

**Population structure,
morphometry and
individual condition of
the non-native crab
Rhithropanopeus harrisi
(Gould, 1841), a recent
coloniser of the Gulf of
Gdańsk (southern Baltic
Sea)***

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Abstract

The aim of this study was to characterise the introduced North American Harris mud crab *Rhithropanopeus harrisi*, which occurs in the Gulf of Gdańsk, Poland (southern Baltic Sea). Of the 920 specimens caught between 2006 and 2010, males and females made up 44 and 40% respectively, whereas juveniles (< 4.4 mm carapace width) comprised 16%. Overall carapace widths ranged from 1.96 mm to 21.40 mm (mean 9.03 ± 4.11 mm). Ovigerous females (mean 11.12 ± 2.76 mm) were present in the population from June to October. Most of the adult specimens

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collected ($n = 158$) had carapace widths between 10.1 and 12.0 mm. The wet weight of *R. harrisii* varied from 0.005 to 4.446 g (mean 0.410 ± 0.569 g). Females exhibited a negative allometric increase in weight ($b = 2.77$), males an isometric increase in weight ($b = 3.02$). The condition factor (K) in *R. harrisii* varied from 0.02 to 0.08 (mean 0.05 ± 0.01).

1. Introduction

Biological invasions are ongoing processes that represent a growing problem, mostly due to the unpredictable impacts of non-native species (Floerl et al. 2005). Specific to marine systems, the risk of unintentional introductions of many species outside their native ranges has increased significantly owing to the rapid development of ship transport (Ruiz et al. 1997, Bij de Vatte et al. 2002). Brackish water, strong anthropogenic influence and a relatively small number of native species make the Baltic Sea conducive to harbouring many introduced species. Although the total number of alien species in the Baltic Sea has reached 119, only a few of them have been documented to negatively impact the environment and economy (Gollasch et al. 2011).

A recent newcomer to the Baltic Sea, the North American Harris mud crab *Rhithropanopeus harrisii* was probably introduced to European waters in ballast tanks (Wolff 1954, Rodriguez & Suarez 2001, Leppäkoski 2005, Projecto-Garcia et al. 2010) and was first recorded in the Netherlands in 1874 (Maitland 1874). Rapid colonisation over the past 130 years has led to established populations in Germany (Nehring & Leuchs 1999), Denmark (Jensen & Knudsen 2005), Poland (Demel 1953, Kujawa 1957, Michalski 1957), the Black and Caspian Seas (Zaitsev & Öztürk 2001), and most recently, Finland (Fowler et al. 2013) and Estonia (Kotta & Ojaveer 2012). In the last decade the sudden appearance of *R. harrisii* has been observed in many coastal sites of the Baltic Sea, for example, the Curonian Lagoon (Bacevičius & Gasiūnaitė 2008), the Odra River estuary (Czerniejewski & Rybczyk 2008, Czerniejewski 2009), the north-eastern Gulf of Riga (Kotta & Ojaveer 2012) and Finnish coastal waters (Fowler et al. 2013). In the Gulf of Gdańsk it was first noted in the 1960s, but since the early 2000s a reproducing population with abundances exceeding 19 indiv./100 m² has become established there (Hegele-Drywa & Normant 2014). Successful colonisation of new regions by *R. harrisii* was possibly due to this species' broad tolerance to abiotic factors, especially temperature and salinity, a broad omnivorous diet, a high rate of reproduction, and the presence of a pelagic larval stage that allows for long-distance transport in ballast waters (Turoboyski 1973, Gollasch & Leppäkoski 1999, Normant & Gibowicz 2008, Forward 2009, Hegele-Drywa & Normant 2009).

Apart from one paper on its distribution and abundance (Hegele-Drywa & Normant 2014), no data has been published concerning the population structure of *R. harrisi* in the Gulf of Gdańsk. This information could be useful for the assessment and management of non-indigenous species according to the European Commission Marine Strategy Framework Directive (Ojaveer et al. 2014). It should also be emphasised that many species colonise environments that are different from their native regions, which can result in the adaptation of a species' physiology or morphology, e.g. against predators, parasites, disease agents or competitors (Cox 2004, Paavola et al. 2005). Moreover, such adaptations have been recorded in populations separated by geographical barriers; they are exhibited by European populations of *R. harrisi*, which show patchy distribution patterns and genetic heterogeneity (Projecto-Garcia et al. 2010). In crustaceans, adaptations frequently encompass changes in morphology, e.g. in the size and shape of the carapace or chelipeds or in individual condition (Seed & Hughes 1995, Silva et al. 2010, Zimmermann et al. 2011, Hepp et al. 2012). Therefore, morphometric analyses are important for identification purposes, for assessing population health, fecundity and invasion potential, and for comparing crustacean populations (Gorce et al. 2006, Duarte et al. 2008, Sangun et al. 2009).

The present study describes the population structure and individual condition of the introduced population of *R. harrisi* in the Gulf of Gdańsk, Poland, based on animals collected between 2006 and 2010. We also estimate the relative growth of this population by analysing the biometric relationships between carapace (width and length) and the major chela (length and height). These data provide information about population growth, which is useful in monitoring and for predicting the expansion of this non-native species, as well as giving an opportunity to compare the different populations of the same species inhabiting different geographical locations.

2. Material and methods

Individuals of the North American Harris mud crab were collected between 2006 and 2010 from the Gulf of Gdańsk at randomly chosen sampling points (Hegele-Drywa & Normant 2014) (Figure 1).

Samples were taken with a bottom dredge (33 × 66 cm, mesh size 0.5 × 0.5 cm) from the r/v 'Oceanograf 2', at 129 randomly chosen sampling points located at depths from 5 to 60 m from 2006 to 2010 (Table 1). The single dredging time was 5 min at a vessel speed of 1.5 knots. CPUE was estimated for four people during five hours. Specimens were hand-sorted from the sampled material and frozen (−20°C) directly after collection.

