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Non-native crab *Rhithropanopeus harrisii* (Gould, 1984) – a new component of the benthic communities in the Gulf of Gdańsk (southern Baltic Sea) *

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Joanna Hegele-Drywa⋆
Monika Normant

[1] Department of Experimental Ecology of Marine Organisms,
University of Gdańsk,
al. Marszałka J. Piłsudskiego 46, 81–378 Gdynia, Poland;

e-mail: ocejhd@ug.edu.pl

⋆corresponding author

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Abstract

The aim of this study was to determine the occurrence, spatial distribution and abundance pattern of the Harris mud crab *Rhithropanopeus harrisii* in the Gulf of Gdańsk (southern Baltic Sea). Between 2006 and 2010, this species was found at 69 out of 129 sampling stations, at depths from 0 to 20 m. Two main aggregations of the Harris mud crab were established: (1) in Puck Bay (max. density 19 indiv. 100 m^{-2}) and (2) in the Gdynia and Sopot area (max. density 5 indiv. 100 m^{-2}). 920 specimens were collected during the whole sampling period: 150 juveniles, 370 females and 400 males. The minimum measured carapace width was 1.96 mm, the maximum 21.40 mm (mean 9.03 ± 4.11 mm).

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1. Introduction

The Baltic Sea is a young water body, geologically and hydrologically unstable, with limited biodiversity on the one hand, but a good many introduced alien species on the other (Leppäkoski et al. 2002, Paavola et al. 2005, Bonsdorff 2006). One of these non-native species is the Harris mud crab *Rhithropanopeus harrisii* (Gould, 1841), the smallest of the three non-native crab species present in this area. Its native areas are the saline to brackish waters of the north-west Atlantic from Canada to the Gulf of Mexico (Williams 1984). The species probably reached Europe in ballast waters (Rodriguez & Suarez 2001, Projecto-Garcia et al. 2010). The first description from Europe comes from the Zuiderzee (the Netherlands) (Maitland 1874). Thereafter, *R. harrisii* gradually spread into Germany, where it was recorded in 1936 (Nehring & Leuchs 1999), and further east to Poland, where it appeared in 1951 (Demel 1953, Kujawa 1957, Michalski 1957). Around 1953 *R. harrisii* was found in Denmark (Jensen & Knudsen 2005). Since 1937, the Harris mud crab has also been found in the Ponto-Caspian region, e.g. in the Black and Caspian Seas, and in the Sea of Azov (Zaitsev & Öztürk 2001).

In Poland, *R. harrisii* was observed for the first time in 1951 in the Vistula Lagoon (Demel 1953). In subsequent years, the species was reported in the Rivers Motława and Dead Vistula, where it managed to establish a self-sustaining population (Kujawa 1957, Michalski 1957). However, the occurrence of this mud crab in the Gulf of Gdańsk (southern Baltic Sea), which lies near the above localities, seems controversial. On the one hand, Żmudziński (1961) and Pautsch et al. (1969) reported single specimens of *R. harrisii* in this basin; on the other, Szudarski (1963) reported the absence of this species along the Polish Baltic coast during the Baltic-Belt Seas Committee in 1963. Apart from these two reports, no further information on the occurrence of the Harris mud crab in the Gulf of Gdańsk came to light for the next 50 years (e.g. Kotwicki 1997). This applies to both planktonic (larval) and benthic (juvenile and adult) forms. We can therefore assume that the presence of single specimens of *R. harrisii* recorded in the Gulf of Gdańsk in the 1960s was probably accidental and that this species should really be regarded as a new component of the benthic communities in the Gulf of Gdańsk. Even though the species began to be observed more frequently in the Gulf of Gdańsk in the early 2000s (Normant & Gibowicz 2008, Hegele-Drywa & Normant 2009), no work was carried out targeting its occurrence in this basin. The appearance of *R. harrisii* in these waters is interesting, because for decades there have been stable populations of the species only in the nearby Dead Vistula and Vistula Lagoon (Turoboyski 1973, Janta 1996, Rychter 1997, 1999, Normant et al. 2004). It should also be noted that in 2007 the species appeared in large numbers in the Odra Estuary, where earlier it had hardly ever been recorded (Czerniejewski & Rybczyk 2008, Czerniejewski 2009). The species has also increased in abundance in the Curonian Lagoon (Bacevičius & Gasiūnaitė 2008), in the shallow north-eastern Gulf of Riga (Kotta & Ojaveer 2012) and along the coast of Finland near Turku (Fowler et al. 2013).

