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# Some aspects of population biology of the mud crab, *Rhithropanopeus harrisii* (Gould, 1841) in the Odra estuary, Poland

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**Key words:** *Rhithropanopeus harrisii*, morphometry, condition, Odra river estuary, body weight.

## Abstract

The mud crab is the only non-indigenous xanthid encountered in the River Odra estuary. In 2007-2008, the crabs were collected, using fish traps, to determine sex and to follow variations in individual weight and carapace length and width over a year. Sex-dependent differences in the crab morphometry were studied as well. The largest catch was that obtained in September (23.48% of the total number of 264 individuals) and October (31.82%). Male crabs accounted for 56.44% of the total number; males dominated in autumn (September-December) and spring (March, May, June) catches. Males showed significantly wider carapaces (16.81 ±3.98 mm; range: 5.60-22.90 mm) and mean individual weight (2.15 ±0.94 g; range: 0.15-3.93 g) than females (mean carapace width of 15.05 ±3.33 mm; range: 5.30-19.80 mm, and mean individual weight of 1.47 ±0.60 g; range: 0.13-2.56 g). Of the 11 morphometric characters analyzed, expressed in relative values (%), related to the carapace width, males showed significantly larger claw dimensions ($CHL_1$, $CHW_1$, $CHH_1$, $CHL_2$, $CHW_2$, $CHH_2$) and smaller abdomen widths (AW).

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## INTRODUCTION

The mud crab is a native of the North-American coast of the Atlantic (Petersen 2006) where it inhabits brackish estuarine waters. Its range extends from Nova Scotia in Canada to the northern coast of the Gulf of Mexico along the coast of Florida. In Europe, the species was first reported in 1874 from the Dutch river Zuiderzee. From there, the crabs moved on to invade coastal waters of the Netherlands and Germany. In 1936, the mud crab migrated, via the Kiel Canal, to the Baltic Sea (Buitendijk and Holthuis 1949). Currently, *R. harrisii* is reported as a non-indigenous species in 21 different countries (Roche and Torchin 2007). In Poland, the mud crab was first recorded in 1951 in the Vistula Lagoon (Demel 1953). In the 1950s, the crab was also found in the Martwa Wisła (Dead Vistula), the Motława, and the coastal part of the Gulf of Gdańsk (Kujawa 1957, Turoboyski 1973, Normant et al. 2004). While those areas support a fairly abundant population of *R. harrisii*, population records in the Odra estuary have been only sporadically kept to date. In September and October of 2007, the mud crab was encountered there at an abundance higher than ever before, which made it possible to carry out a preliminary study on selected aspects of the species' feeding biology in the Odra estuary (Czerniejewski and Rybczyk 2008). A consistent sampling program, conducted in the subsequent months, supplied detailed biological and population biology-related data.

This work was aimed at determining the variability of biological characteristics (size and condition) as well as of those characteristics important for population biology (including sex ratio, carapace width, and individual weight) of the mud crab in the Odra estuary throughout the year. Morphometric characters of males and females were determined as well.

## MATERIALS AND METHODS

The study involved the examination of 264 mud crab individuals caught between September 1, 2007 and August 28, 2008 with 5 mm mesh size fish traps deployed in Lake Dąbie, in the southern part of the Szczecin Lagoon, and in the Międzyodrze waters (Fig. 1). The crabs were transported to the laboratory of the Department of Fisheries Management in Open Waters (West Pomeranian University of Technology, Szczecin, Poland) to be weighed (to 0.01 g) on electronic scales. The crabs were also sexed (sex was determined by examining abdominal structures, as proposed by Buitendijk and Holthuis (1949), and the following 11 measurements were taken (to ±0.1 mm) from each individual, in line with the measurement system for crabs presented by Czerniejewski et al. (2003, 2007): carapace length (CL), width (CW), and height (CH); right claw

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**Fig. 1.** Mud crab capture sites (red points) in the Odra estuary.