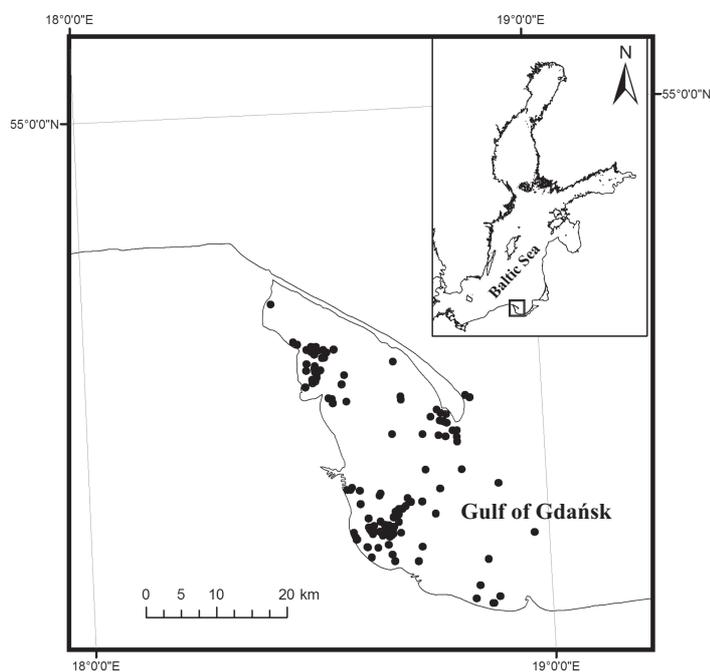


Figure 1. Sampling points in the Gulf of Gdańsk (2006–2010) (Hegele-Drywa & Normant 2014)

Table 1. Months in each year when *Rhithropanopeus harrisi* was sampled in the Gulf of Gdańsk

Year	Months of sampling
2006	VI, VIII, XI, XII
2007	III, VI, VII, VIII, XI
2008	I, II, III, IV, V, VI, VIII
2009	I, II, III, IV, VI, VII, VIII, IX
2010	II, IV, V, VI, VII, VIII

In the laboratory, the crabs were sexed on the basis of abdominal structure and pleopod shape (De Man 1892). Furthermore, during examination crabs were analysed for evidence of the external form of the rhizocephalan *Loxothylacus panopaei* (Gissler 1884). Specimens with a carapace width < 4.4 mm were classified as juveniles (Turoboyski 1973), and females with eggs attached to the pleopods were classified as ovigerous. Carapace width (CW) and length (CL) and major chela length (CHL) and height (CHH) were measured (± 0.01 mm) with slide calipers. Moreover, while

these measurements were being made, right vs. left claw dominance was determined. Growth ratios for the independent variable (CW) and dependent variables (CL, CHL) were determined by using the logarithmic transformation ($\log y = \log a + b \log x$) and the function $y = axb$, where x is the independent variable (CW), y is the dependent variable, a is the intercept (value of y when $x = 0$), and b the slope of the regression line. The value of b indicates the growth patterns of the variables: $b = 1$ (isometry), $b < 1$ (negative allometry), $b > 1$ (positive allometry) (Hartnoll 1982). The statistical significance of b was tested using Student's t -test.

After surface water had been blotted off the individual animals with soft tissue paper, their wet weight was measured with an accuracy of ± 0.001 g. They were then dried at 55°C to constant weight and reweighed. The crabs were divided into 2 mm carapace width classes. Some of the crabs were incomplete (e.g. with a missing walking leg or chela); therefore fewer specimens were used in a particular analysis (e.g. the carapace width-wet weight relationship) than the total number of specimens collected. Fulton's condition factor (K) was calculated for each individual according to the equation given by Nash et al. (2006):

$$K = 100 \times \text{WW}/\text{CW}^b,$$

where WW is the wet weight of an individual [g], CW is the carapace width [mm] and b is the regression coefficient of the carapace width-wet weight relationship.

Analyses were carried out using the STATISTICA 8.0 PL program.

3. Results

In 2006–2010 *Rhithropanopeus harrisii* was recorded at 69 out of 129 sampling points, at depths up to 20 m (Hegele-Drywa & Normant 2014). Of the 920 specimens caught males and females respectively comprised 44 and 40% of the entire population (sex ratio 1.1:1), whereas juveniles (< 4.4 mm carapace width) made up 16% ($n = 150$). The lowest number of specimens was collected in 2006 ($n = 39$) and the highest number in 2010 ($n = 317$). 55 females were ovigerous, (15% of the total number of females collected) and all were collected between June and October. The carapace width (CW) of all 920 *R. harrisii* individuals ranged from 1.96 to 21.40 mm (mean 9.03 ± 4.11 mm). There was no statistically significant difference ($p > 0.05$) in CW between females (range 4.41–19.41 mm; mean 10.17 ± 3.15 mm; $n = 370$) and males (4.41–21.40 mm; mean 9.90 ± 3.97 mm; $n = 400$).

Most of the adult crabs ($n = 158$) belonged to CW class 10.1–12.0 mm. Most females (40%; $n = 147$) were between 8.1–10.0 mm CW, while most males (33%; $n = 303$) were between 4.5 and 12.0 mm CW. Few males from

the largest size classes were collected (18.1–22.0 mm CW), and only males attained CW larger than 20.1 mm (Figure 2).

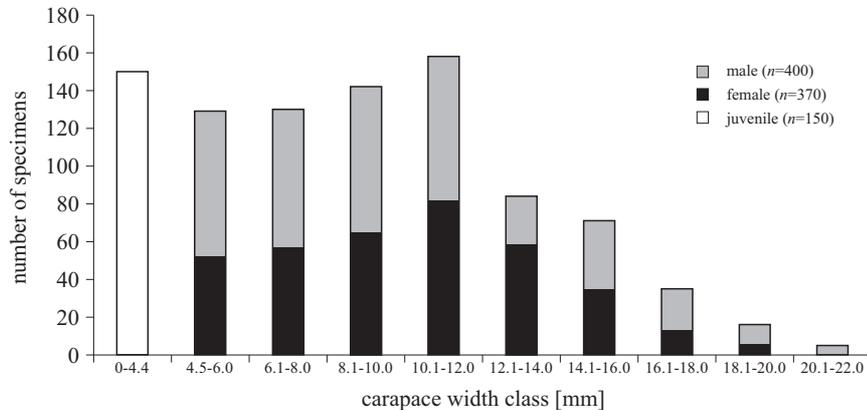


Figure 2. Carapace width class distribution of the mud crab *Rhithropanopeus harrisi* collected in the Gulf of Gdańsk between 2006 and 2010

The carapaces of the Harris mud crabs collected in the Gulf of Gdańsk were broader than they were long, showing isometric growth as described by the function $\log CL = -0.0325 + 0.9418 \log CW$ ($R^2 = 0.98$). Comparison of the relationships between carapace width and length in juveniles, females and males indicated a statistically significant difference ($p < 0.05$) between juvenile and adult specimens (Figure 3). The CL: CW ratio was equal to $1 : 1.19 \pm 0.06$ in juveniles and $1 : 1.22 \pm 0.07$ in both males and females.

Both males (91.5%) and females (97.7%) exhibited right claw dominance. Major chela length was significantly ($p < 0.05$) correlated with CW in males ($R^2 = 0.97$) and females ($R^2 = 0.95$, Figure 4). Males had significantly ($p < 0.05$) longer chela than females of the same CW. Moreover, both females and males showed positive allometric growth when major chela length (CHL) was compared to CW (Figure 4). The CHL: CW ratio amounted, on average, to $1 : 1.59 \pm 0.20$ in females and $1 : 1.50 \pm 0.20$ in males.

There was no significant difference ($p > 0.05$) between chela length (CHL) and height (CHH) in females and males of *R. harrisi*. The growth of the major chela can be described by the function $\log CHL = -0.3856 + 1.096 \log CHH$ ($R^2 = 0.94$). The CHH: CHL ratio in both sexes was $1 : 2.08 \pm 0.30$.

