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Research Article

Population structure and density of a new invasive species *Rangia cuneata* in the Szczecin Lagoon (Odra/Oder estuary, Poland)

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Abstract

The native North American bivalve species *Rangia cuneata* was unintentionally introduced into European waters during the first decade of the 21st century. In the Baltic Sea, it is mostly found along the southeastern coast, but in 2018 researchers also discovered the species in the Bay of Pomerania, which indicated that it could eventually inhabit the adjacent Szczecin Lagoon and Odra River. In 2021, the species was discovered for the first time in the Szczecin Lagoon during a sampling campaign, at 5 out of the 12 dispersed study sites with diverse bottom substrates.

The goal of this study was to ascertain *R. cuneata* population density, morphometric parameters, individual growth, and the potential for further expansion in the southern Baltic Sea waters. For the study, 201 individuals of this species were collected. Compared to other sites in the southeast Baltic, the Szczecin Lagoon had a much lower average *R. cuneata* population density, at 13.2 ± 7.11 individuals m^{-2} of the bottom area. The highest population density was found at sites with more silt (4–63 µm) and less sand (>63 µm). *R. cuneata* shells had an average length of 30.9 ± 4.6 mm and an average weight of 6.6 ± 2.8 g. The collected specimens were greater in size than other populations of the species in the Baltic Sea and were comparable in size to populations from the nearby Bay of Pomerania. There were no specimens that were under 10 mm in length, and the population was dominated by specimens in the 25–30 mm and 30–35 mm ranges, as well as the 3+ and 4+ age groups. Given the *R. cuneata*'s invasive potential and its fast rate of colonization of new areas, it would be prudent to monitor this population and the species migration patterns across the estuary waters of the western Baltic.

Key words: Atlantic rangia, clams, abundance, size and age structure, growth, habitat

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Introduction

Invasive species often have a negative impact on biodiversity and ecosystem services (Ojaveer et al. 2015). The traits that allow them to spread quickly to new places include tolerance to a wide range of environmental conditions, large numbers of generations per year, early sexual maturation, and high fecundity (Grabowski et al. 2007). Among 132 non-indigenous species in the Baltic Sea (Ojaveer et al. 2017), some species such as the barnacle *Amphibalanus improvisus* or the sandfly *Mya arenaria* are settled for many years, and are now an essential part of the ecosystem, not posing a threat to indigenous species (Janas and Kendzierska 2014). However, other alien species may be harmful (Ojaveer et al. 2010; Ojaveer et al. 2015) and induce devastating effects on the local economy (Haubrock et al. 2021). They enter the Baltic Sea via the network of European rivers (Grabowski et al. 2005) or ship ballast water (Zatoń et al. 2022). This difficulty only increases the significance of monitoring water bodies for the detection of new alien species (Gruszka et al. 2013). Despite problems associated with the fact that the juvenile stages of invasive species are frequently very similar to native species (Miller 1986), the detection of a non-native species in the environment can enable prompt implementation of measures to eradicate the organism from the environment (Green and Grosholz 2021).

An alien species recently discovered in the Baltic (Warzocha and Drgas 2013) is the Atlantic rangia (*Rangia cuneata* G.B. Sowerby I, 1832), a bivalve native to the Gulf of Mexico, which by the 1960s had expanded its range northward to the Chesapeake Bay and the lower parts of the Hudson River (Turgeon et al. 2009). It was initially discovered in European waters in August 2005 (Verween et al. 2006), in the harbor waters of Antwerp, Belgium, from where the species later expanded to the estuaries of the southern and northern North Sea (Neckheim 2013).

In the Baltic Sea, the species was first detected in the port of Kaliningrad in 2010 and moved quickly to the neighboring Vistula Lagoon (Rudinskaya and Gusev 2012). It was first discovered in Poland's portion of the Vistula Lagoon in 2011 (Warzocha and Drgas 2013; Janas et al. 2014), and then in Lithuania's Pärnu Bay and the Gulf of Riga off the coast of Estonia in 2013 (Solovjova 2014; Möller and Kotta 2017). Unexpectedly, it also appeared in the Bay of Pomerania and along the German portion of the Baltic Sea coast (Panicz et al. 2022). In 2016, *R. cuneata* was observed in the Swedish part of the Baltic coast (Florin 2017). A study by Panicz et al. (2022) showed that this species is already a relatively permanent component of the malacofauna of the waters of the southwestern part of the Baltic Sea, and there is a real threat of expansion of *R. cuneata* towards the inland waters of the Odra River estuary.

In its natural range, *Rangia cuneata* primarily inhabits the muddy and sandy bottoms of estuaries, and is most commonly found in salinities ranging from 0 to 10 PSU. Although a salinity range of 2.5–14 PSU is required for reproduction, adult individuals can tolerate higher salinity levels up to 33 PSU (Hopkins et al. 1974; LaSalle and de la Cruz 1985; Wakida-Kusunoki and MacKenzie 2004). The Atlantic rangia has an average adult size of 2.5 to 6 cm, with a lifespan estimated between 4 to 5 years based on average length (Wolfe and Petteway 1968). In the study by LaSalle and de la Cruz (1985), it was estimated that a large specimen of 7.5 cm had reached the age of 10 years. As a suspension feeder, the clam consumes large quantities of seasonally available suspended detritus and phytoplankton (Wakida-Kusunoki and MacKenzie 2004; Janas et al. 2014).

