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Spread of the warm-water clam *Rangia cuneata* in the temperate coastal waters of the Gulf of Gdańsk (southern Baltic Sea)

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Abstract
The Atlantic wedge clam or common rangia, *Rangia cuneata*, was reported in the Gdańsk Basin (southern Baltic Sea) around 2010. In the Gulf of Gdańsk, outside the Vistula Lagoon, specimens of the common rangia were collected for the first time in 2014. This paper reports on the spread of the species in the coastal waters of the Gulf of Gdańsk following its arrival.

Keywords
Rangia cuneata; Baltic Sea; Gulf of Gdańsk

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The aim of this paper was to present observations of the common rangia *Rangia cuneata* (GB Sowerby I, 1831) in the Gulf of Gdańsk (southern Baltic Sea) in 2014–2024 and to summarise the environmental conditions in which it occurs in the Baltic Sea. The common rangia is a Mactridae clam native to the Gulf of Mexico (Hopkins, 1970; LaSalle and de la Cruz, 1985). In the Baltic Sea, at least two-year-old specimens of this species were first recorded in the eastern part of the Vistula Lagoon in 2010 (Rudinskaya and Gusev, 2012). The rapid spread of the common rangia has resulted in the species also inhabiting the western part of the Vistula Lagoon (Warzocha and Drgas, 2013; Warzocha et al., 2016). In the subsequent years, reports of population establishment came from the southern Baltic (Janas et al., 2014; Wiese et al., 2016; Janas and Kendzierska, 2022; Panicz et al., 2022; Czerniejewski et al., 2023) and other areas of the Baltic Sea (Solovjova, 2014; Florin, 2017; Möller and Kotta, 2017; Solovjova et al., 2019; Karlson et al., 2024).

We present observations on the occurrence of the common rangia in the Gulf of Gdańsk (Figure 1), excluding the Vistula Lagoon. The presence of *R. cuneata* was noted during multiple macrozoobenthos studies carried out in different seasons between 2014 and 2024, using both qualitative and quantitative methods. In the distributaries of the Vistula River (the Martwa Wisła River, the Wisła Śmiała River), the Motława estuary, and the Puck Lagoon, sampling was conducted from small vessels. In the open waters, samples were collected from the decks of the r/v *Elisabeth Mann-Borgese* and r/v *Oceanograf*. Quantitative samples were collected using a Van Veen grab sampler (0.1 m^2 sampling area, 1 mm sieve). Qualitative samples were collected manually in the near-shore zone, using hand nets and small dredges, and in deeper waters by dredging from vessels, or using small hand grabbers from piers and marinas. At several sites, sampling was carried out more than once. At all sites, bottom water was analysed for temperature and salinity using portable WTW GmbH meters.

In the study area, the common rangia was first observed in the Wisła Śmiała River in 2014 (Figure 1) (Janas et al., 2014), and in the same year also in the coastal zone of the Gulf of Gdańsk near Gdynia (Skóra, 2015) and in the Vistula River prodelta (Figure 1). In the subsequent years, individuals were observed in the distributaries of the Vistula River and the Motława River, in the Puck Lagoon (for the first time in 2017) and in the open waters of the Gulf of Gdańsk. In the conducted surveys, the common rangia was observed at sites with depths ranging from 0.3

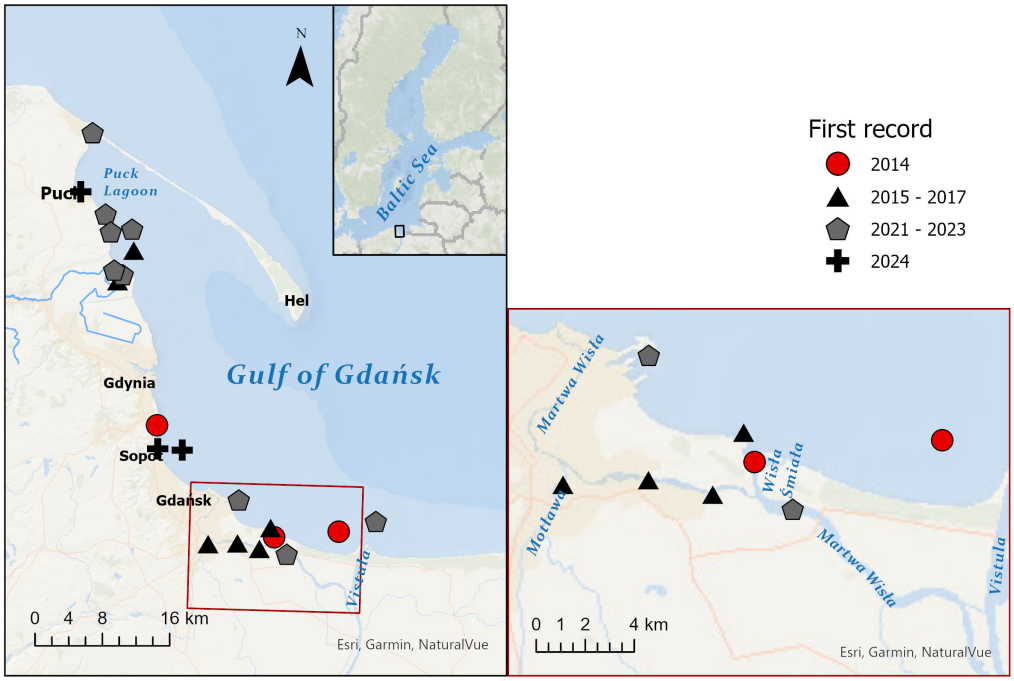

Figure 1. Year of the first observations of *Rangia cuneata* in the Gulf of Gdańsk in 2014–2024.