Here we present for the first time data on (1) the occurrence, distribution and density of *R. harrisii* in the Gulf of Gdańsk, (2) the structure of the benthic communities of which it is a component, and (3) preliminary characteristics of the individuals with regard to sex and size. Based on material collected in 2006–2010, this study provides new information on this non-native species. Together with other ecological data (e.g. on food preferences and consumption rate), the results may find application, e.g. in ecological models, or be useful in the development of management strategies for the species.

2. Material and methods

Samples were taken with a bottom dredge (33×66 cm, mesh size 0.5×0.5 cm) from r/v 'Oceanograf 2' at 129 randomly chosen sampling points located at depths from 5 to 60 m. The dredging time of 5 min as well as the vessel's speed of 1.5 knots were recorded to estimate the abundance of *R. harrisii*. In order to obtain information on seasonal variations in Harris mud crab abundance, material was also collected monthly from January to September (excluding May 2009) from two depth profiles located in Gdynia (G) and Sopot (S). Three sampling points were fixed at each profile. The same dredging procedure was repeated three times at each sampling point (Table 1).

Table 1. Characteristics of the sampling points from both depth profiles in Gdynia (G) and Sopot (S)

Sampling points	Longitude (N)	Latitude (E)	Depth [m]
Gdynia			
G1	54°27′90″	18°36′40″	10
G2	54°29′00″	18°40′00″	14
G3	54°29′40″	18°41′40″	17
Sopot			
S1	54°26′37″	18°36′13″	8
S2	54°27′52″	18°37′90″	10
S3	54°28′59″	18°39′71″	15

At each sampling point temperature ($\pm 0.1°$) and salinity (± 0.1 PSU) were determined with a Multi340i multimeter (WTW, Germany). The macrobenthic taxa found in the sample were identified as accurately as possible, based on Stańczykowska (1986), Żmudziński (1999), Kołodziejczyk & Koperski (2000) and Barnes (2005). The frequency of co-occurring taxa was determined at 46 random sampling points in Puck Bay ($n = 17$) and in the Gdynia and Sopot area ($n = 29$). Additional information on the occurrence of *R. harrisii* in shallow waters (< 5 m) was obtained from divers and the local community.

After collection, the animals were immediately frozen at $-20°$C. In the laboratory the crabs were sexed on the basis of their abdominal structure and pleopod shape (De Man 1892), and their carapace width was measured (± 0.01 mm) with slide calipers (ECOTONE, Poland). In accordance with Turoboyski (1973), specimens with a carapace width under 4.4 mm were classified as juveniles. The results were expressed as mean plus standard deviation (mean $\pm$ SD). The maps were prepared in the ArcGIS 8.x. program.

3. Results

In 2006–2010 *Rhithropanopeus harrisii* was recorded at 69 out of 129 sampling points, at depths from 0 to 20 m (Figure 1a).

In the samples from Puck Bay, which has a muddy bottom, gammarids were dominant among the organisms co-occurring with *R. harrisii. Crangon crangon* and *Cerastoderma glaucum* were recorded in more than 50% of samples containing the Harris mud crab (Figure 2a). In the samples collected from the Gdynia and Sopot area *Mytilus edulis trossulus* and *Balanus improvisus* were dominant among the organisms co-occurring with the Harris mud crab. *C. glaucum* and gammarids were recorded in more than 50% samples with mud cab (Figure 2b).

The highest density of the Harris mud crab was recorded in Puck Bay (19 indiv. 100 m^{-2}; av. 12.0 ± 5.3 indiv. 100 m^{-2}). The maximum density of *R. harrisii* recorded in the waters off Gdynia and Sopot was 5 indiv. 100 m^{-2} (av. 3.0 ± 1.8 indiv. 100 m^{-2}) (Figure 1b). In the Gdańsk area, where the bottom is sandy, *C. crangon* and *C. glaucum* were dominant, but no Harris mud crab specimens were present in the samples.

