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New records of Conrad's false mussel *Mytilopsis leucophaeata* (Conrad, 1831) in the Vistula Delta

by

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Abstract

Mytilopsis leucophaeata (Conrad, 1831) is native to the western Atlantic coast of North America. It has been reported in many regions outside its home range, including the Gulf of Gdańsk (the southern Baltic Sea). Although the conditions in the area seem to be favorable for the species, there have been no reports about its presence elsewhere in the gulf. However, the data probably did not reflect its actual distribution in the region, as the species can be easily misidentified for other bivalves living in the area, and it prefers hard substrates, which have not been studied as extensively as soft substrates. Our study was aimed at determining the actual distribution of *M. leucophaeata* in the Gulf of Gdańsk, the Vistula Delta and the Vistula Lagoon. The results showed that the species was not widely distributed in the Gulf of Gdańsk and was absent in the Vistula Lagoon. The only new records come from the Vistula Delta where the abundance of *M. leucophaeata* was up to 69 ind. m^{-2}, i.e. significantly higher than in the Gulf of Gdańsk. Individuals found in the Vistula Delta were also significantly larger, with the length of shells reaching 22-23 mm, which is considered to be the maximum for the species.

Key words: *Mytilopsis leucophaeata*, Conrad's false mussel, alien species, Baltic Sea, Vistula River, Vistula Lagoon, dreissenid bivalve

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Introduction

Conrad's false mussel (also known as dark false mussel) *Mytilopsis leucophaeata* (Conrad, 1831) is a dreissenid bivalve native to the Gulf of Mexico and the western Atlantic Coast of North America (the North American east coast), where it lives mainly in estuaries and lagoons (Garcia-Cubas 1981; Marelli & Gray 1983; Garcia-Cubas et al. 1990; Smith & Boss 1996). Similarly to some other dreissenids, such as the zebra mussel *Dreissena polymorpha* (Pallas, 1771) and the quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1897), *M. leucophaeata* has invaded many regions outside its home range, including European waters. The earliest records of the species in Europe come from South Wales around 1800-1830 (Oliver 2015) and from the port of Antwerp (Belgium) in 1835 (Verween et al. 2006). Currently, *M. leucophaeata* occurs in estuaries along the Atlantic and the North Sea coast from Spain to Germany and in Great Britain, as well as in Mediterranean France, the Black Sea and the Caspian Sea (Oliver et al. 1998; Verween et al. 2005; Zhulidov et al. 2016). It is generally believed that the spread of the species is caused by shipping and its wide tolerance to salinity and temperature (Nehring 2002; Laine et al. 2006; Kerckhof et al. 2007; van der Gaag et al. 2016). In the Baltic Sea, the species was recorded for the first time in the Kiel Canal, but the population has probably died out (Boettger 1933; Schlesch 1937 after Laine et al. 2006). More recently, another population was found in the Warnow river estuary, northern Germany (Darr & Zettler 2000). In 2004, *M. leucophaeata* was recorded in the Gulf of Finland, near the nuclear power plant (Laine et al. 2006). It was later discovered in the Gulf of Bothnia, also in the vicinity of a nuclear power plant (Florin et al. 2013). In both cases, the cooling water of the nuclear plants caused a rise in the water temperature that may have facilitated the settlement of *M. leucophaeata*. The latest reports indicate that the species has spread to an area up to 120 km away from the nuclear plant in the Gulf of Finland (Forsström et al. 2016). In the Polish part of the Baltic Sea, *M. leucophaeata* was recorded for the first time by Dziubińska (2011), who found several juvenile individuals settled on experimental panels in the Gulf of Gdańsk in August and September of 2010. Since all individuals were juvenile, it remained uncertain whether the species was able to successfully develop and reproduce in the region, until 2 years later when Brzana & Janas (2016) discovered some adults in samples collected from a concrete offshore construction located approximately 4.5 km away from the site of the former record. Since then several individuals have been found every year during repetitive sampling and underwater observations at this site, but there have been no reports on the occurrence of the species elsewhere in the Gulf of Gdańsk or other nearby areas, for example in the Vistula Lagoon or the Vistula Delta. Although salinity and temperature conditions in the area seem to be favorable for the species, which is described as eurythermal and euryhaline, it usually prefers to live in brackish waters with high temperature being optimal for its successful reproduction (von Reshöft 1961 cited in Kennedy 2010; Sidall 1980; Deaton et al. 1989; Rajagopal et al. 2005; Verween et al. 2005; Verween et al. 2007; Verween et al. 2010; van der Gaag et al. 2014). It must be noted that *M. leucophaeata* prefers hard substrates, which are rare in the southern Baltic Sea and not studied as extensively as soft substrates. Moreover, the species can be easily misidentified with other mussel-like bivalves that already inhabit the southern Baltic Sea such as the native blue mussel *Mytilus edulis trossulus*, commonly found in the Gulf of Gdańsk, or alien *D. polymorpha*, which is widely spread in the Vistula Lagoon (Verween et al. 2010; Dziubińska 2011). An examination of the internal features of the shell is necessary for a correct identification, especially in the case of juveniles (Pathy & Mackie 1993; Laine et al. 2006; Dziubińska 2011). However, in the case of adult individuals, an experienced observer is capable of distinguishing *M. leucophaeata* by looking at its external morphology (personal observations). Because of the scarce information available on the actual distribution of *M. leucophaeata*, we decided to conduct a study aimed at determining the actual distribution in the Polish marine waters.