The wet weight of *R. harrisi* ranged between 0.005 and 4.446 g (average 0.410 ± 0.569 g; $n = 920$). Juvenile wet weight was from 0.005 to 0.065 g (mean 0.027 ± 0.010 g; $n = 97$), while females and males were heavier, as expected (females: range 0.027–2.395 g, mean 0.472 ± 0.438 g, $n = 276$; males: range 0.029–4.446 g, mean 0.531 ± 0.711 g, $n = 325$).

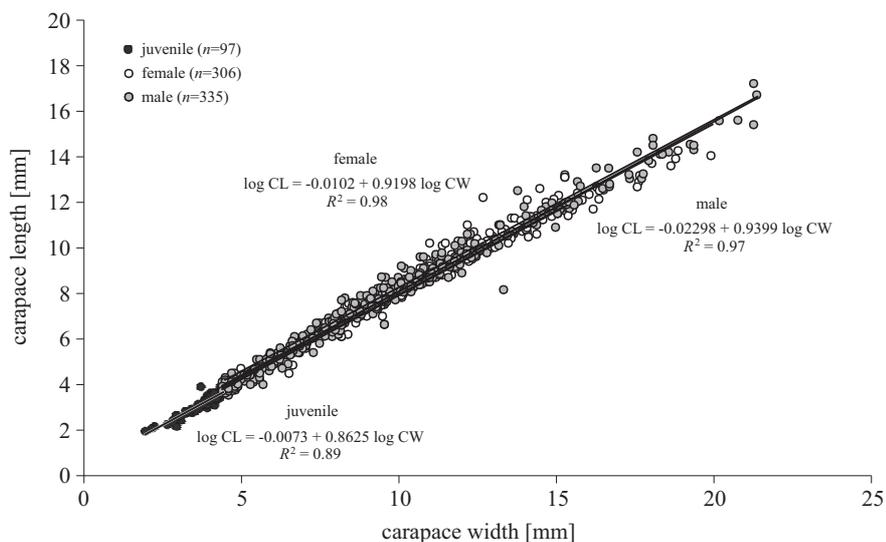


Figure 3. Relationships between carapace width and carapace length of juvenile, female and male *Rhithropanopeus harrisii* collected in the Gulf of Gdańsk between 2006 and 2010

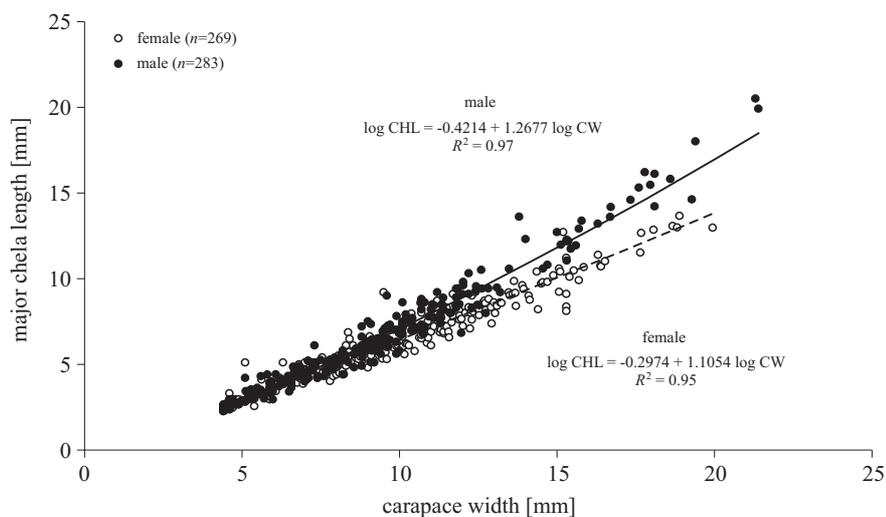


Figure 4. Relationship between carapace width and major chela length in females and males of *Rhithropanopeus harrisii* collected in the Gulf of Gdańsk between 2006 and 2010

Individual wet weight was significantly ($p < 0.05$) correlated with CW of females ($R^2 = 0.93$, $n = 276$) and males ($R^2 = 0.98$, $n = 325$). Females showed a negative allometric increase in weight with increasing CW ($b = 2.77$),

whereas males showed an isometric increase in weight with increasing CW ($b = 3.02$) (Figure 5). The CW : WW ratio for all specimens was determined by the function $CW = 0.0005 WW^{2.90}$ ($R^2 = 0.96$, $p < 0.05$).

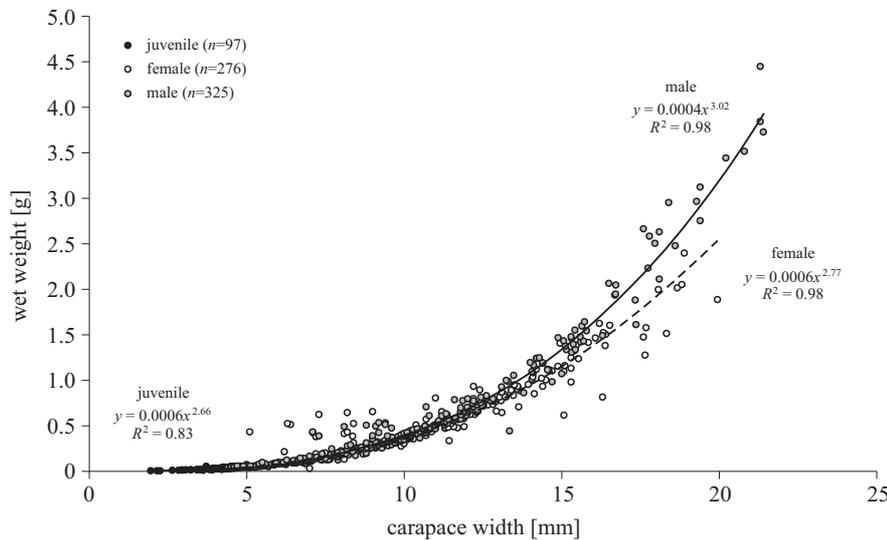


Figure 5. Relationship between carapace width and wet weight of juveniles, females and males of *Rhithropanopeus harrisi* collected in the Gulf of Gdańsk between 2006 and 2010

The condition factor K of all *R. harrisi* taken together varied from 0.02 to 0.08 (mean 0.05 ± 0.01 ; $n = 601$). In females ($n = 276$) it ranged from 0.03 to 0.08 (mean 0.06 ± 0.08), whereas in males ($n = 325$) it was significantly lower ($p < 0.05$), from 0.02 to 0.07 (mean 0.04 ± 0.06).