to 20 m, in different seasons of the year. In general, in the Gulf of Gdańsk, wedge clams were observed at shallow sites, down to a depth of 9.5 m, with two exceptions: the sites in the vicinity of Sopot (12 m) in the western part of the Gulf and in the Vistula River prodelta, where the species was observed up to a depth of 20 m. No *R. cuneata* individuals or empty shells were observed at sites deeper than 20 m.

Salinity (< 7.5) and a wide range of temperatures (from close to 0°Cto as high as 22°C) of the bottom water at the sites where the common rangia was collected (Table 1) correspond to those reported in different areas of its occurrence in the Baltic Sea (i.e., Rudinskaya and Gusev, 2012; Möller and Kotta, 2017; Solovjova et al., 2019). In its native range, the common rangia lives in estuaries with salinity ranging from 0 to 15 (LaSalle and de la Cruz, 1985) and a temperature ranging from 2°C to 30°C (Cain, 1975). During the analysed period, we recorded a low abundance of the common rangia in the Gulf of Gdańsk (up to 10 ind. m^{-2}) and the Puck Lagoon (10–30 ind. m^{-2}). The highest densities were recorded in the distributaries of the Vistula River and the Motława River, ranging from 10 ind. m^{-2} to a maximum abundance of 1940 ind. m^{-2} in the Wisła Śmiała River (Figure 2). In other regions of the Baltic Sea, the highest abundance of the common rangia was recorded in the eastern part of the Vistula Lagoon (Rudinskaya and Gusev, 2012). High abundance of the bivalves (> 100 ind. m^{-2}) was observed across a wide range of salinity (from 3.6 to 6.8) and temperature (from 0.6°C to 21°C). Both at the lowest and highest temperatures, the abundance exceeded 500 ind. m^{-2} (Figure 2). Based on the data obtained in these studies, it is not possible to conclude whether *R. cuneata* shows any preference for specific combinations of recorded temperature and salinity. Very few records of the species come from areas with both low salinity and low temperature, as we did not collect samples in such conditions. In the Vistula Lagoon and the Szczecin Lagoon (southern Baltic Sea), the common rangia was observed in areas with very low salinity, ranging respectively from 0.5 to 4.8 (Warzocha et al., 2016) and from 0.3 to 2.0 (Czerniejewski et al., 2023), where temperatures range from 0°C to 27°C and are also low in winter (Rudinskaya and Gusev, 2012; Dąbrowski et al., 2023).

In the Gulf of Mexico, *R. cuneata* occurs on various types of seabed, including sandy, muddy, and vegetated substrates (LaSalle and de la Cruz, 1985; Auil-Marshalleck et al., 2000). At all observation sites in the Baltic Sea to date, *R. cuneata* has been recorded on a wide range of sediments, from silt and sandy-muddy sediments rich in organic matter (Vistula Lagoon, Motława estuary, Vistula Delta, northern part of the Stockholm archipelago, Szczecin Lagoon – PROEKO, 2010; Warzocha et al., 2016; Czerniejewski et al., 2023; Miernik et al., 2023; Karlson et al., 2024) through fine- and medium-grained sands (Vistula Lagoon, Puck Lagoon, Wisła Śmiała River, Vistula River prodelta, southern part of the Stockholm archipelago, Pomeranian Bay – PROEKO, 2010; Warzocha et al., 2016; Jegliński et al., 2022; Panicz et al., 2022; Miernik et al., 2023; Karlson