length ($CHL_1$), width ($CHW_1$), and height ($CHH_1$); left claw length ($CHL_2$), width ($CHW_2$), and height ($CHH_2$); abdomen length (AL) and width (AW) (Fig. 2). All measurements were taken with electronic callipers coupled with a computer and standardized by expressing them as a percentage of carapace width (CW) according to Tamone et al. (2007) and Czerniejewski et al. (2007). The data were processed statistically to calculate arithmetic means, standard deviations, and coefficients of variation. Differences in morphometric and biological characters between males and females were tested for significance with the Mann-Whitney *U*-test (Sokal and Rohlf 1995). The crab condition was

assessed from parameters of the carapace width-individual weight relationship, as in the formula:

$$W = aL^b$$

where:
W – individual weight (g);
L – carapace width (mm);
a, b – regression equation parameters calculated from empirical data.

In addition, to compare size distributions of males and females, the crabs were divided into 3-mm wide carapace width classes.

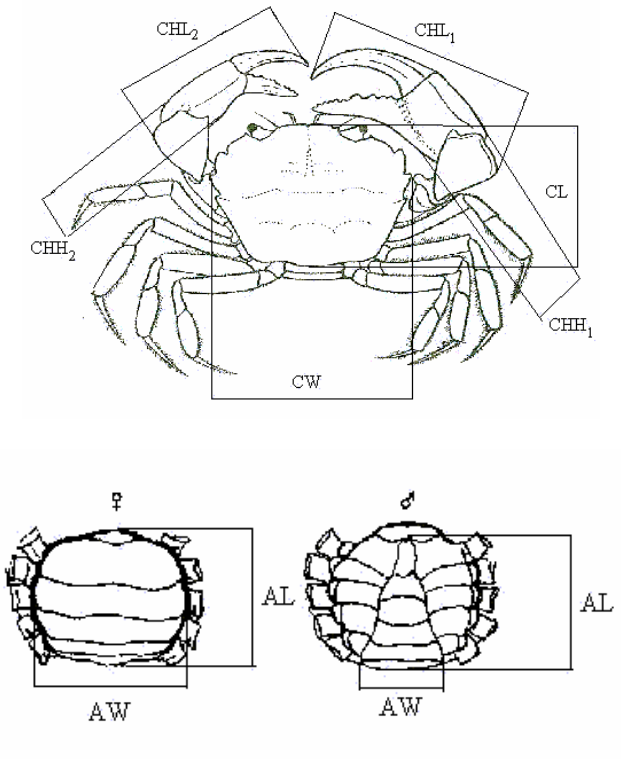


**Fig. 2.** A schematic of mud crab morphometric measurements (after Czerniejewski et al. 2003).

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## RESULTS

The Odra estuary mud crab sample showed a slightly skewed sex ratio, with 149 males (56.44%), and 115 females (43.56%). Not all females were ovigerous. The highest numbers of crabs were caught in September 2007 (23.48% of the total number caught) and October 2007 (31.82%) (Fig. 3). Males were found to dominate in catches obtained in autumn (September-December 2007) and spring (March, May, and June 2008). Females dominated in the August 2008 catch only (53.85%). This difference between females and males is not statistically significant ($p>0.05$).