The water content in the mud crabs varied from 57.9 to 91.5% of the total body weight (mean $73.6 \pm 7.5\%$; $n = 248$), but this differed between juveniles and adults and between the sexes (juveniles: 65.1–87.5%, mean $74.1 \pm 5.5\%$, $n = 87$; females: 57.9–91.3%, mean $74.9 \pm 8.7\%$, $n = 79$; males: 58.6–91.5%, mean $71.8 \pm 7.9\%$, $n = 82$). The water content was not significantly related ($p > 0.05$) to carapace width (CW), although there were statistically significant differences ($p < 0.05$) in water content between both sexes and between males and juveniles.

4. Discussion

Invasive species, for many reasons such as their broad environmental tolerances, can reduce native biological diversity and even become dominant organisms in non-native regions by replacing or coexisting with indigenous species (Ba et al. 2010). Although *Rhithropanopeus harrisi* has been present

in the Gulf of Gdańsk for at least a decade, its negative influence on native species has been not reported (Hegele-Drywa & Normant 2014).

Between 2006 and 2010, over 200 specimens of *R. harrisii* were collected each year, except for 2006 and 2009. In 2006, sampling started later than usual, and in 2009, in order to obtain information on seasonal variations in crab abundance, the material was collected from only two depth profiles (see Hegele-Drywa & Normant 2014).

Sexually mature specimens dominated the samples, and the sex ratio was skewed slightly towards more males: this has been observed in other populations inhabiting Polish waters (i.e. the Dead Vistula River, the Vistula Lagoon and the Odra Estuary) (Turoboyski 1973, Rychter 1999, Normant et al. 2004, Czerniejewski & Rybczyk 2008, Czerniejewski 2009), Chesapeake Bay (Ryan 1956) and the Panama Canal (Roche & Torchin 2007). The dominance of males over females occurs frequently in crab populations, including other species from the Xanthidae family (De Goes & Fransozo 2000, Warburg et al. 2012). According to Morgan et al. (1988) this is normal in natural environments, but for high spawning rates it is more advantageous when there is a higher proportion of females. Laboratory studies showed that *R. harrisii* spawning was greater when males were less abundant than females, perhaps because a few males can mate with many females (de Rivera et al. 2003). Additionally, females would be less vulnerable to attack by more aggressive males while moulting (Morgan et al. 1988).

In 2009–2010 juveniles (< 4.4 mm CW) dominated the samples, and their abundance contributed to almost one-sixth of all individuals collected. Such a high number of juveniles has never been recorded in any of the populations from other regions. Juvenile specimens were reported but never at abundances exceeding 10% of all the individuals sampled (e.g. Ryan 1956, Rychter 1999, Roche & Torchin 2007, Fowler et al. 2013). Even though both Roche & Torchin (2007) and Fowler et al. (2013) regard juveniles as specimens with CW < 2.5 mm, their data should be taken into account, because according to López-Greco & Rodríguez (1999) and Luppi et al. (2004) acquiring maturity is a long process. Moreover, functional, gonadal and morphometric maturities are not always synchronised and can be reached at different stages of growth. In addition, our particular method of collection, the bottom dredge, could have contributed to the large abundance of smaller individuals as this method traps small, cryptic specimens hidden among other organisms (e.g. blue mussels or macrophytes). A high abundance of smaller individuals may indicate the reproductive success of *R. harrisii* in the Gulf of Gdańsk, and as a consequence, explain the demographic expansion of the target population.

According to Gonçalves et al. (1995), *R. harrisi* larvae are produced from April to September in temperate areas. In the Gulf of Gdańsk, ovigerous females of *R. harrisi* were found between June and October, just like the population inhabiting Finnish coastal waters (Fowler et al. 2013). Compared to other studies in the southern Baltic Sea (i.e. the Dead Vistula River or the Vistula Lagoon), females in the Gulf of Gdańsk appear to produce egg masses earlier and retain them later than other populations (Turoboyski 1973, Rychter 1999, Normant et al. 2004). While the differences may result from the application of a diversity of sampling regimes (i.e. dredging instead of traps), this extended reproductive period could be due to several environmental factors. In the Gulf of Gdańsk, *R. harrisi* experiences much more stable sea surface temperatures as compared to the Dead Vistula River or the Vistula Lagoon, which are shallower areas that undergo rapid temperature changes (Majewski 1972, Kondracki 2002). These fast temperature changes have been shown to impact the zooplankton communities in the Dead Vistula (Paturej & Kruk 2011).

Many crab species, including *R. harrisi*, exhibit sexual dimorphism with males attaining larger sizes than females – this has been observed in *R. harrisi* populations in the Dead Vistula River and the Odra Estuary (Normant et al. 2004, Czerniejewski 2009). However, in the Gulf of Gdańsk population and other populations inhabiting Finland (introduced) and Louisiana (native), there were no significant size differences between the sexes (Fowler et al. 2013). The biggest male found in the Gulf of Gdańsk was smaller than the biggest males from other populations inhabiting Polish waters (Table 2). On the other hand, the largest female found in the Gulf of Gdańsk was larger than the largest females from other populations inhabiting Polish waters, with the exception of females found in the Odra Estuary (Table 2). The mean carapace length of specimens from the Gulf of Gdańsk was lower than that reported by Normant et al. (2004) and Czerniejewski (2009) for specimens from the Dead Vistula and Odra Estuary respectively. *R. harrisi* from the Gulf of Gdańsk is also larger than specimens from native regions (Williams 1984, Table 2). According to Fowler et al. (2013), this might be due to favourable growing conditions or the lack of parasites, which may allow crabs to invest more energy in growth and reproduction. The carapace width of adult specimens of *R. harrisi* from the Gulf of Gdańsk is 1.2 times greater than its length: this corroborates the observations by Czerniejewski (2009) for specimens inhabiting the Odra Estuary. On the other hand, the ratio of carapace width to carapace length is lower than the ratio of 1.3:1 given by Żmudziński (1961) and Normant et al. (2004) from the Dead Vistula.