Study area

The study was conducted in three different areas: the Gulf of Gdańsk, the Vistula Delta and the Vistula Lagoon. Of these three areas, the Gulf of Gdańsk is the most affected by water inflow from the Baltic Sea, which leads to a relatively high and stable salinity of 6-7 PSU and temperature that varies from -0.4°C to 20°C (Sztobryn et al. 1997; Nowacki & Matciak 2000). On the contrary, the Vistula Lagoon is separated from the Baltic Sea by a stable sand barrier that reduces the water exchange with the sea and increases the influence of riverine input, leading to salinity values from 0.5 PSU to 4.8 PSU in the Polish part of the lagoon (Chubarenko & Margoński 2008). With a mean depth of 2.7 m, it is also much shallower than the gulf (mean depth of 59 m) (Majewski 1994), which causes the lagoon to heat up quickly during summer resulting in higher water temperatures that may vary from -0.2°C to 25°C (Chubarenko & Margoński 2008). Conditions in the Vistula Delta are highly diverse as it consists of two different branches. One of them is a man-made continuation of the main Vistula stream, where salinity is usually 0.5 PSU or lower. The other one is a natural, old Vistula branch, which consists of the Martwa Wisła and Wisła Śmiała separated from the main stream by a lock, which makes it almost devoid of riverine currents and strengthens the importance of water exchange with the Gulf of Gdańsk, leading to relatively high salinities of 3 to 7 PSU (Klekot 1972; personal observations). The bottom in all three areas is dominated by sandy and muddy sediments. Natural hard bottom is present only as boulder fields in a few shallow spots in the Gulf of Gdańsk. However, an artificial hard substrate is present in all three basins as piers, breakwaters, jetties, shipwrecks, and offshore constructions (Klekot 1972; Majewski 1990; Chubarenko & Margoński 2008; Huzarska 2013; personal observations).

Materials and methods

Seventeen sites were selected for the collection of samples: seven sites in the Gulf of Gdańsk, five sites in the Vistula Delta and five sites in the Vistula Lagoon. They included piers, breakwaters, shipwrecks, offshore constructions and natural boulder fields (Fig. 1). Samples were collected from March to July of 2016 by a scientific SCUBA diver experienced in sampling of hard bottom benthic communities as well as *M. leucophaeata* identification. Before collection of samples, every site was carefully examined to identify the substrate covered by *M. leucophaeata*. Every time the diver encountered the species, he collected four quantitative samples. In other cases, four quantitative samples were collected from randomly selected spots. If possible, samples were collected using a modified Kautsky sampler with a catch area of 400 cm^2 (following Andrulewicz et al. 2004). At some sites, the use of the Kautsky sampler was impossible due to the rough and irregular surface of the substrate. In such cases, *M. leucophaeata* individuals were counted and collected inside four rectangular spots, measured with a range ruler in order to cover a similar area as the Kautsky sampler. Additionally, qualitative samples were collected for the identification of accompanying taxa. After the sampling, all samples were preserved in 4% solution of formaldehyde. Analysis of samples was performed using a stereomicroscope. During the analysis, all *M. leucophaeata* individuals were sorted out, counted and measured (shell length with 0.1 mm accuracy). Individuals