Analysis of the depth profiles G (Gdynia) and S (Sopot) showed that the depth at which *R. harrisii* was recorded most frequently in the Gulf of Gdańsk was 14 m. Between January and September 2009 (except May), 21 of the 58 specimens were collected at this depth. Also, more than 10

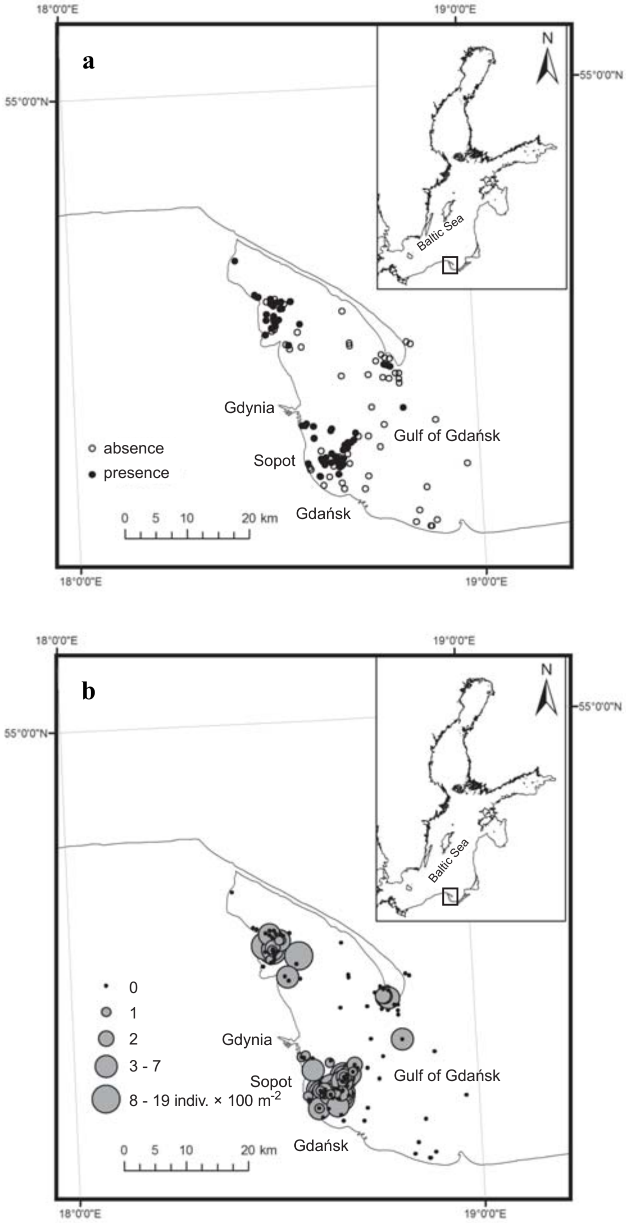

Figure 1. *Rhithropanopeus harrisii* in the Gulf of Gdańsk in 2006–2010: a) map showing sites of presence or absence, b) map showing abundance

individuals were recorded at depths of 8, 10 and 15 m. At 17 m depth only one individual of *R. harrisii* was recorded throughout the study period (Figure 3).