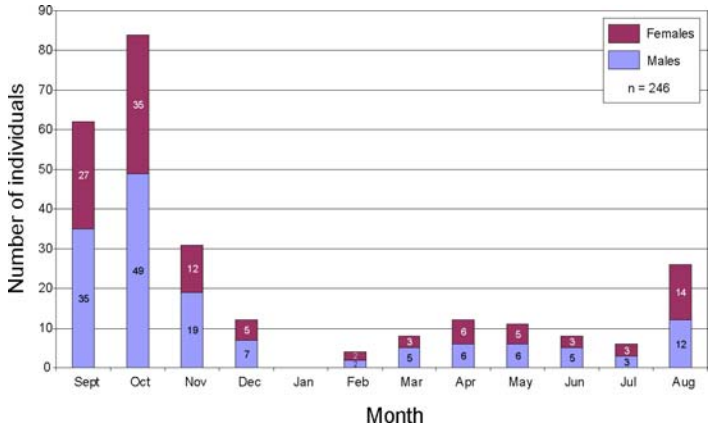


**Fig. 3.** Numbers of males and females of mud crabs caught in the Odra estuary in different months.

Table 1 provides data on carapace length and width and on individual weight. Statistical analysis showed that males and females do differ in their carapace width and individual weight ($p<0.001$) as well as in their carapace length ($p<0.05$).

**Table 1**

Ranges as well as mean values of carapace width, length, and individual weight of mud crab in the Odra estuary.

| Sex | n | Carapace width (mm) | | Carapace length (mm) | | Weight (g) | |
|---|---|---|---|---|---|---|---|
| | | Range | Mean ±std | Range | Mean ±SD | Range | Mean ±std |
| Female | 115 | 5.30-19.80 | 15.05* ±3.33 | 3.60-16.40 | 12.50 ±3.26 | 0.13-2.56 | 1.47* ±0.60 |
| Male | 149 | 5.60-22.90 | 16.81* ±3.98 | 3.90-19.00 | 13.81 ±3.49 | 0.15-3.93 | 2.15* ±0.94 |
| Total | 264 | 5.30-22.90 | 16.09 ±3.86 | 3.60-19.00 | 13.20 ±3.72 | 0.13-3.93 | 1.91 ±0.89 |

*- difference between males and females statistically significant ($p<0.05$)

The 264 individuals measured were dominated by 173 individuals assigned to classes 14.1-17.0 and 17.1-20.0 mm, which – taken together – accounted for 65.53% (Fig. 4). Females were most abundant in classes 14.1-17.0 mm (15.53%) and 17.1-20.0 (15.91%), while most males belonged to the class 17.1-20.0 (21.21%) (Fig. 4). The numbers of females and males assigned to individual carapace width classes was found to vary throughout the year (Fig. 5). In autumn (September 2007- December 2007), more crabs with carapaces 17.1-20.0 mm wide were observed. For example, from September 2007 to December 2007 the percent contribution of that crab group was found to vary from 24.35% to 45.24%, but in September small individuals (CW<8.0 mm) were found (3.23%). In addition, autumn catches were distinct in containing the highest proportion of the largest individuals, assigned to the carapace width class 20.1-23.0 mm. In November 2007 and December 2007, those crabs accounted for 16.12 and 25.0%, respectively (Fig. 5). Early in the year (February 2008 and March 2008), those individuals with carapace widths measuring 14.1-17.0 mm were most abundant (75.0% in February 2008, and 62.5% in March 2008). Young individuals with carapaces 5.0-8.0 mm wide occurred in catches obtained from July 2008 to August 2008 and accounted for 6.26-16.66% of all the crabs examined.