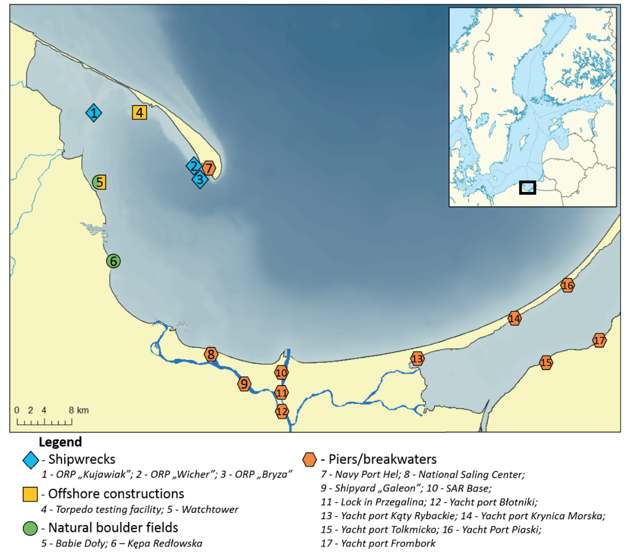

Figure 1

Locations of the study sites. GIS layers used for drawing the map were obtained from the GIS Centre of the University of Gdańsk

identified as *M. leucophaeata* during underwater observations were opened to confirm the field identifications. The field identification proved to be 100% accurate. Accompanying fauna was identified to the lowest possible taxonomic level.

Results and disscusion

We did not observe *M. leucophaeata* in the Gulf of Gdańsk, except the area where it has already been recorded since 2010 (Dziubińska 2011; Brzana & Janas 2016). Moreover, the species was observed on artificial hard substrates, but not on nearby natural boulders. This may result from the fact that the above natural hard substrate was located at a depth of 8 meters, while on the artificial substrate the species was not present at a depth greater than 5 meters. Similarly, Dziubińska (2011) did not find the species on a substrate located deeper than 6 meters. Additionally, boulders can be affected by an increased sedimentation due to the resuspension of particles caused by bottom currents, leading to unfavorable conditions for filter-feeding organisms like *M. leucophaeata*. On the other hand, vertical walls located several meters above the bottom are probably much less affected by sedimentation.

The species was absent at every site located in the Vistula Lagoon (Table 1). Since brackish conditions are described as optimal for the species (Kennedy 2010;

Table 1

Information about *Mytilopsis leucophaeata* and parameters measured at the study sites. Numbers in brackets presented in the "site" column refer to the numbers of sites used in Figure 1

Mytilopsis leucophaeata								
Site		Abundance (ind. m^{-2})	Shell length (mm)	Temperature (°C)	Salinity (PSU)	Depth (m)	Substrate description	Dominant accompanying species
Gulf of Gdańsk	Torpedo testing facility (4)	19	5 -13	14	6.9	7.5	Rough, concrete walls	*Amphibalanus improvisus* *Mytilus edulis trossulus* *Gonothyraea loveni*
	Other 6 sites (1-3, 5-7)	0	-	5 -18	6.8 -7.2	5 -20	Rough, concrete walls, steel shipwrecks, natural boulders	*Amphibalanus improvisus* *Mytilus edulis trossulus* Hydrozoa
Wisła Śmiała	National Sailing Center (8)	69	11 -21	19	4.2	4	Very rough steel plating	*Amphibalanus improvisus* *Mytilus edulis trossulus* *Rhithropanopeus harrisii*
Martwa Wisła	"Galeon" shipyard (9)	31	13 -22	19	6.4	4	Rough steel plating	*Amphibalanus improvisus* Porifera *Rhithropanopeus harrisii*
	Błotniki Yacht Port (12)	1[a)]	16	19	6.2	4	Smooth steel pile	*Amphibalanus improvisus* Porifera
Vistula	2 sites (10, 11)	0	-	18	0.4	2 -3	Rough concrete pier and steel piles	*Dreissena polymorpha* *Gammarus* spp.
Vistula Lagoon	5 sites (13-17)	0	-	17 -19	2.5 -4.0	2 -3	Rough and smooth concrete pier	*Dreissena polymorpha* *Rhithropanopeus harrisii*