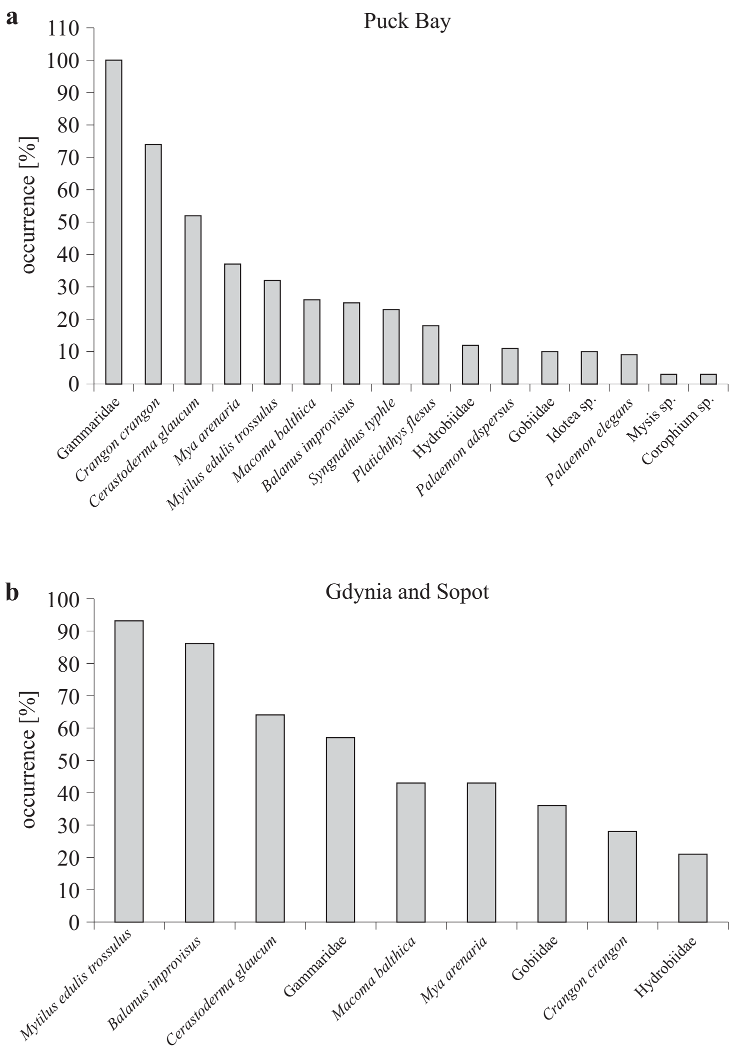

Figure 2. Frequency of organisms co-occurring with *Rhithropanopeus harrisii*: a) Puck Bay (17 sampling points), b) waters off Gdynia and Sopot (29 sampling points)

The work carried out in 2009 at depth profiles G and S showed that there were seasonal changes in the crab's distribution. The minimum water temperature at which *R. harrisii* was collected there was 2.9°C, and the maximum was no higher than 18.8°C. The number of specimens recorded rose with increasing temperature. Abundance was the highest in the summer months (June and July), when the water temperature ranged from 13.2 to 18.1°, and the lowest when the water temperature was ≤ 8.0°C (Figure 4).

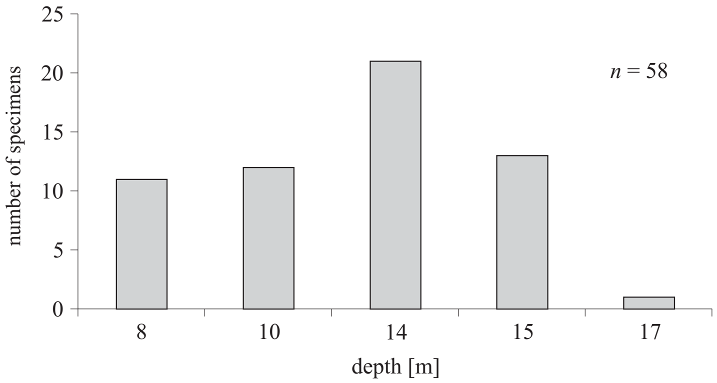

Figure 3. Number of *Rhithropanopeus harrisii* specimens found at different depths from January to September 2006 at two profiles – Gdynia (G) and Sopot (S) – in the Gulf of Gdańsk

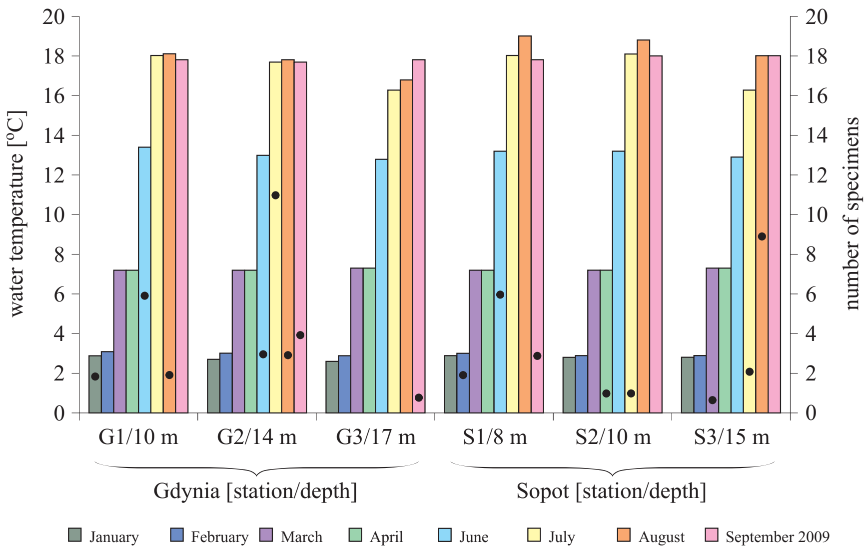

Figure 4. Number of *Rhithropanopeus harrisii* specimens (black dots) with respect to water temperature (coloured bars) collected from January to September 2009 at depth profiles Gdynia (G) and Sopot (S) in the Gulf of Gdańsk

In 2006–2010, a total of 920 specimens of *R. harrisii* were collected: 150 juveniles, 370 females and 400 males (Table 2). The minimum recorded carapace width was 1.96 mm, while the maximum was 21.40 mm (mean 9.03 ± 4.11 mm). The mean carapace width of females was 10.17 ± 3.50 mm, and of males 9.90 ± 3.97 mm (Table 2).