The goal of the current study – the first to document the presence of this invasive species in the Szczecin Lagoon – was to ascertain the size and age distribution of the *R. cuneata* population, assess its density as well as the morphometric characteristics and individual growth of this species during the colonization phase. Another objective was to evaluate the potential for further expansion in the waters of the southern Baltic catchment by comparing the habitat of *R. cuneata* in the Szczecin Lagoon to other waters where this species occurs.

Materials and methods

Study area

Study stations were located in the Polish part of Szczecin Lagoon. The Szczecin Lagoon, a body of water covering 687 km^2, is a secondary estuary of the Odra River situated in the southern part of the Baltic Sea (410 km^2 in Polish territory, where it is also known as the Great Lagoon, and 277 km^2 in Germany – as the Kleines Haff) (Figure 1). The lagoon's average depth is 3.8 meters with a greatest natural depth of 8.5 meters (Radziejewska and Schernewski 2008). The basin is connected to the Pomeranian Bay by three straits: Peene Strait, Swina Strait, and Dziwna Strait (Wolnomiejski and Witek 2013). The lagoon has a shipping channel with a depth of 10.5 m running to Szczecin (work is currently underway to deepen the waterway to 12.5 m). The salinity of the water ranges from 0.5 to 2.0 ppm (0.2–1.6 ppm on the surface, and 0.3–2.0 ppm on the bottom) (Wolnomiejski and Witek 2013). The Szczecin Lagoon is characterized by high primary production and biodiversity of the aquatic fauna (Radziejewska and Schernewski 2008). In the Szczecin Lagoon, a total of 31 mussel species have been identified, including several non-native species (Kontula and Haldin 2012; Wolnomiejski and Witek 2013). Among them, the zebra mussel *Dreissena polymorpha* is the most abundant (Radziejewska and Schernewski 2008). It is likely that *R. cuneata* may compete with other filter-feeding species in the Szczecin Lagoon for food, such as *M. arenaria*, *M. edulis*, *Unio tumidus*, *U. pictorum*, *Mytilopsis leucophaeata*.

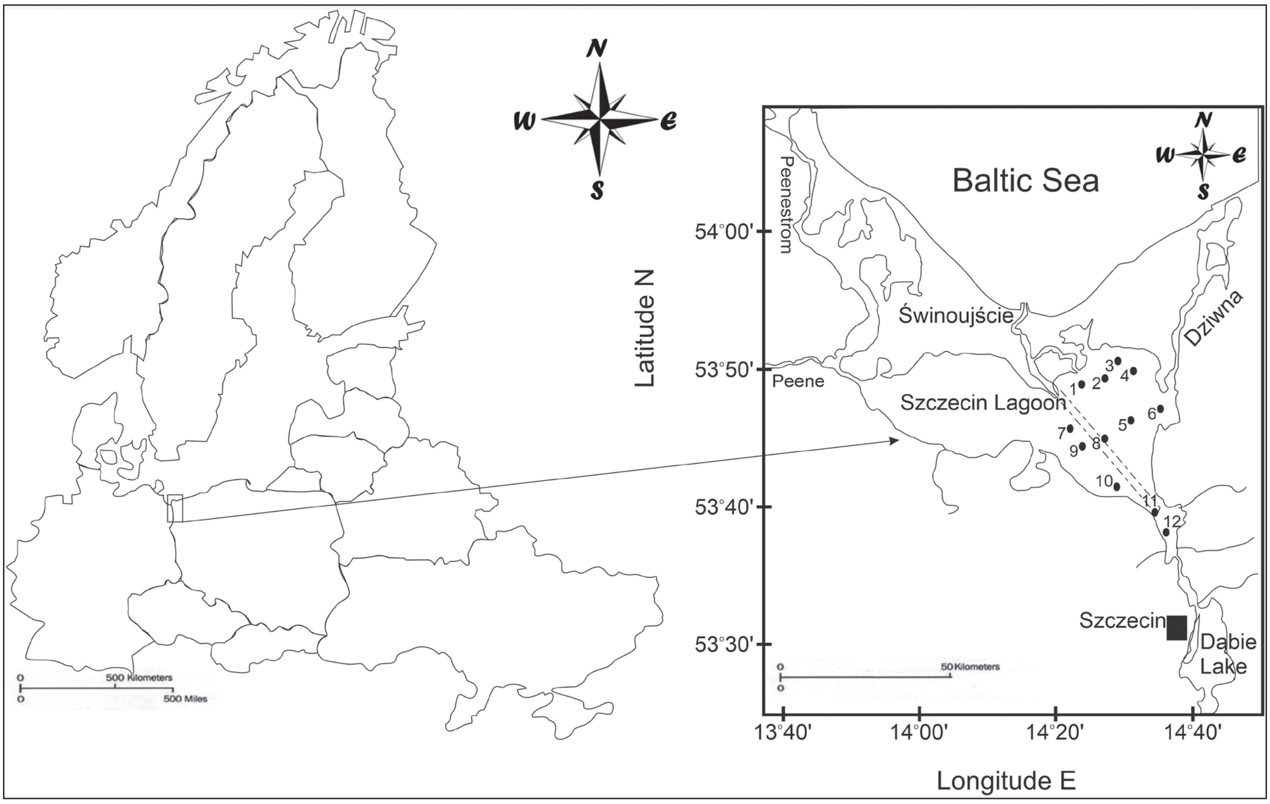

Figure 1. Location of sites for *Rangia cuneata* collection in the Szczecin Lagoon.