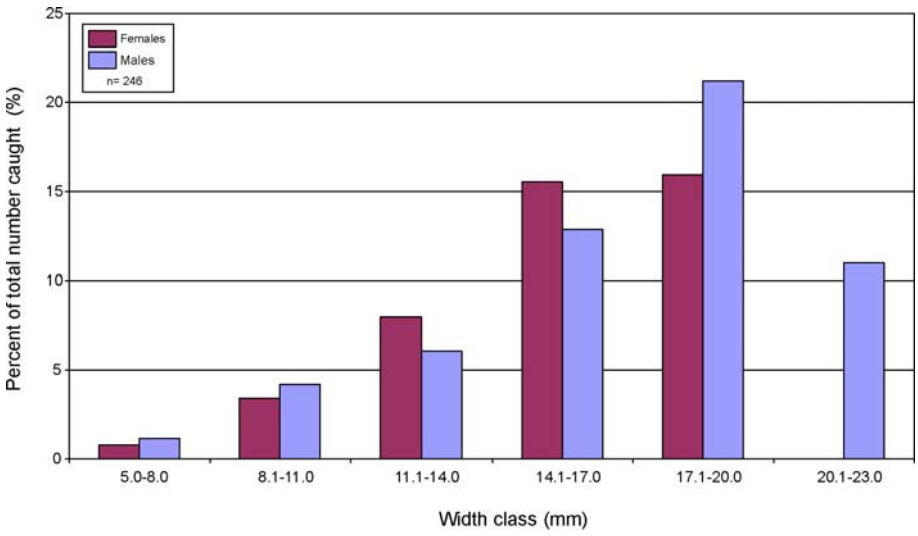


**Fig. 4.** Carapace width distribution of the mud crab in the Odra estuary.

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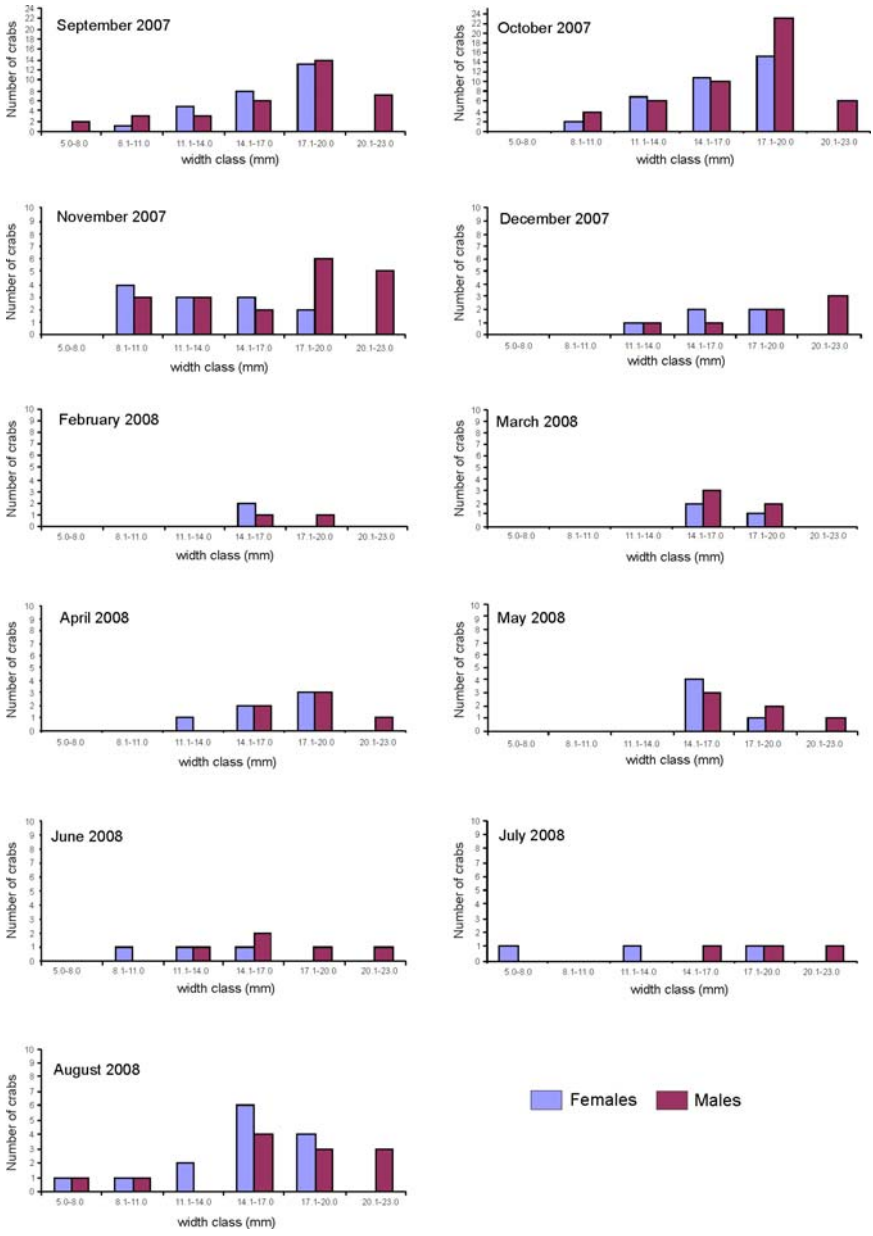