Table 2. Number of specimens with respect to sex, carapace width (range, mean ± standard deviation) of *Rhithropanopeus harrisii* collected in the Gulf of Gdańsk in 2006–2010

Year	Number of specimens			Carapace widith [mm]		Mean ± SD
	Juvenile	Female	Male	Min.	Max.	
2006	1	13	25	3.70	21.40	10.40 ± 4.04
2007	44	85	78	3.40	16.40	8.40 ± 3.64
2008	4	130	146	3.35	19.40	10.37 ± 3.21
2009	10	37	30	3.00	17.36	9.95 ± 3.18
2010	91	105	121	1.96	21.30	7.89 ± 3.84

4. Discussion

According to the International Union for Conservation of Nature, invasive species are a major threat to local biodiversity. Although in some areas, such as the Baltic Sea, their presence leads mostly to an increase in species diversity, in others it may seriously affect community composition and ecosystem functioning (Stachowicz et al. 2002, Levine et al. 2003, Dukes & Mooney 2004). Owing to its high tolerance to salinity and temperature variations, as well as its omnivority, *R. harrisii* has an extensive history as a world-wide invader (Mordukhay-Boltovskoy 1952, Szudarski 1963, Turoboyski 1973, Bacevičius & Gasiūnaitė 2008, Fowler et al. 2013). It should be therefore expected that under favourable conditions, the species will expand its territory from the sites where it has been introduced. Since the 2000s, this is the situation in the Gulf of Gdańsk. Already in 2002, males, females and juvenile individuals were recorded in the Sopot area on a regular basis (authors' own observations).

Over the five years of sampling, *R. harrisii* was present at the same depths, not exceeding 20 m. Moreover, this crab was recorded in shallow coastal areas at depths of a few centimetres along the beaches of Gdynia and Sopot (Halina Kendzierska and Karolina Zaborowska, pers. comm.). Individuals have also been recorded during diving surveys at 1 m depth (Anna Dziubińska, pers. comm.), as well as during dredging from a research vessel at greater depths. There have been similar situations in other parts of the world, where this species lives mostly in shallow estuaries and lagoons (Diamond et al. 1989, Gonçalves 1995, Roche et al. 2009). Our analyses also confirmed the patchy distribution of *R. harrisii* in the Gulf of Gdańsk, which may be the result of larval retention mechanisms (Cronin 1982, Cronin & Forward 1986, Projecto-Gracia et al. 2010). The population's low mobility and its variable occurrence have also been recorded in the Iberian Peninsula: *R. harrisii* was found only in the Mondego Estuary (central Portugal) and in the River Guadalquivir on the Atlantic south coast of Spain (Gonçalves et al. 1995). However, not only larval retention mechanisms affect the occurrence and distribution of this species. Food availability, bottom structure and physico-chemical conditions determine the occurrence range of non-native species (Colautti & MacIsaac 2004, Galil et al. 2009). This is the case in the Gulf of Gdańsk, where the sampling points differ with regards to bottom composition, and various benthic community compositions, which can also determine the probable occurrence and density of *R. harrisii.*

Unfortunately, there are very scanty data in the extant literature on the abundance of *R. harrisii*, which makes comparison of our data difficult. The only available information relates to the shallow brackish-water limans (coastal lagoons) of the Sea of Azov (Zaitsev & Öztürk 2001). Compared to these habitats, the density of the mud crab estimated in Puck Bay was significantly lower. It also has to be pointed out that the application of different sampling methods makes comparison hard. In the majority of studies baited traps were used (e.g. Rychter 1999, Roche & Torchin 2007, Czerniejewski et al. 2009, Roche et al. 2009).

The large variety of benthic species occurring in Puck Bay that constitute established food items of the Harris mud crab's diet, especially gammarids (Czerniejewski & Rybczyk 2009, Hegele-Drywa & Normant 2009), may partly explain the highest density recorded in this region. The lowest density of mud crabs was reported near Gdynia and Sopot, on a bottom covered by mussels and barnacles, where gammarids are frequent. This is somewhat surprising, because both mussels and barnacles can offer the mud crab perfect concealment and, together with the gammarids, suitable food resources (Czerniejewski & Rybczyk 2009, Hegele-Drywa & Normant 2009). *R. harrisii* was not recorded only in the vicinity of Gdańsk, where the most common organisms were *C. crangon* and *C. glaucum.* It seems that Harris mud crabs prefer muddy substrates, where they hide in shells or debris, and do not find suitable conditions on relatively hard, sandy bottoms (Turoboyski 1973, Galil et al. 2011). In addition, this region is subject to the inflows from the River Vistula, which frequently change the physical and chemical parameters of the water, especially after the spring floods (Buszewski et al. 2005).

