. the southern (marine) migration path of the mollusk. By analogy with the initial intrusion into the European river system, we assume that the appearance of *Corbicula fluminea* in the lower reaches of the Don is mainly associated with navigation activity. Transportation of the invasive material to the river system of the lower Don could occur with ships’ ballast waters from the river system of the Danube through the Black and Azov Seas.

Since the *Corbicula fluminea* is characterized by the sufficiently wide range of temperature tolerance (2 to 34 °C) [McMahon, 1983], one of the limiting factors of its further settlement in the river system of the Don is undoubtedly the low winter temperatures leading to the formation of a stable ice cover: up to 5 days in mild and up to 138 days in the most severe winters [Delta ..., 2009]. In the lower reaches of the Don, during the coldest month of the year (January), the water temperature often falls below 2°C [Project 365 Celsius, our data] that goes beyond the ecological range of thermal tolerance of the species. At the same time, at the Novocherkasskaya hydroelectric power station its Warm Channel entering the main bed of the lower Don is nonfreezing, and, according to our monitoring data obtained in 2017, its temperature in winter was 14°C higher than in the adjacent river arms. The thermal refugia of heated-water discharge plumes from power plants gives an opportunity to survive *Corbicula* under relatively severe winters. Such areas where *Corbicula fluminea* can survive through a period of unfavorable conditions are known, for example, nearby warm water discharging zone of power plants on the rivers St. Clair [French et al., 1996] and lower Connecticut River [Morgan et al., 1995; 2004] in the north and northeast of the USA.

The appearance of *Corbicula fluminea* in the lower reaches of the Don evidence about the new stage in the further expansion of this alien species in the Don and Volga river systems that are connected through the Volga-Danube Canal. Taking into account a certain probability that *Corbicula* are able to live in brackish-water
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basins with salinity up to 5–14 ‰ [Morton, Tong, 1985; Coan et al., 2000; Alexandrov et al., 2007; Son, 2007; Sousa et al., 2008b], there is possibility of further colonization by this mollusk also the most desalinated northeastern part of the Azov Sea.

Acknowledgements
The authors are grateful to the staff of the Department of Oceanography and Environmental Research of "AzNIIRKH" for providing materials on hydrological and hydrochemical measurements, as well as personally to O. V. Strelchenko for the hydrobiological sampling during the field surveys.

References
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