**Fig. 5.** Distribution of males and females of the mud crab in consecutive carapace width classes throughout the sampling period September 2007 - October 2008.

The mud crabs examined showed a fairly wide range of individual weight (Table 1), the variability being particularly pronounced in males (0.15-3.93 g) whose mean individual weight was statistically higher than that of females. Males were dominated by individuals weighing 2.51-3.00 g (16.7% of all individuals), and the highest proportion of females was found within the 1.51-2.00 g (13.89%) individual weight range.

Table 2 contains mean values, standard deviations, and coefficients of variation (CV) of morphometric characters (converted to percent carapace width) of the mud crabs examined. As shown by results of the Mann-Whitney *U*-test, males and females differed significantly in 7 metric characters; 6 of those metrics were related to claws ($CHL_1$, $CHW_1$, $CHH_1$, $CHL_2$, $CHW_2$, $CHH_2$) and one to abdomen width (AW). Males showed significantly larger claws and significantly narrower abdomens. Noteworthy are the high coefficients of variation (CV) in claw-related metrics, particularly in males. The variations stem most probably from the mud crab being heterochelous. The Odra estuary population was dominated, in both its male and female parts, by right-handed individuals (83.52 and 87.92%, respectively) which showed significantly higher (Mann-Whitney *U*-test, $p<0.05$) linear dimensions of the right-hand side of the body (Table 2).

**Table 2**

Mean values of morphometric characters expressed as % carapace width (CV – coefficient of variation) of the Odra estuary mud crab.

| Character | values of mophometric characters (mm) | | | | as % carapace width | | | |
|---|---|---|---|---|---|---|---|---|
| | females | | males | | females | | males | |
| | mean ±std | CV | mean ±std | CV | mean ±std | CV | mean ±std | CV |
| CL | 12.50 ±3.26 | 26.08 | 13.81 ±3.49 | 25.27 | 81.34 ±3.65 | 4.50 | 81.43 ±3.38 | 4.10 |
| CW | 15.05 ±3.33 | 22.13 | 16.81 ±3.98 | 23.68 | - | - | - | - |
| CH | 6.62 ±1.35 | 20.40 | 7.54 ±2.65 | 34.65 | 44.34 ±0.43 | 0.90 | 44.91 ±0.94 | 2.10 |
| $CHL_1$* | 10.02 ±2.12 | 21.13 | 11.07 ±2.86 | 26.23 | 65.87 ±3.54 | 5.40 | 78.20 ±11.31 | 14.50 |
| $CHW_1$* | 4.62 ±1.44 | 30.86 | 5.27 ±1.56 | 31.06 | 31.37 ±2.24 | 7.10 | 38.67 ±7.11 | 18.40 |
| $CHH_1$* | 2.95 ±0.95 | 31.03 | 3.38 ±1.53 | 42.12 | 20.12 ±1.58 | 7.80 | 24.86 ±4.40 | 17.70 |
| $CHL_2$* | 9.85 ±1.64 | 17.20 | 10.73 ±2.75 | 26.23 | 63.85 ±6.53 | 10.20 | 72.47 ±8.67 | 11.90 |
| $CHW_2$* | 4.45 ±1.12 | 24.32 | 4.79 ±1.64 | 32.11 | 28.47 ±4.23 | 14.90 | 34.03 ±6.31 | 18.50 |
| $CHH_2$* | 2.78 ±0.65 | 22.22 | 2.95 ±0.86 | 28.76 | 17.55 ±3.05 | 17.40 | 21.29 ±3.94 | 18.50 |
| AL | 7.21 ±1.09 | 15.36 | 7.78 ±1.21 | 15.86 | 46.31 ±4.54 | 9.80 | 43.99 ±4.15 | 9.40 |
| AW* | 6.87 ±1.10 | 14.39 | 7.54 ±1.03 | 13.42 | 44.83 ±2.79 | 6.20 | 34.80 ±3.56 | 10.20 |