a) - only one individual found during underwater observations

Verween et al. 2010; van der Gaag et al. 2016), we expected it to be widely spread on hard substrates, both in the Gulf of Gdańsk and in the Vistula Lagoon. Thermal conditions, especially in the Vistula Lagoon, also seem to be favorable for the species. It is possible that two other bivalves – *M. edulis trossulus* or *D. polymorpha* – prevented further expansion of the species. Both species are competitors of *M. leucophaeata* for food and space, due to similar modes of life. Underwater observations at the sites located in the Vistula Lagoon revealed that multi-layered patches of *D. polymorpha* completely covered the substrates. The substrates studied in the Gulf of Gdańsk were covered by *M. edulis trossulus* in a similar manner. *Mytilopsis leucophaeata* inhabited only those parts of the substrate that were dominated by the bay barnacle *Amphibalanus improvisus* (Darwin, 1854), with only few *M. edulis trossulus* individuals present. *Mytilopsis leucophaeata* was also absent in the main Vistula branch, probably due to very low salinity (<0.5 PSU).

The only new records of *M. leucophaeata* come from the old branch of the Vistula Delta, consisting of Martwa Wisła and Wisła Śmiała, where the abundance of the species was higher (up to 69 ind. m^{-2}) than in the Gulf of Gdańsk (19 ind. m^{-2}) (Table 1). This is probably caused by a reduced competition from other bivalves. Underwater observations and collected samples revealed that *D. polymorpha* was absent at every site in the old Vistula branch, while *M. edulis trossulus* was present only in Wisła Śmiała (Table 1) and in relatively low numbers. The salinity in the old Vistula branch was slightly lower than in the Gulf of Gdańsk, but the temperature was higher and similar to that observed in the Vistula Lagoon. Such conditions are probably less favorable for both bivalves. Although *M. edulis trossulus* is known to tolerate low salinities (Riisgård et al. 2013), it is susceptible to temperatures exceeding 20°C (Brenko & Calabrese 1969; Hayhurst 1997; Hiebenthal et al. 2012). On the other hand, *D. polymorpha* tolerates high temperatures, but prefers lower salinities with 2-4 PSU, which is the upper limit of its tolerance (Smit et al. 1992; Kilgour et al. 1994; van der Gaag et al. 2016). The abundance of *M. leucophaeata* in the Vistula Delta was similar to that in the Kiel Canal (50 ind. m^{-2}) reported by Darr & Zettler (2000), but much lower than in the areas affected by warm water discharge, for example in the Gulf of Finland, where Laine et al. (2006) observed 28 000 ind. m^{-2}, and in the Gulf of Bothnia, where Florin et al. (2013) observed 8000 ind. m^{-2}. Individuals collected in the Vistula Delta were almost twice as large as those in the Gulf of Gdańsk (Table 1). Their length of 23 mm was the maximum length described in the literature (Verween et al. 2010). As the old Vistula branch is relatively shallow and isolated from other basins, the water can heat up quickly during summer, leading to longer periods of high water temperature, which is optimal for *M. leucophaeata* growth (Verween et al. 2010, van der Gaag et al. 2014). Individuals collected in Martwa Wisła and Wisła Śmiała were similar in size to individuals collected near the nuclear power plants of the northern Baltic Sea (Laine et al. 2006; Florin et al. 2013). They were also larger than individuals collected by Forsström et al. (2016) in an area unaffected by warm water discharges. It is possible that the species was introduced to the Vistula Delta first and spread to the Gulf of Gdańsk later. It is also likely that *M. leucophaeata* will spread to or is already present in other, highly industrialized, artificial basins of marine ports or shipyards of the southern Baltic, which were not selected for sampling. The building of a nuclear power plant on the Polish coast, scheduled for 2027, will probably facilitate the establishment of a large population of the species, similarly as in the Gulf of Finland and the Gulf of Bothnia. It appears that *M. leucophaeata* in the Polish part of the Baltic Sea occurs only in areas that were significantly altered as a result of human activity. Therefore, we conclude that the activity resulting in creation of artificial hard substrates or artificial basins has facilitated the settlement of this non-indigenous species in the area. Along with the observations by other authors, this shows the importance of human activities for the spread of alien species, not only in terms of their transport to new areas e.g. via shipping, but also in terms of creating artificial habitats with conditions that meet the species preferences. A limited distribution of the species in the area, where thermal and salinity conditions seem to be close to optimal, indicates that there are other significant factors determining its distribution, for example interactions with other species. These factors should be explored to better predict the potential future spread of *M. leucophaeata*.

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