Material

A total of 201 *Rangia cuneata* individuals were collected between 16 and 25 November 2021 during monitoring work related to macrozoobenthos collection from the bottom of the Polish part of Szczecin Lagoon and conducted with a Van Veen grab sampler with a sample area of 0.1 m^2 and sediment penetration of 10–20 cm (volume 0.01–0.02 m^3). Individuals of this species were collected at 5 of the 12 stations located in the central and southern part of the Szczecin Lagoon (Table 1, Figure 1). At each station, 5–8 random samples were taken from each station to determine the density of *R. cuneata* and to catch an appropriate number of individuals for further analysis. Sediment was also collected, and later sieved in the laboratory to exactly classify its composition according to standard methods – after transferring the substrate to the laboratory, it was dried for 24 h at 105°C and then sieved through a differential. Each fraction was weighed and then dried again for 3.5 hours at 550°C to determine the mass of organic matter and the mass of the remaining fraction. The sediment grain size was classified into three major groups: sand (>63 µm), silt (4–63 µm), and clay (<4 µm) (Wong et al. 2010). A Folk diagram (Figure 2) was used to visualize the different textural classes based on percentages of gravel, sand, and mud (Folk 1954). After sampling mussels by Van Veen grab at these stations where *R. cuneata* was collected we used a benthic drag (length 0.6 m, height 0.3 m, breadth 0.4 m) to collect more individuals for population analysis.

Table 1. Location of monitoring stations, characteristics of the substrate, and the density of *R. cuneata* in Szczecin Lagoon.

Site	Geographical coordinates	Number of replicates by station	Bottom structure	Folk classes (Folk 1954)	Density of *R. cuneata* individuals m^{-2} (± SD)
1	14.39749, 53.69444	7	sand (32%), silt (58%), and clay (10%)	Sandy-mud	0
2	14.32111, 53.75000	5	sand (41%), silt (52%), and clay (7%)	Sandy-mud	0
3	14.58277, 53.78305	6	sand (58%), silt (31%), and clay (11%)	Muddy-sand	0
4	14.55083, 53.78138	5	sand (41%), silt (54%), and clay (5%)	Sandy-mud	0
5	14.44472, 53.81611	5	sand (78%), silt (22%)	Muddy-sand	0
6	14.37027, 53.81611	6	sand (68%), silt (32%)	Muddy-sand	0
7	14.40010, 53.77388	8	sand (21%), silt (79%)	Sandy-mud	16.1±4.95
8	14.48305, 53.68388	8	sand (20%), silt (80%)	Sandy-mud	8.2±3.22
9	14.46472, 53.71388	8	sand (11%), silt (89%)	Sandy-mud	17.3±4.95
10	14.56777, 53.64972	8	sand (8%), silt (92%)	Mud	21.1±2.65
11	14.57826, 53.60492	8	sand (16%) silt (84%)	Sandy-mud	3.3±1.79
12	14.58944, 53.63444	6	sand (35%), silt (64%), and clay (1%)	Sandy-mud	0

Individual measurements

The 201 specimens collected were measured according to Czerniejewski et al. (2021) (Figure 3) using an electronic caliper (Kamasa Tool, Sweden) with an accuracy of 0.01 mm. The wet weight of the specimens was determined to the nearest 0.01 g on a WPS 600/C/2 balance from RadWag® (Poland).

Age was determined by counting the annual rings on the surface of the shells (Johnsson et al. 2013). Vernier calipers (0.01 mm measurement accuracy) were used to measure the length of the individuals at each annual ring. The growth of the shells was described using the von Bertalanffy equation (Czerniejewski et al. 2021):