*- difference between males and females statistically significant ($p<0.05$) in values of morphometric characters expressed as % carapace width

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Data from carapace width measurements and determination of individual weights of males and females were used to calculate parameters of the relationship between the two characters. As shown in Fig. 6, carapace width and individual weight were highly correlated, the coefficient of determination being significant ($R^2$=0.91 to 0.94, p<0.05). On the other hand, differences in exponential functions describing the relationships in males and females point to a slower growth of individual weight of females, compared to males (Fig. 6). The carapace width/specimen weight ratio for all mud crabs is determined by the function:

$$CW = 0.003W^{2.279}\left(R = 0.93; p < 0.5\right)$$

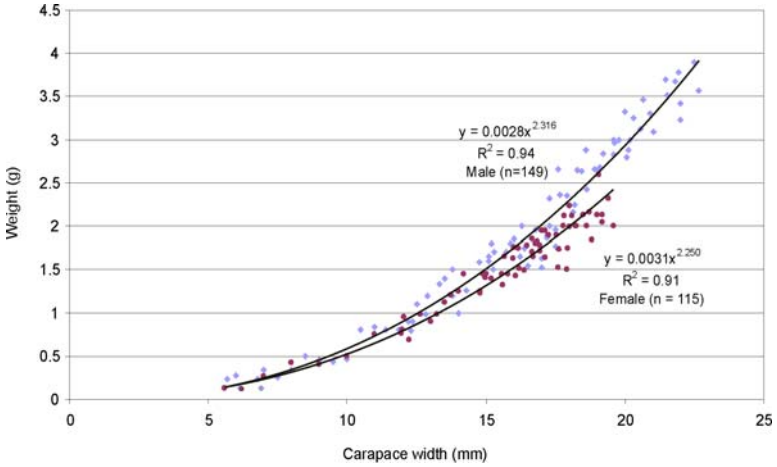


**Fig. 6.** Carapace width-individual weight relationship in female and male mud crabs from the Odra estuary.

## DISCUSSION

Intensified shipping and an increase in the number of vessels has resulted in an increased abundance of non-indigenous species appearing in aquatic ecosystems (Grosholz and Ruiz 2003). According to Leppäkoski et al. (2002), the last two centuries witnessed the presence of about 100 alien species in the Baltic alone. Of these, as many as 20 non-native species were identified in the Odra estuary (Gruszka 1999). Some of these species became dominant (e.g.,

*Dreissena polymorpha* Pallas, 1771 and *Potamopyrgus antipodarum* Gray, 1843 in the Szczecin Lagoon and *Marenzelleria* cf. *viridis* Verrill, 1773 in the Pomeranian Bay), while others (e.g., *Branchiura sowerbyi* Beddard, 1872, and *Rhithropanopeus harrisii* Gould, 1841) were only sporadically recorded in the Odra estuary (Wawrzyniak-Wydrowska and Gruszka 2005).