Table 2. Carapace width (minimum, maximum and mean \pm SD) with respect to sex of the Harris mud crab *Rhithropanopeus harrisi* from various regions (adapted from Fowler et al. 2013)

Carapace width [mm]								Region of occurrence	References
males				females					
<i>n</i>	min	max	mean \pm SD	<i>n</i>	min	max	mean \pm SD		
Polish waters									
637	4.40	26.10	11.32 \pm 3.49	555	4.40	19.00	10.76 \pm 2.43	Dead Vistula River, Poland	Turoboyski (1973)
733	2.90	21.90	11.27 \pm 4.43	372	1.90	16.10	9.23 \pm 3.14	Vistula Lagoon, Poland	Rychter (1999)
149	5.60	22.90	16.81 \pm 3.98	115	5.30	19.80	15.05 \pm 3.33	Odra River estuary, Poland	Czerniejewski (2009)
400	4.41	21.40	9.90 \pm 3.97	370	4.41	19.41	10.17 \pm 3.15	Gulf of Gdańsk, Poland	present study
Other regions									
572	4.10	14.60	8.04 \pm 2.31	391	4.40	12.60	7.25 \pm 1.31	Chesapeake Bay, USA	Ryan (1956)
45	3.10	17.70	9.3	19	4.90	10.90	8.0	Panama Canal	Roche & Torchin (2007)
532	1.80	12.80	4.39 \pm 2.38	591	1.80	15.40	4.29 \pm 2.03	Louisiana, USA	Fowler et al. (2013)
239	2.21	22.0	7.14 \pm 5.29	234	2.07	20.21	6.61 \pm 4.10	Archipelago Sea, Finland	Fowler et al. (2013)

The majority of adult individuals had $CW = 10.1\text{--}12.0$ mm, which is similar to the observations by Rychter (1999) and Normant et al. (2004) in the Vistula Lagoon and the Dead Vistula. However, in the Odra estuary, the majority of *R. harrisii* individuals were much larger with $CW = 14.1\text{--}20.0$ mm. The size of the sampled Harris mud crabs could depend on the sampling gear used or on the sampling season, which is closely linked with reproduction or moulting periods as well as foraging behaviour. On the other hand, differences in carapace dimensions (e.g. carapace length) or sex ratio were also observed in other crab species inhabiting distant locations (Czerniejewski 2010, Mantelatto et al. 2010, Srijaya et al. 2010).

In many brachyuran crabs the major chela is on the right-hand side of the body (Abby-Kalio & Warner 1989, Seed & Hughes 1995). The proportion of right-dominant Harris mud crab females and males in the Gulf of Gdańsk population was greater than that reported from native populations in the Choptank River in the USA (Milke & Kennedy 2001) and from non-native populations in the Odra Estuary (Czerniejewski 2009). Major chela length compared to carapace width is one of the features of sexual dimorphism in some crustaceans. Males of *R. harrisii* had significantly longer chela than females of the same carapace width. Moreover, the major chela length was twice as long as the major chela height. The male crab can use the dominant chela as a weapon, in addition to its feeding function (Mariappan et al. 2000, Fransozo et al. 2003, Costa & Soares-Gomes 2008). However, a few specimens, both females and males, were characterised by shorter (regenerated) major chela. The loss of a chela in males could be due to competition, whereas female chelae loss is most probably a consequence of moulting (Matheson & Gagnon 2012). The width of the major chela in females from the Gulf of Gdańsk was slightly greater (by about 7%) than in females from the Choptank River (USA); males from the Gulf of Gdańsk exhibited a shorter major chelae width than native males (by about 7%) (Milke & Kennedy 2001).

The wet weight (WW) of *R. harrisii* inhabiting the Gulf of Gdańsk was sexually dimorphic and differed significantly between the sexes; this has been shown for other crab species (Fransozo et al. 2003, Czerniejewski & Wawrzyniak 2006, Pinheiro & Hattori 2006). According to Fransozo et al. (2003), this could be due to a difference in energy allocation resulting from reproductive differences (i.e. females cannot attain the larger sizes or heavier weights of males owing to the larger energy requirements of egg production). In some crab species, this weight difference is due to the males' positive allometric growth of chelipeds (Pinheiro & Hattori 2006). According to Turoboyski (1973), *R. harrisii* male claw weight accounts for up to 64.0% of the total body weight, whereas female claws contribute only

11.1 to 28.0% to the total body weight. This may also explain why males of *R. harrisii* were heavier than females of the same carapace width.

However, a few individual females were outliers and exhibited either higher or lower wet weights in regard to the power function fitted to the empirical points of this CW:WW relationship. A greater wet weight might be observed prior to the female laying eggs when the gonads are heavy; a lower wet weight could indicate that the female had already produced an egg mass and the eggs had hatched. Moreover, individual variation in wet weight could also be influenced by differential stomach fullness.

According to Le Cren (1951), the condition factor can provide important information about the 'well-being' of a species and can indicate such aspects as recent feeding conditions and the degree of adjustment to the environment. Based on the condition factor, *R. harrisii* females from Gulf of Gdańsk are in better condition than males even though the males in this population grow faster than females of the same carapace width as a consequence of isometric weight gain. While most studies show a higher condition factor for males (Emmanuel 2008, Mohapatra et al. 2010, Patil & Patil 2012), the condition factor is known to be species-specific and can also vary between populations with female gonadal development and time of year (Branco & Masunari 2000, Pinheiro & Fiscarelli 2009). Some crustacean females increase the weight/volume of the hepatopancreas, the gland responsible for the storage and transport of energy reserves to the ovaries during vitellogenesis (Hæfner & Spaargaren 1993). Therefore, in some crab populations like swimming crabs (*Callinectes danae*, *Dilocarcinus pagei*) or West African blue crabs (*Callinectes pallidus*), the condition factor for females was higher than males (Branco & Masunari 2000, Pinheiro & Taddei 2005, Oluwatoyin et al. 2013). *R. harrisii* males also had a higher water content than females and juveniles, which could additionally affect their condition factor. The average water content in specimens from the Gulf of Gdańsk was significantly higher than in specimens from the Dead Vistula and the Vistula Lagoon (Rychter 1999, Normant et al. 2004). It is known that the water content in crab tissues is not only species-specific, but can also exhibit interpopulational variability (Normant et al. 2000, Balasubramanian & Suseelan 2001).

It seems that, in the Gulf of Gdańsk, *R. harrisii* has established a stable population in favourable living conditions that enable its successful development; this is manifested by the growing number of specimens collected (Hegele-Drywa & Normant 2009, 2014). The high number of smallest-size specimens indicates the reproductive success of *R. harrisii* in this region. The Harris mud crab population from the Gulf of Gdańsk revealed similar morphometric features (e.g. carapace width, wet weight)

like other European populations and, because of the lack of parasites, achieves greater carapace widths than specimens from its native regions. Additionally, based on the condition of specimens inhabiting the Gulf of Gdańsk, which was similar to that in specimens from a self-sustainable population established over 60 years ago, it might be assumed that this species is likely to expand its distribution range along the Baltic coast. Therefore, more detailed studies of the ecology of this species are needed in order to explore the possible influence of this species on the aquatic habitat and community of the Gulf of Gdańsk.