$$L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right)$$

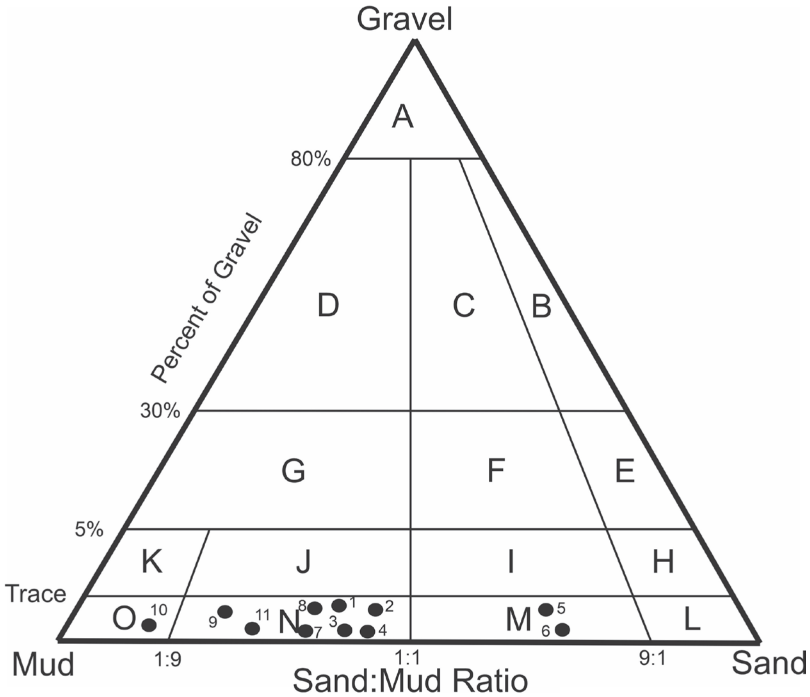

Figure 2. Sediment textural groups defined by and published in Folk (1954) with the samples according to our analyses. Folk's names for these textural classes are as follows: **A)** gravel, **B)** sandy gravel, **C)** muddy sandy gravel, **D)** muddy gravel, **E)** gravelly sand, **F)** gravelly muddy sand, **G)** gravelly mud, **H)** slightly gravelly sand, **I)** slightly gravelly muddy sand, **J)** slightly gravelly sandy mud, **K)** slightly gravelly mud, **L)** sand, **M)** muddy sand, **N)** sandy mud, **O)** mud.

where: L_t is length (mm) at time *t* (age in years), L_∞ is length (mm) at time infinity (the predicted mean maximum length for the population), *K* is a growth constant that describes the rate at which L_{inf} is attained (mm, year^{-1}), *t* is age (years) and t_0 is the time at which length = 0. The parameters of this equation were calculated in the R programming environment using the FSA packages nlstools, magrittr, and dplyr (Ogle 2016).

Statistical analyses

The data were tested for normality using Kolmogorov-Smirnov tests and the Levene's test of equality of variances. The length-weight relationships (LWRs) were estimated from the formula W = a*L^b, where W is wet weight (g), L is the length (mm), a and b are the coefficients of the functional regression between W and L. The values of constants a and b were estimated by the least-square linear regression from the log-transformed values of length and weight: log W = log a + b log L. The slope of the regression (allometric coefficient) was used as an indicator of the type of differential growth, considering the 95% confidence intervals calculated for each coefficient. The statistical analyses were conducted with Statistica 13.0 (Statsoft Inc.), the R programming environment (R Core Team 2018), and the R packages: nlme (Pinheiro et al. 2023) and ggplot2 (Dubossarsky and Song 2020).

Results and discussion

R. cuneata density and bottom substrate

The occurrence of this species in the Szczecin Lagoon, with a salinity of 0.2–2.0 ppm, confirms the possibility of colonizing large European river estuaries. Within its natural range, *R. cuneata* requires a salinity between 5 and 15 ppm (Wakida-Kusunoki and

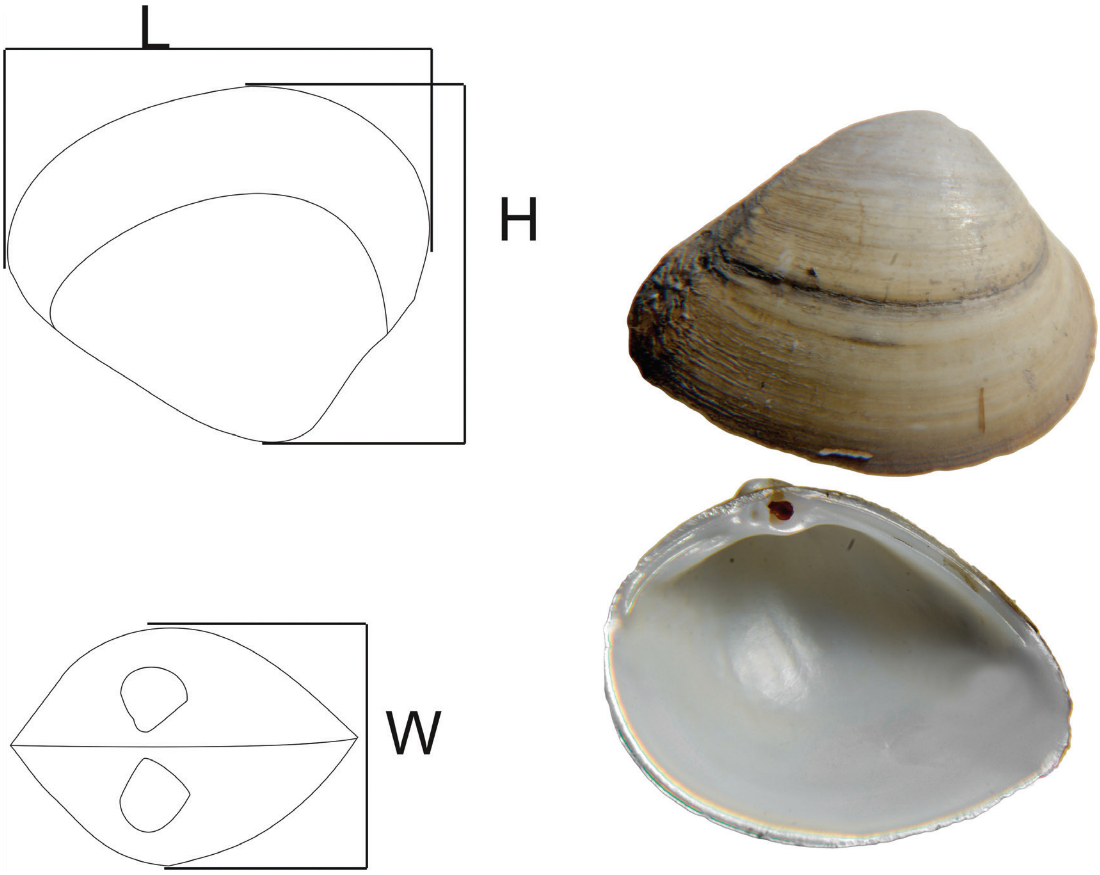

Figure 3. The schema of measurements and picture of shell of *Rangia cuneata* specimens (Czerniejewski et al. 2021, modified by the authors), where: L – length of the shell, H – height of the shell, W – width of the shell.