It seems that the Odra estuary *R. harrisii* population is slightly larger than that reported earlier, as evidenced by the increasing numbers of the crabs caught by fish traps (Czerniejewski and Rybczyk 2008). Analysis of the abundance of the mud crab caught in this study in different months showed a distinct increase in autumn and a reduction in winter and spring. A similar pattern was reported in the Dead Vistula population (Turoboyski 1973). The changes in abundance are likely a results of the mud crab habit of overwintering, at 3-5°C, in burrows dug in the bottom sediment (Kinne and Rotthauwe 1952). The crabs remained very inactive, and refused to accept food. Only when the water temperature increased above 10°C did the crabs regain full activity, begin to eat vigorously. In summer move to the shallow, littoral zone of a water body (Turoboyski 1973). Presumably, this behavior accounts for the apparent absence of crabs in the natural habitat during winter.

Polish estuaries support the mud crab weighing from 0.045 to 4.299 g (Normant et al. 2004), with the carapace width varying within 1.9-26.1 mm (Table 3). In the Odra estuary, too, the ranges of individual weight and carapace width were similar to those reported by Turoboyski (1973), Normant et al. (2004), Janta (1996), and Rychter (1999). However, the mean carapace width in the Odra estuary mud crabs was higher than that in the Vistula Lagoon and in the Chesapeake Bay (Table 3). It should be emphasized that the Odra estuary mud crab population was dominated by individuals with carapace width belonging to classes 14.1-17.0 and 17.1-20.0 mm, but it does not preclude the presence of larval stages and juveniles. In the Odra estuary individuals smaller than 5.0 mm were not found; such specimens are reported as occasionally caught in, for example, the Dead Vistula (Turoboyski 1973, Rychter 1999, Normant et al. 2004), but this might be caused by sampling method (traps with mesh size 5 mm). It seems that the mud crabs caught in the Odra estuary were adults, because, according to Turoboyski (1973), crabs with carapace widths higher than 4.4 mm are capable of reproduction. This, however, does not rule out the possibility of the presence of juveniles in the Odra estuary. Juveniles have been caught in the Vistula Lagoon (Rychter 1999) and presumably, as necessary, leave their shelters located most often close to the shore. These two groups (immature crabs and adults) have been reported from other areas, but never at abundances exceeding 10% of the total number of individuals caught (Ryan 1956, Roche and Torchin 2007).

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**Table 3**

Comparison of carapace widths of mud crabs from various regions.

| Males | | | Females | | | Reference |
|---|---|---|---|---|---|---|
| n | Range | Mean ±SD | n | Range | Mean ±SD | |
| 637 | 4.4-26.1 | 11.32 ±3.49 | 555 | 4.4-19.0 | 10.76 ±2.43 | Turoboyski (1973) |
| 20 | 14.0-20.0 | 16.80 | 28 | 10.0-18.0 | 13.11 | Janta (1996) |
| 733 | 2.9-21.9 | 11.27 ±4.43 | 372 | 1.9-16.1 | 9.23 ±3.14 | Rychter (1999) |
| 125 | 5.0-22.4 | 13.37 ±3.95 | 95 | 4.9-18.3 | 12.16 ±2.56 | Normant et al. (2004) |
| 45 | 3.1-17.7 | 9.3 | 19 | 4.9-10.9 | 8.0 | Roche and Torchin (2007) |
| 527 | 4.1-14.6 | 8.04 ±2.31 | 391 | 4.4-12.6 | 7.25 ±1.31 | Ryan (1956) |
| 149 | 5.6-22.9 | 16.81 ±3.98 | 115 | 5.3-19.8 | 15.05 ±3.33 | This study |

In mud crabs, the carapace width is correlated with the carapace length (Normant et al. 2004). In the Odra estuary, the carapace length is about 81.42% of the carapace width. Żmudziński (1961), too, reported the carapace width to be about 1.3 carapace length. The carapace length range of the Odra estuary mud crabs was slightly shorter than that reported by Normant et al. (2004) for the Dead Vistula population.