References

- Abby-Kalio N. J., Warner G. F., 1989, *Heterochely and handedness in the shore crab *Carcinus maenas* (L.) (Crustacea: Brachyura)*, Zool. J. Linn. Soc.-Lond., 96 (1), 19–26, <http://dx.doi.org/10.1111/j.1096-3642.1989.tb01819.x>.
- Ba J., Hou Z., Platvoet D., Zhu L., Li S., 2010, *Is *Gammarus tigrinus* (Crustacea, Amphipoda) becoming cosmopolitan through shipping? Predicting its potential invasive range using ecological niche modeling*, Hydrobiologia, 649 (1), 183–194, <http://dx.doi.org/10.1007/s10750-010-0244-5>.
- Bacevičius E., Gasiūnaitė Z. R., 2008, *Two crab species-Chinese mitten crab (*Eriocheir sinensis* Milne-Edwards) and mud crab (*Rhithropanopeus harrisi* Gould ssp. *Tridentatus* Maitland) in the Lithuanian coastal waters, Baltic Sea*, Trans. Wat. Bull., 2, 63–68.
- Balasubramanian C. P., Suseelan C., 2001, *Biochemical composition of the deep-water crab *Charybdis smithii**, Indian J. Fish., 48 (3), 333–335.
- Bij de Vaate A., Jażdżewski K., Ketelaars H. A. M., Gollasch S., van der Velde G., 2002, *Geographical patterns in the range extension of Ponto-Caspian macroinvertebrate species in Europe*, Can. J. Fish. Aquat. Sci., 59 (7), 1159–1174, <http://dx.doi.org/10.1139/f02-098>.
- Branco J. O., Masunari S., 2000, *Reproductive ecology of the blue crab *Callinectes danae* Smith, 1869 in the Conceição lagoon system, Santa Catarina Isle, Brazil*, Rev. Brasil. Biol., 60 (1), 17–27.
- Costa T., Soares-Gomes A., 2008, *Relative growth of the fiddler crab *Uca rapax* (Crustacea: Decapoda: Ocypodidae) in a tropical lagoon (Itaipu), Southeast Brazil*, Pan-American J. Aquat. Sci., 3 (2), 94–100.
- Cox G. W., 2004, *Alien species and evolution: the evolutionary ecology of exotic plants, animals, microbes, and interacting native species*, Island Pr., 400 pp.
- Czerniejewski P., 2009, *Some aspects of population biology of the mud crab, *Rhithropanopeus harrisi* (Gould, 1841) in the Odra estuary, Poland*, Oceanol. Hydrobiol. Stud., 38 (4), 49–62.
- Czerniejewski P., 2010, *Changes in condition and in carapace length and width of the Chinese mitten crab (*Eriocheir sinensis* H. Milne Edwards, 1853) harvested in the Odra River estuary in 1999–2007*, Oceanol. Hydrobiol. Stud., 39 (2), 25–36, <http://dx.doi.org/10.2478/v10009-010-0017-5>.

- Czerniejewski P., Rybczyk A., 2008, *Body weight, morphometry, and diet of the mud crab Rhithropanopeus harrisi tridentatus (Maitland, 1874) in the Odra Estuary, Poland*, Crustaceana, 81 (11), 1289–1299, <http://dx.doi.org/10.1163/156854008X369483>.
- Czerniejewski P., Wawrzyniak W., 2006, *Body weight, condition and carapace width and length in the Chinese mitten crab (Eriocheir sinensis H. Milne-Edwards, 1853) collected from the Szczecin Lagoon (NW Poland) in spring and autumn 2001*, Oceanologia, 48 (2), 275–285.
- De Goes Y. M., Fransozo A., 2000, *Sex ratio analysis in Eriphia gonagra (Decapoda, Xanthidae)*, Inheringia Zool., 88, 151–157.
- De Man J. G., 1892, *Carcinological studies in the Leyden Museum*, Notes Leyden Mus., 14, 225–264.
- Demel K., 1953, *Nowy gatunek w faunie Bałtyku*, Kosmos, 2, 105–106.
- De Rivera C. E., Backwell P. R. Y., Christy J. H. C., Vehrencamp S. L., 2003, *Density affects female and male mate searching in the fiddler crab, Uca beebei*, Behav. Ecol. Sociobiol., 53, 72–83.
- Duarte M. S., Maia-Lima F. A., Molina W. F., 2008, *Interpopulational morphological analyses and fluctuating asymmetry in the brackish crab Cardisoma guanhumi Latreille (Decapoda, Gecarcinidae), on the Brazilian Northeast coastline*, Pan-American J. Aquat. Sci., 3 (3), 294–303.
- Emmanuel B. E., 2008, *The fishery and bionomics of the swimming crab, Callinectes amnicola (DeRocheburne, 1883) from a tropical lagoon and its adjacent creek, South West, Nigeria*, J. Fish. Aquat. Sci., 3 (2), 114–125.
- Floerl O., Inglis G. J., Hayden B. J., 2005, *A risk-based predictive tool to prevent accidental introductions of nonindigenous marine species*, Environ. Manage., 35 (6), 765–778, <http://dx.doi.org/10.1007/s00267-004-0193-8>.
- Forward Jr. R. B., 2009, *Larval Biology of the Crab Rhithropanopeus harrisi (Gould): a synthesis*, Biol. Bull., 216 (3), 243–256.
- Fowler A. E., Forsström T., von Numers M., Vesakoski O., 2013, *The North American mud crab Rhithropanopeus harrisi (Gould, 1841) in newly colonized Northern Baltic Sea: distribution and ecology*, Aquat. Inv., 8 (1), 89–96, <http://dx.doi.org/10.3391/ai.2013.8.1.10>.
- Fransozo A., Garcia R. B., Mantelatto F. L. M., 2003, *Morphometry and sexual maturity of the tropical hermit crab Calcinus tibicen (Crustacea, Anomura) from Brazil*, J. Nat. Hist., 37 (3), 297–304, <http://dx.doi.org/10.1080/713834686>.
- Gissler C. F., 1884, *The crab parasite, Saccilina*, Am. Nat., 18 (3), 225–229, <http://dx.doi.org/10.1086/273608>.
- Gollasch S., David M., Leppäkoski E., 2011, *Pilot risk assessments of alien species transfer on intra-Baltic ship voyages*, Helsinki Comm. – Baltic Mar. Environ. Protect. Comm., HELCOM, 98 pp.
- Gollasch S., Leppäkoski E., 1999, *Initial risk assessment of alien species in Nordic coastal waters*, Nord. Counc. Minist., Copenhagen, 244 pp.