MacKenzie 2004), although it does occur in lower salinity waters in colonized areas (Rudinskaya and Gusev 2012; Möller and Kotta 2017; Solovjova et al. 2019). Wakida-Kusunoki and MacKenzie (2004) have reported that the species is most common in shallow areas up to 6 m deep, with a preference for waters up to 2.5 m deep. In the Szczecin Lagoon, *R. cuneata* has been recorded at sites with depths ranging from 2.0 m to 3.5 m, and the highest densities were recorded at sites whose bottom substrate was mainly silt (4–63 μm) and less often sandy substrates (>63 μm). According to Faillettaz et al. (2020), this bivalve prefers sandy substrates of fine to medium granularity but can also occur on sandy-clay and silty substrates (Verween et al. 2006), probably because there it can burrow to its preferred depth (Kornijów et al. 2018).

At the study sites, the average density of *R. cuneata* was 13.2±7.11 individuals m^{-2} of the bottom surface, with a maximum of 21.1 individuals m^{-2}. This is very low compared to the maximum density of this species in the Vistula Lagoon, at 4,040 individuals m^{-2} (Rudinskaya and Gusev 2012), and 540 individuals m^{-2} in the coastal waters of the Gulf of Gdańsk (Janas et al. 2014). In contrast, in the waters of northwestern France, densities ranged from 8.55 to 132.48 individuals m^{-2} (Faillettaz et al. 2020).

Size and population structure of *R. cuneata*

The average length (L), height (H), and width (W) of *R. cuneata* shells from the Szczecin Lagoon were, respectively, 30.9 mm (± 4.6 mm), 24.6 mm (± 3.7 mm), and 17.4 mm (± 2.9 mm). In contrast, the average weight was 6.6 g (± 2.8 g), showing a high variability (CV = 42.13%) compared to the shell dimensions (CV ranged from 14.77% to 16.61%) (Figure 4).

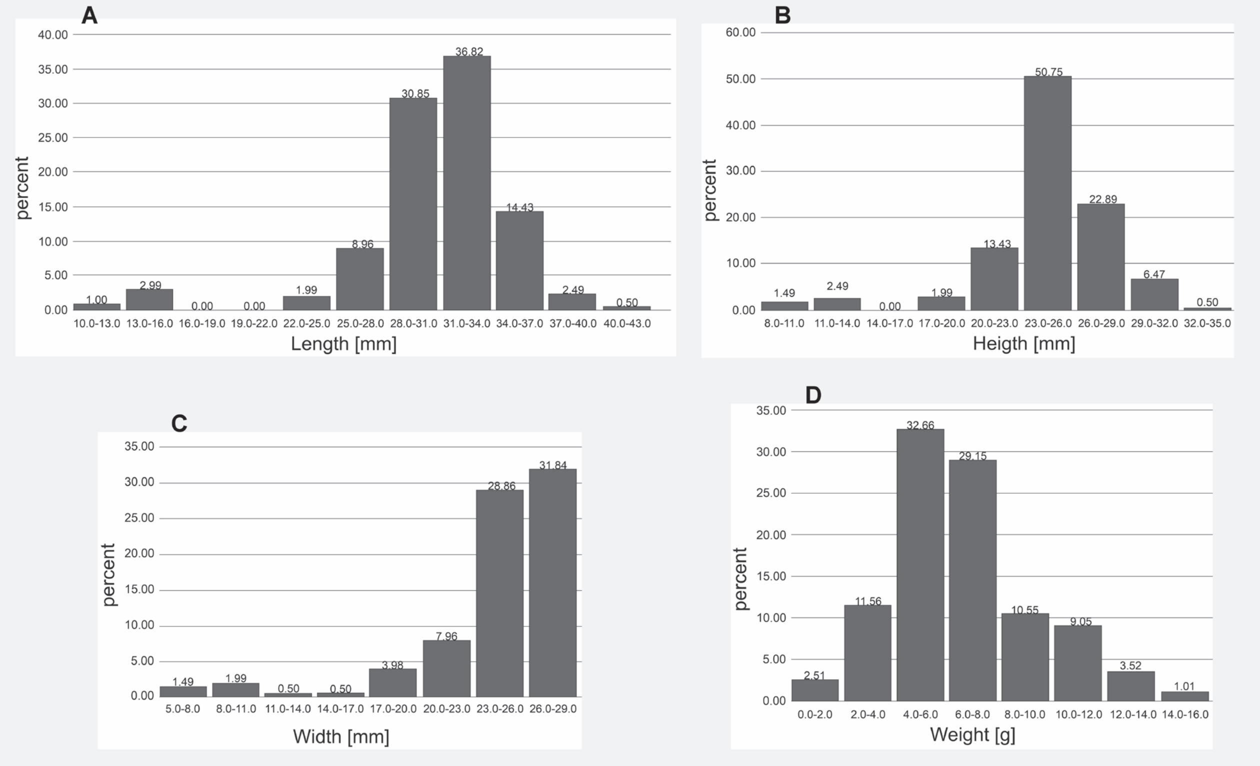

Figure 4. Distribution of length (**A**), height (**B**), shell width (**C**), and unit weight (**D**) of *R. cuneata* in the Szczecin Lagoon.