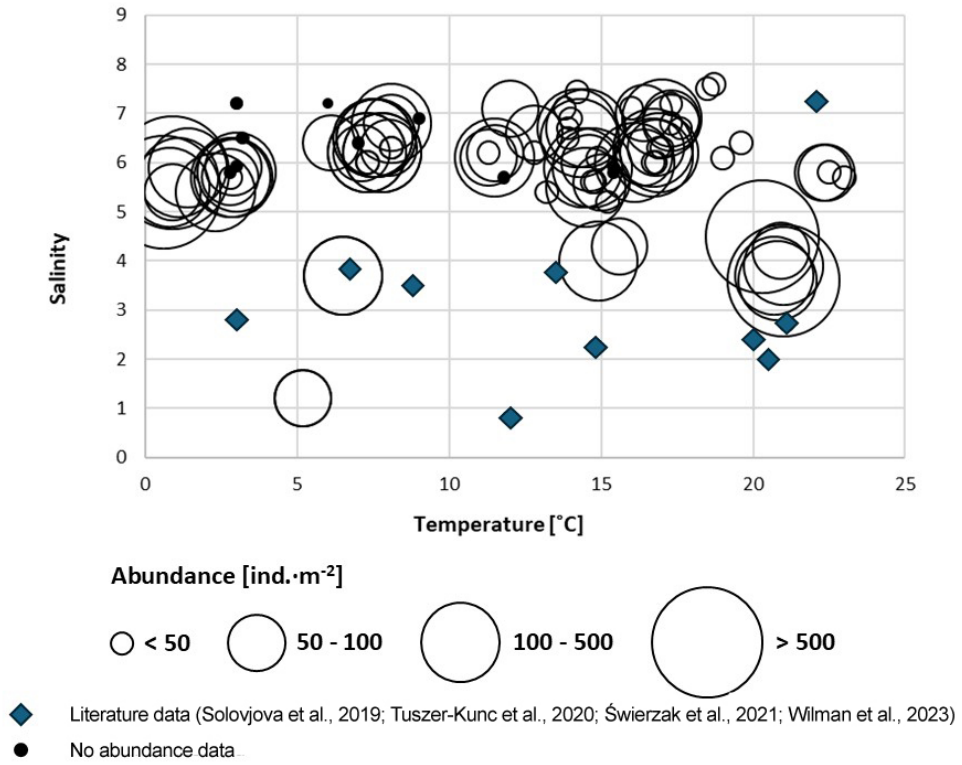

Figure 2. Salinity and temperature at sites with *Rangia cuneata* in the Baltic Sea. The circles represent the abundance (ind. m^{-2}) of *R. cuneata* calculated from a single grab per site; black dots represent the presence of the common rangia (qualitative samples); blue diamonds represent data from the literature (Solovjova et al., 2019; Tuszer-Kunc et al., 2020; Świeżak et al., 2021; Wilman et al., 2023).

et al., 2024), to coarse-grained sand and gyttja outcrops (Puck Lagoon – Jegliński et al., 2022).

In our study, specimens ranging from 1.4 mm to 50.4 mm in length were collected. Except for two observations, one in the Vistula River prodelta (2014) and one in the Puck Lagoon (2017), adult bivalves, i.e., those larger than 10 mm according to Karlson et al. (2024), were found at all stations. The largest individuals reported to date from the Baltic Sea were a 48.1 mm long specimen from the southern part of the Puck Lagoon and a 50.4 mm long clam from the mouth of the Wisła Śmiała River, both collected in 2022. *R. cuneata* collected in the Vistula River prodelta did not exceed 35.8 mm (2022). Although in their native habitat individuals of this species can reach a length of over 80 mm (LaSalle and de la Cruz, 1985), research on the length of specimens from the Baltic Sea (Ezhova, 2012; Warzocha and Drgas, 2013; Dąbrowski et al., 2023) has not reported individuals larger than those observed in the Gulf of Gdańsk.

Since the first observations of *R. cuneata* in the southern part of the Puck Lagoon and in the distributaries of the Vistula River, clams have been recorded in benthic studies in the subsequent years, in all seasons. In late spring 2022 in the Puck Lagoon and in summer 2023 in the Wisła Śmiała River and the Martwa Wisła River, we observed a mass mortality resulting in thousands of empty shells lying on the surface of sediment or remaining buried in the surface sediments. This phenomenon is known from the Vistula Lagoon, where mass mortality after winter was explained by the exhaustion of organisms caused by low temperatures during long winters, dissolved oxygen deficiencies in the bottom zone, and bacterial infections (Warzocha et al., 2016; Kornijów et al., 2018; Świeżak et al., 2021) or high energy expenditure on osmoregulatory processes (Tuszer-Kunc et al., 2020). Mass mortality of the common rangia in the Puck Lagoon results in its patchy and ephemeral distribution, which is a known effect in the case of alien species found in their non-indigenous habitats (Houziauks et al., 2011). However, due to its r-reproductive strategy and hydrographic characteristics of the distributaries of the Vistula River (Cieśliński et al., 2017), *R. cuneata* is a stable component of the Vistula River.

Given the conditions under which the common rangia lives in the Baltic Sea and in its native range, the species has the potential to spread further in the Baltic waters, particularly in brackish zones characterised by high biological productivity. Its occurrence is possible not only in further estuaries, but potentially also in brackish and

Table 1. Depth range and environmental parameters at the sites where *Rangia cuneata* was found in 2014–2024.

Parameter	Vistula Delta, Motława estuary	Puck Lagoon	Gulf of Gdańsk excluding Puck Lagoon
Depth range [m]	3.5–9.5	0.3–5.2	0.3–19.5
Salinity	1.2–7.1	5.8–7.3	6.9–7.0
Temperature [°C]	0.7–23.0	2.8–22.1	4.0–18.7

saline water reservoirs, such as coastal lakes or inland water channels, as a result of human activity, if introduced there. The increase in coastal water temperature in the Baltic Sea (Zalewska et al., 2024) due to climate change may also be a factor favouring the spread of this warm-water clam. By altering the habitat and the food web in the invaded area, the common rangia may definitely affect the functioning of the colonised ecosystem.

Conflict of interest

None declared.

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