- Gonçalves F., Ribeiro R., Soares M. V. M., 1995, *Rhithropanopeus harrisi* (Gould), an American crab in the Estuary of the Mondego River, J. Crust. Biol., 15 (4), 756–762, <http://dx.doi.org/10.2307/1548824>.
- Gorce G., Erguden D., Sangun L., Cekic M., Alagoz S., 2006, *Width/length relationship of the blue crab (Callinectes spaidus Rathbun 1986) population living in Camlik Lagoon Lake (Yumurtalik)*, Pakistan J. Biol. Sci., 9 (8), 1460–1486, <http://dx.doi.org/10.3923/pjbs.2006.1460.1464>.
- Hæfner P. A. Jr., Spaargaren D. H., 1993, *Interactions of ovary and hepatopancreas during reproductive cycle of Crangon crangon (L.) I. Weight and volume relationships*, J. Crust. Biol., 13 (3), 523–531, <http://dx.doi.org/10.2307/1548792>.
- Hartnoll R. G., 1969, *Mating in Brachyura*, Crustaceana, 161–181, <http://dx.doi.org/10.1163/156854069X00420>.
- Hegele-Drywa J., Normant M., 2009, *Feeding ecology of the American crab Rhithropanopeus harrisi (Crustacea, Decapoda) in the coastal waters of the Baltic Sea*, Oceanologia, 51 (3), 361–375, <http://dx.doi.org/10.5697/oc.51-3.361>.
- Hegele-Drywa J., Normant M., 2014, *Non-native crab Rhithropanopeus harrisi (Gould, 1984) – a new component of the benthic communities in the Gulf of Gdańsk (southern Baltic Sea)*, Oceanologia, 56 (1), 125–139, <http://dx.doi.org/10.5697/oc.56-1.125>.
- Hepp L. U., Fornel R., Restello R. M., Trevisan A., Santos S., 2012, *Intraspecific morphological variation in a freshwater crustacean Aegla Plana in Southern Brazil: effects of geographical isolation on carapace shape*, J. Crust. Biol., 32 (4), 511–518, <http://dx.doi.org/10.1163/193724012X630660>.
- Jensen K. R., Knudsen J., 2005, *A summary of alien marine benthic invertebrates in Danish waters*, Oceanol. Hydrobiol. Stud., 34 (Suppl. 1), 137–162.
- Kondracki J., 2002, *Regional geography of Poland*, Wyd. Nauk. PWN, Warszawa, 463 pp., (in Polish).
- Kotta J., Ojaveer H., 2012, *Rapid establishment of the alien crab Rhithropanopeus harrisi (Gould) in the Gulf of Riga*, Est. J. Ecol., 61, 4 pp., 293–298.
- Kujawa S., 1957, *Biology and culture of the crab Rhithropanopeus harrisi (Gould) subsp. tridentatus (Maitland) from Vistula Lagoon*, Wszechświat, 2, 57–59, (in Polish).
- Le Cren E. D., 1951, *The length-weight relationship and seasonal cycle in gonad weight and condition factor in the perch (Perca fluviatilis)*, J. Anim. Ecol., 20 (2), 201–219, <http://dx.doi.org/10.2307/1540>.
- Leppäkoski E., 2005, *The first twenty years of invasion biology in the Baltic Sea area*, Oceanol. Hydrobiol. Stud., 34 (Suppl. 1), 5–17.
- López-Greco L. S., Rodríguez E. M., 1999, *Annual reproduction and growth of adult crabs Chasmagnathus granulata (Crustacea, Brachyura, Grapsidae)*, Cah. Biol. Mar., 40, 155–164.

- Luppi T. A., Spivak E. D., Bas C. C., Anger K., 2004, *Molt and growth of an estuarine crab, Chasmagnathus granulatus (Brachyura: Varunidae), in Mar Chiquita coastal lagoon, Argentina*, J. Appl. Ichthyol., 20, 333–344, <http://dx.doi.org/10.1111/j.1439-0426.2004.00575.x>.
- Maitland R. T., 1874, *Naamlijst van Nederlandsche Schaaldieren*, Tijdschr. Nederl. Deirk. Ver., 1, 228–269.
- Majewski A., 1972, *Hydrological characteristics of Polish coastal estuary waters, Gdańsk*, PIHM, 105, 3–37, (in Polish).
- Mantelatto F. L., Fernandes-Góes L. C., Fanticci M. Z., Pardo L. M., de Góes J. M., 2010, *A comparative study of population traits between two South American populations of the striped-legged hermit crab Clibanarius vittatus*, Acta Oecol., 36 (1), 10–15, <http://dx.doi.org/10.1016/j.actao.2009.09.003>.
- Mariappan P., Balasundaram C., Schmitz B., 2000, *Decapod crustacean chelipeds: an overview*, J. Biosci., 25 (3), 301–313, <http://dx.doi.org/10.1007/BF02703939>.
- Matheson K., Gagnon P., 2012, *Effects of temperature, body size, and chela loss on competition for a limited food resource between indigenous rock crab (Cancer irroratus Say) and recently introduced green crab (Carcinus maenas L.)*, J. Exp. Mar. Biol. Ecol., 428, 49–56, <http://dx.doi.org/10.1016/j.jembe.2012.06.003>
- Michalski K., 1957, *Rhithropanopeus harrisii subsp. tridentata (Mtl.) in the Rivers Vistula and Mottawa*, Prz. Zool., 1 (1), 68–69, (in Polish).
- Milke L. M., Kennedy V. S., 2001, *Mud crabs (Xanthidae) in Chesapeake Bay: claw characteristics and predation on epifaunal bivalves*, Invert. Biol., 120 (1), 67–77, <http://dx.doi.org/10.1111/j.1744-7410.2001.tb00027.x>.
- Mohapatra A., Mohanty R. K., Mohanty S. K., Dey S. K., 2010, *Carapace width and weight relationships, condition factor, relative condition factor and gonadosomatic index (GSI) of mud crabs (Scylla spp.) from Chilika Lagoon, India*, Indian J. Mar. Sci., 39 (1), 120–127.
- Morgan S. G., Goy J. W., Costlow J. D., 1998, *Effect of density, sex ratio, and refractory period on spawning of the mud crab Rhithropanopeus harrisii in the laboratory*, J. Crust. Biol., 8 (2), 245–249, <http://dx.doi.org/10.2307/1548316>.
- Nash R. D. M., Valencia A. H., Geffen A. J., 2006, *The origin of Fulton's Condition Factor – setting the record straight*, Fisheries, 31 (5), 236–238.
- Nehring S., Leuchs H., 1999, *Rhithropanopeus harrisii (Gould, 1841) (Crustacea: Decapoda) – ein amerikanisches Neozoon im Elbeästuar*, Lauterbornia, 35, 49–51.
- Normant M., Gibowicz M., 2008, *Salinity induced changes in haemolymph osmolality and total metabolic rate of the mud crab Rhithropanopeus harrisii Gould, 1841 from Baltic coastal waters*, J. Exp. Mar. Biol. Ecol., 355 (2), 145–152, <http://dx.doi.org/10.1016/j.jembe.2007.12.014>.
- Normant M., Miernik J., Szaniawska A., 2004, *Remarks on the morphology and the life cycle of Rhithropanopeus harrisii tridentatus (Maitland) from the Dead Vistula River*, Oceanol. Hydrobiol. Stud., 33 (4), 93–102.