In the originated areas, *R. cuneata* grows up to 70 mm in length (Wolfe and Petteway 1968), with the largest ever individual reaching 94 mm (LaSalle and de la Cruz 1985). The most abundant individuals are 25.0–40.0 mm long (Wong et al. 2010). Also, in European waters, their length rarely exceeds 40 mm. For example, in Dutch waters, the shell length ranges from 4.0 to 40.0 mm (Verween et al. 2006), while in northwestern France it is 9.8–56.8 mm (Faillettaz et al. 2020). In the Baltic Sea, individuals of shorter lengths have been recorded in Baltic waters. For example, in Pärnu Bay (Estonia), the maximum length of these bivalves is 34 mm (Möller and Kotta 2017), while in the coastal waters of Lithuania and the waters of the Vistula Lagoon it does not exceed 37 mm (Rudinskaya and Gusev 2012; Janas et al. 2014; Solovjova et al. 2019). Therefore, the largest individuals recorded in the Szczecin Lagoon were larger and probably older than other Baltic populations of the species. On the other hand, they do not exceed the maximum length and age reported for this species (LaSalle and de la Cruz 1985; Faillettaz et al. 2020).

The occurrence of adults in our sample from the Szczecin Lagoon, with a small number of juveniles, may be due to the type of bottom substrate, which was mainly silt (grain size 4–63 μm). LaSalle and de la Cruz (1985) report that soft substrate and clay silt (size < 50 μm) are favorable for the presence of adults and may not be optimal for juveniles (Sundberg and Kennedy 1993). However, the Szczecin Lagoon, similar to the Curonian Lagoon in the eastern Baltic (Dailidienė and Davulienė 2008), appears to have favorable reproductive conditions for this species in terms of temperature, oxygen content, and salinity. Gametogenesis of *R. cuneata* is initiated by temperatures above 15°C and salinity between 0 and 15 ppm (Verween et al. 2006), both of which occur in the Odra estuary. On the other hand, it has been noted that freshwater *R. cuneata* individuals are characterized by significantly lower recruitment of juveniles (Tang et al. 2019), which may be the reason for the slowdown in inland water colonization.

In the case of length-weight relationship for *R. cuneata* from the Szczecin Lagoon, the model Log weight = -6.614*Log length + 2.935 was obtained at R^2 = 0.698

(F = 453.8, p < 0.00001). The slope (b) of 2.935 for this model indicates an allometric type of growth ($R^2 = 0.9209$, $p < 0.00001$). Also, Möller and Kotta (2017), in their study on this species in the Bay of Pärnu, observed an allometric increase in the weight of both the shell and the body of *R. cuneata*, defining the equations for the whole shell as y = 2E-05x^3.5708, and for the rank body as y = 5E-05x^2.5004.

Growth of *R. cuneata*

Figure 5 shows an increase in length (L) of *R. cuneata* shells as determined by the von Bertalanffy model, with the parameters of the equation given in Table 2. These bivalves in the Szczecin Lagoon are characterized by a rapid increase in length, width and height in the first 3 years of life and a nearly 2-fold decrease in these increments in subsequent years (Table 3).

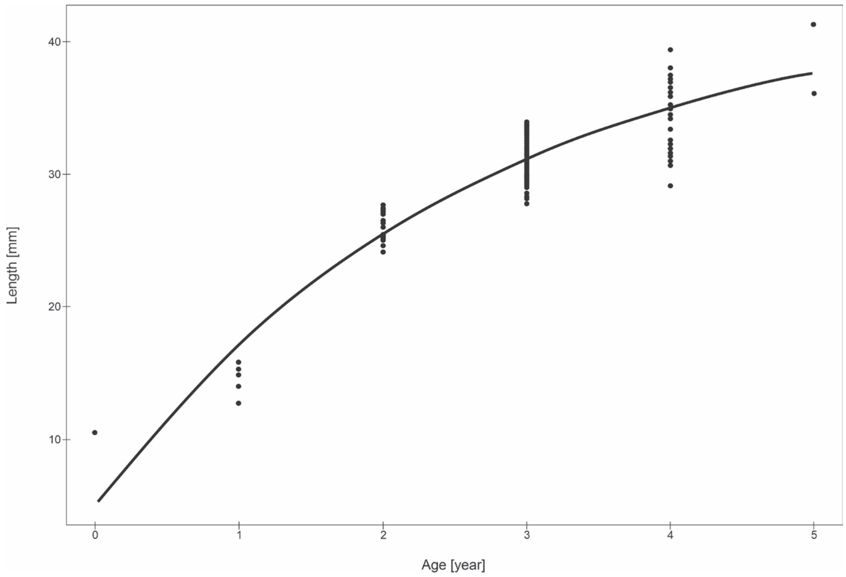

Figure 5. Theoretical growth of *R. cuneata* from the waters of the Szczecin Lagoon using the Von Bertalanffy model.

Table 2. Length growth parameters of *R. cuneata* according to the von Bertalanffy model.