Harris mud crabs collected in the Gulf of Gdańsk were characterised by a similar carapace width range as the specimens collected in other regions, such as the Dead Vistula, the Vistula Lagoon or the Odra Estuary. Rychter (1999) made very similar observations for the Vistula Lagoon population (Rychter 1999, Normant et al. 2004, Czerniejewski 2009). The size distribution of the Gulf of Gdańsk population exhibits a normal pattern, but worth noting nonetheless is the presence of a large number of juveniles. In 2009–2010, juveniles were dominant in the samples, their abundance exceeding 31% of the total number of individuals collected. Such a high number of juveniles has never been recorded in any of the analysed populations from other regions. Juvenile specimens have been reported but never at abundances exceeding 10% of the sampled individuals (Ryan 1956, Roche & Torchin 2007). On the one hand, the presence of such a large number of juveniles may be due to dredging instead of using baited traps, but on the other it may indicate a demographic expansion of the population under scrutiny. During dredging, small specimens are trapped between other material, whereas in the case of baited traps, only larger individuals, actively looking for food are usually caught (Miller 1990).

Temperature in the Gulf of Gdańsk exhibits seasonal variations up to 20°C (Piliczewski 2001). This factor appears to be significant in determining the occurrence of *R. harrisii*, as observed in other poikilothermic organisms living in the temperate zone (Schmidt-Nielsen 1997). On the other hand, the greater depth range of the Gulf of Gdańsk gives the crab the opportunity of remaining in its preferred temperature longer than in shallow waters. This has been confirmed by seasonal studies demonstrating that the species migrates to other depths in response to changes in the water temperature. The abundance of *R. harrisii* increases in the summer months and decreases in the winter. A similar pattern was observed in the Dead Vistula and the Odra Estuary population (Turoboyski 1973, Czerniejewski 2009). The changes in distribution are likely to be caused by the mud crab's habit of overwintering, when the animals bury into the bottom sediment or hide between the shells (authors' own observations) and remain inactive. This behaviour probably accounts for the apparent absence of crabs in their natural habitat during winter (Turoboyski 1973, Czerniejewski 2009). On the other hand, at water temperatures within the 18.1–19.1°C range no specimens were recorded either. This could be due to the mud crab's migration to even warmer shallow coastal waters for reproduction and moulting, as observed by Turoboyski (1973). He reported large numbers of crabs in the shallow bays of the Dead Vistula during the summer. The optimum for egg laying and embryonic development lies at temperatures above 20°C (Kujawa 1957, Christiansen & Costlow 1975, Gonçalves et al. 1995, Forward 2009).

In an ecosystem context, it is crucial to know where non-native species occur and how they are distributed. It can be inferred from the results of this study that *R. harrisii* is now a quite widely, though patchily, distributed and well-established component of the benthic communities in the Gulf of Gdańsk. On the one hand this situation could be due to larval retention mechanisms, but on the other it may be determined to a significant extent by tolerance of environmental factors and the community in which the species lives. The *R. harrisii* population inhabiting the Gulf of Gdańsk has a strong reproductive potential, which has been demonstrated by the increasing numbers of juvenile individuals. In addition, the stable salinity lowers the metabolic costs associated with osmoregulation with respect to those in oligohaline waters (Normant & Gibowicz 2008). Therefore, more energy is available for growth and reproduction.

The depth-related thermal conditions, the stable salinity as well as the permanent availability of food in the Gulf of Gdańsk lead to the conclusion that this basin offers favourable conditions for the life and development of *R. harrisii*. Although at present *R. harrisii* does not pose a threat to the local aquatic community, its rate of spreading and population dynamics patterns have to be monitored. It should be kept in mind that despite its small size, *R. harrisii* is a non-native, omnivorous organism, with a high reproductive potential. Therefore, its possible effects on the aquatic habitat and community of the Gulf of Gdańsk have to be assessed; this is the aim of further research on *R. harrisii* inhabiting the Gulf of Gdańsk (Hegele-Drywa et al. in prep.).

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