- Normant M., Wiszniewska A., Szaniawska A., 2000, *The Chinese mitten crab *Eriocheir sinensis* (Decapoda: Grapsidae) from Polish waters*, *Oceanologia*, 42 (3), 375–383.
- Ojaveer H., Galil B.S., Minchin D., Olenin S., Amorim A., Canning-Clode J., Chainho P., Copp G.H., Gollasch S., Jelmert A., Lehtiniemi M., McKenzie C., Mikuš J., Miossec L., Occhipinti-Ambrogi A., Pećarević M., Pederson J., Quilez-Badia G., Wijsman J.W.M., Zenetos A., 2014, *Ten recommendations for advancing the assessment and management of non-indigenous species in marine ecosystems*, *Mar. Policy*, 44, 160–165, <http://dx.doi.org/10.1016/j.marpol.2013.08.019>.
- Oluwatoyin A., Akintade A., Edwin C., Victor K., 2013, *A Study of length-weight relationship and condition factor of West African Blue Crab (*Callinectes pallidus*) from Ojo Creek, Lagos, Nigeria*, *Am. J. Res. Comm.*, 1 (3), 102–144.
- Paavola M., Olenin S., Leppäkoski E., 2005, *Are invasive species most successful in habitat of low native species richness across European brackish water seas?*, *Estuar. Coast. Shelf Sci.*, 64 (4), 738–750, <http://dx.doi.org/10.1016/j.ecss.2005.03.021>.
- Patil K.M., Patil M.U., 2012, *Length-weight relationship and condition factor of freshwater crab *Barytelphusa gurini*, (Decapoda, Brachyura)*, *J. Exp. Sci.*, 3 (5), 13–15.
- Paturej E., Kruk W., 2011, *The impact of environmental factors on Zooplankton communities in the Vistula Lagoon*, *Oceanol. Hydrobiol. Stud.*, 40 (2), 37–48.
- Pinheiro M.A.A., Taddei F.G., 2005, *Relationship between weight/carapace width and condition factor of *Dilocarcinus pagei* Stimpson (Crustacea, Trichodactylidae) from Preto River in São José, São Paulo, Brasil*, *Revis. Brasil. Zool.*, 22, 825–829, (in Portuguese).
- Pinheiro M.A.A., Hattori G.Y., 2006, *Relative growth of mangrove crab *Ucides cordatus* (Crustacea, Brachyura, Ocypodidae) at Iguape (SP), Brazil*, *Braz. Arch. Biol. Technol.*, 49 (5), 813–823, <http://dx.doi.org/10.1590/S1516-89132006000600016>.
- Pinheiro M.A.A., Fiscarelli A.G., 2009, *Length-weight relationship and condition factor of the mangrove crab *Ucides cordatus* (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae)*, *Braz. Arch. Biol. Technol.*, 52 (2), 397–406, <http://dx.doi.org/10.1590/S1516-89132009000200017>.
- Projecto-Garcia J., Cabral H., Schubart C.D., 2010, *High regional differentiation in a North American crab species throughout its native range and invaded European waters: a phylogeographic analysis*, *Biol. Invasions*, 12 (1), 253–263, <http://dx.doi.org/10.1007/s10530-009-9447-y>.
- Roche D.G., Torchin M.E., 2007, *Established population of the North American Harris mud crab, *Rhithropanopeus harrisi* (Gould 1841) (Crustacea: Brachyura: Xanthidae) in the Panama Canal*, *Aquat. Inv.*, 2 (3), 155–161, <http://dx.doi.org/10.3391/ai.2007.2.3.1>.

- Rodriguez G., Suarez H., 2001, *Anthropogenic dispersal of decapod crustaceans in aquatic environments*, Intersciencia, 26 (7), 282–288.
- Ruiz G. M., Carlton J. T., Grosholz E. D., Hines A. H., 1997, *Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences*, Integr. Comp. Biol., 37 (6), 621–632, <http://dx.doi.org/10.1093/icb/37.6.621>.
- Ryan E. P., 1956, *Observations on the life history and the distribution of the Xanthide (mud crabs) of Chesapeake Bay*, Am. Midl. Nat., 56 (1), 138–162, <http://dx.doi.org/10.2307/2422450>.
- Rychter A., 1999, *Energy value and metabolism of the mud crab Rhithropanopeus harrisi tridentatus (Crustacea, Decapoda) in relation to ecological conditions*, Ph.D. thesis, Univ. Gdańsk, Gdynia, 108 pp., (in Polish).
- Sangun L., Tureli C., Akamca E., Duysak O., 2009, *Width/length-weight and width-length relationships for 8 crab species from north-Mediterranean coast of Turkey*, J. Anim. Vet. Adv., 8 (1), 75–79.
- Seed R., Hughes R. N., 1995, *Criteria for prey size-selection in molluscivorous crabs with contrasting claw morphologies*, J. Exp. Mar. Biol. Ecol., 193 (1–2), 177–195, [http://dx.doi.org/10.1016/0022-0981\(95\)00117-4](http://dx.doi.org/10.1016/0022-0981(95)00117-4).
- Silva A. C., Silva I. C., Hawkins S. J., Boaventura D. M., Thompson R. C., 2010, *Cheliped morphological variation of the intertidal crab Eriphia verrucosa across shores of differing exposure to wave action*, J. Exp. Mar. Biol. Ecol., 391 (1–2), 84–91, <http://dx.doi.org/10.1016/j.jembe.2010.06.012>.
- Srijaya T. C., Pradeep P. J., Mithun S., Hassan A., Shaharom F., Chatterji A., 2010, *A new record on the morphometric variations in the populations of Horseshoe Crab (Carcinoscorpius rotundicauda Latreille) obtained from two different ecological habitats of peninsular Malaysia*, Our Nature, 8 (1), 204–211, <http://dx.doi.org/10.3126/on.v8i1.4329>.
- Turoboyski K., 1973, *Biology and ecology of the crab Rhithropanopeus harrisi ssp. tridentatus*, Mar. Biol., 23 (4), 303–313, <http://dx.doi.org/10.1007/BF00389338>.
- Warburg M. R., Davidson D., Yifrach H., Sayag L., Tichomirova Y., 2012, *Changes in population structure and body dimensions of two xanthid crabs: a long-term study in a single boulder-shore*, Arthropods, 1 (2), 40–54.
- Williams A. B., 1984, *Shrimps, lobsters, and crabs of the Atlantic Coast of the eastern United States, Maine to Florida*, Smith. Inst. Press, Washington D. C., 401–404.
- Wolff T., 1954, *Occurrence of two east American species of crabs in European waters*, Nature, 174 (4421), 188–189, <http://dx.doi.org/10.1038/174188a0>.
- Zaitsev Y., Öztürk B., 2001, *Exotic species in the Aegean, Marmara, Black, Azov and Caspian Seas*, Turkish Mar. Res. Foun., Istanbul, 265 pp.
- Zimmermann G., Bosc P., Valade P., Cornette R., Améziane N., Debat V., 2011, *Geometric morphometrics of carapace of Macrobrachium australe (Crustacea: Palaemonidae) from Reunion Island*, Acta Zool., 93 (4), 492–500, <http://dx.doi.org/10.1111/j.1463-6395.2011.00524.x>.

Żmudziński L., 1961, *Decapods of the Baltic Sea*, Prz. Zool., 5 (4), 352–360, (in Polish).