Parameter	Estimate	Std. Error	t value	Pr(>|t|)	Signif. level
$L\infty$	43.38	1.78	24.43	0.0000	***
K	0.38	0.04	8.81	0.0000	***
t_0	-0.32	0.11	-2.81	0.0055	**

Significance codes: '***' - 0, '**' - 0.001, '*' - 0.01, '.' - 0.05, ' ' - 0.1; Pr(>t) - Student's t-tests.

Table 3. Average values of length, height and width in the range (2.5–97.5%) in different clam age classes determined by the number of annual rings.

Age [year]	Length [mm]		Height [mm]		Width [mm]	
	Mean	2.5–97.5%	Mean	2.5–97.5%	Mean	2.5–97.5%
0	5.01	2.51–7.64	3.90	1.47–6.14	2.54	0.13–4.78
1	17.18	16.28–18.13	13.73	12.91–14.53	9.47	8.67–10.30
2	25.50	25.01–25.95	20.36	19.94–20.80	14.26	13.88–14.68
3	31.17	30.88–31.42	24.84	24.60–25.08	17.57	17.35–17.81
4	35.04	34.60–35.52	27.86	27.46–28.25	19.87	19.47–20.28
5	37.68	36.84–38.74	29.89	29.11–30.72	21.46	20.72–22.25

Wolfe and Petteway (1968) were among the first to investigate the growth of *R. cuneata* using the von Bertalanffy model, indicating a rapid increase in length up to age 2 with a decline in growth in subsequent years. For example, in Louisiana, 2-year-old specimens had an annual length increase of 5–9 mm, while in 3-year-old specimens it was only 4–5 mm. In St. Lawrence Lagoon, length mean gain in year 1 was 12.17 mm, in year 2 they were 8.32 mm, and in year 3 they were 5.67 mm, and then nearly halved compared to year 3 and remained at a similar level each year. In our study, the length of *R. cuneata* in the Szczecin Lagoon in the first year of life seems high, although not reaching the values reported by Rudinskaya and Gusev (2012), i.e. 14 mm in length in the first year of life. Our results are similar to the study by Faillettaz et al. (2020), who, based on analyses of populations from northwestern France, observed a decrease in growth between the 2nd and 3rd years of life, and then a stabilization of very small growth in subsequent years.

The variation in the growth of *R. cuneata* is influenced by environmental conditions, particularly salinity (Tang et al. 2019) and water temperature (Wong et al. 2010). Comparing the growth of *R. cuneata* found in Louisiana waters (Wolfe and Petteway 1968), where summer water temperatures exceed 30°C (Windham et al. 2019), to populations inhabiting lower-temperature European waters (Tang et. al. 2019; Faillettaz et al. 2020; Panicz et al. 2022; own study), it can be seen that in the cooler estuarine waters of the Baltic Sea basin, where the maximum temperature is around 20°C, its growth is slower (Figure 6).

Possible vectors of introduction and further dispersal

Rangia cuneata is commonly considered a semi-tropical species that has colonized European river estuaries, and its likely vector of transmission is ballast water from ships. This is evidenced by bivalves measuring 11–22 mm which survived in that