Analysis of the Odra estuary mud crab sex ratio showed a slight domination of males (sex ratio of 1:0.8), particularly in September, October and November. A similar proportion of males was recorded from the Dead Vistula (Turoboyski 1973, Normant et al. 2004), Chesapeake Bay (Ryan 1956), and the Panama Canal (Roche and Torchin 2007). However, Rychter (1999) found the proportion of males to be almost 2 times higher than that of females in the Vistula Lagoon. In the opinion of Normant et al. (2004), the differences in the sex ratios reported were caused by different techniques of capturing the mud crab. According to Rieznichenko (1958), the sex ratio depends also on the month of capture. In autumn, males comprised 84.2% of the Azov Sea population, which helps to explain the high proportion of females in the Odra estuary in September 2007 (56.45%), October 2007 (58.33%), November 2007 (61.29%), and December 2007 (58.33%), compared to the summer months when the proportions of the two sexes were similar, with females dominating (53.8%) in August 2008. Rychter (1999) explained the higher proportion of males relative to that of females by the higher motility of the first, rendering them more amenable to catching. By being more motile, the male crabs apparently are better able to obtain food, whereby they have a faster growth rate and attain better condition. The plausibility of this hypothesis is born out by the clearly better condition, as expressed by the parameters of the carapace width-individual weight relationship, and higher condition coefficients of males,

compared to those of females. It should be emphasised that the allometric coefficient *b* in the carapace width-individual weight relationship of the Odra estuary mud crabs is clearly lower (2.250-2.316) than that of the Vistula Lagoon population (2.79-3.16) (Normant et al. 2004, Rychter 1999). The differences in mass might also result from the better trophic conditions in the Vistula Lagoon, which induce a more rapid increase in specimen mass. A similar situation was observed during studies of the Chinese mitten crab *E. sinensis* from the Odra river estuary (Czerniejewski et al. 2003) and the Gulf of Gdańsk (Normant et al. 2002*)*. Specimens from the Gulf of Gdańsk were heavier when the width of the carapace was the same.

In addition to the higher individual weight at identical carapace width, sexual dimorphism in crabs is particularly strongly expressed in claw dimensions (Flores and Negreiros-Fransozo 1999, Jesse 2001, Czerniejewski et al. 2003). In the mud crab males, claw weight accounts for up to 64.0% of the body weight, compared to as little as 28.0% in females (Turoboyski 1973). The statistical analysis of the Odra estuary mud crab body dimensions also showed the largest differences between males and females to occur in linear dimensions of claws and abdomens. When explaining the adaptive significance of larger male claws, Jesse (2001) invoked intraspecific competition for mates among cancerids on the Chilean coast, a contention strengthened by the male-favoring sex ratios (males were more numerous than females in the populations of *Cancer polyodon*, *C. coronatus*, and *C. porteri* she studied).

Most species of xanthid crabs showed their right claws to be more developed than the left (Abby-Kalio and Warner 1989). Among the mud crabs they examined, Milke and Kennedy (2001) found as many as 91% of the males and 89% of the females to be right-handed. The Odra estuary population was dominated by right-handed individuals as well: 87.92% and 83.52% of all the males and females, respectively, were right-handed. The claw dimensions relative to the carapace width were much larger than those in the other allochthonous crab in the estuary, the Chinese mitten crab (Czerniejewski et al. 2003). The difference was caused by the feeding preference of the mud crab which has been reported to feed mainly on bivalves (Milke and Kennedy 2001). The stomach contents of the Odra estuary individuals, too, were found to contain remains of blue mussel (*Mytilus edulis)* and zebra mussel (*Dreissena polymorpha*) as well as fragments of copepod and insect appendages. However, the diet was dominated by detritus (61.08%) (Czerniejewski and Rybczyk 2008). In view of its dietary preferences and because of its small population size in the Odra estuary, *R. harrisii* does not, at present, pose a threat to the aquatic community of the estuary. However, should the population increase in size, it should be monitored to determine its effects on the aquatic habitat and its community.

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