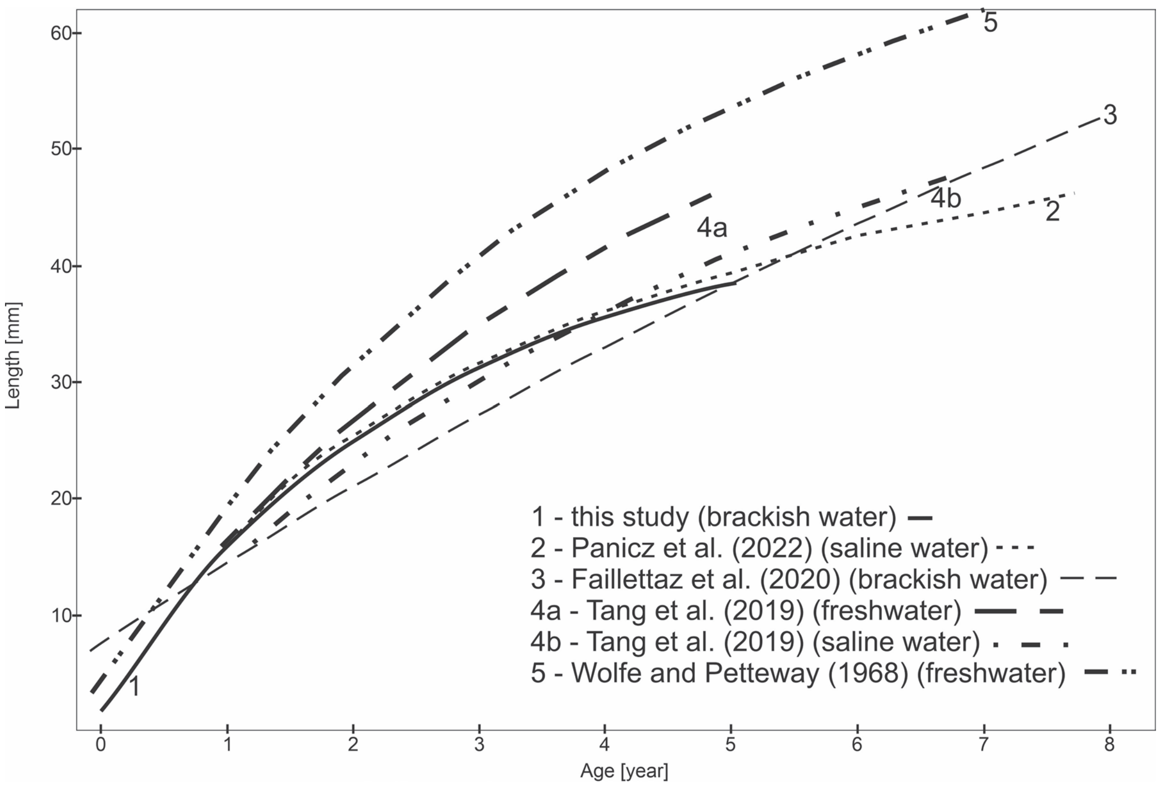

Figure 6. Comparison of the growth of *R. cuneata* in different waters as reported by other authors.

environment for up to 15 days (Hopkins et al. 1974). Nowadays, colonization of new areas can take place not only through ballast water, but also over shorter distances through the occasional transfer of juvenile stages by waterbirds (Banha et al. 2016), and primarily through natural river systems or upstream movement of ships. In the Odra estuary, the presence of this species was first recorded in 2014, when *R. cuneata* was found in the waters of the Bay of Pomerania (Panicz et al. 2022).

In our study, the age of the oldest individuals caught in the Szczecin Lagoon suggests that these bivalves were already present in that body of water in 2016. Their entry into the waters of the Szczecin Lagoon from the Bay of Pomeranian is facilitated by the phenomena of a so-called "backflow" caused by inflows of saline Baltic waters into the lagoon via Dziwna Strait, Swina Strait, and Peene Strait (Wolnomiejski and Witek 2013). Moreover, as suggested by Solovjova et al. (2019), estuarine areas are more suitable for such colonization due to higher levels of eutrophication and higher water temperatures than in the open sea. Given the speed of expansion and the wide tolerance of this species, it can be predicted that there will be further invasion upstream of the Odra River and into the waters of neighboring river systems connected to the Odra River by channels. This can be harmful because the impact of *R. cuneata* on native ecosystems is not fully known. According to Panicz et al. (2022), it is likely that it may compete with our native mussels for living space and food. Unfortunately, the rate of expansion will also be affected by climate change, most notably rising water temperatures in these bodies of water (Möller and Kotta 2017).

It is difficult to assess the role that this new species will play in the ecosystem of the Szczecin Lagoon, especially with the low observed density of individuals. However, research by Kemp et al. (2018) suggests that *R. cuneata* has a high relative impact potential (RIP) and a propensity to drive ecosystem changes, posing a threat to native aquatic fauna, particularly benthic species such as the duck mussel (*Anodonta anatina*). Despite these negative effects, *R. cuneata* may be integrated harmlessly into ecosystems and even contribute to biodiversity enrichment (Goulletquer 2016), or provide a new source of food for native species (Failletaz et al. 2020). For example, Pezzy et al. (2022) reported that native European herring gulls (*Larus argentatus*) fed on *R. cuneata*.

Among the common fish species in the Szczecin Lagoon (Radziejewska and Schernewski (2008), the roach (*Rutilus rutilus*) is known to actively feed on mussels, mainly the zebra mussel (*Dreissena polymorpha*) (Kottelat and Freyhof 2007), which indicates that it may also feed on *R. cuneata*. This clam may also serve as a dietary component for the round goby (*Neogobius melanostomus*), which is abundant in the Szczecin Lagoon and feeds on various mussel species (Charlebois et al. 1997). Kornijów et al. (2018) observed *R. cuneata* in the stomachs of the common carp (*Carassius gibelio*), the silver bream (*Blicca bjoerkna storni*), the European flounder (*Platichthys flesus*), and the European eel (*Anguilla anguilla*) in the Vistula Lagoon.

One potential positive role of *R. cuneata* in the Szczecin Lagoon, similar to *Dreissena polymorpha*, is its habitat-forming ability. Other organisms such as leeches and crayfish may find shelter among clams (Nalepa and Schosser 2012).

Conclusions

Surveys conducted in various parts of the Szczecin Lagoon, i.e. the estuarine waters of the Odra River, have shown for the first time the presence of the invasive *Rangia cuneata* and confirmed the possibility of its further expansion. The lower density of individuals found in this body of water compared to the natural area of occurrence and the waters where the species has been observed for many years may indicate the beginnings of invasion into the Szczecin Lagoon. The size and age structure of the *R. cuneata* population indicate larger individual sizes than those recorded in other waters of the Baltic Sea, which can be explained by good environmental conditions, bottom structure, and food abundance in the Szczecin Lagoon which are conducive to colonization. It is possible that the species may spread further into the inland waters of the Odra estuary, facilitated by the high trophicity of these waters and human activity, which may be a vector for the transfer of individuals in larval and juvenile stages. Taking the above into account, it seems necessary to closely monitor this population and the directions of the species spread in the estuarine waters of the western part of the Baltic Sea.

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Authors Contribution statement

Conceptualization: PC; Methodology: PC, JD; Formal analysis and investigation: PC, JD, AB; Writing - original draft preparation: PC, JD, AB; Writing - review and editing: KF; Funding acquisition: West Pomeranian University of Technology in Szczecin.

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