# **Energy value of the mud crab** *Rhithropanopeus harrisii* **ssp.** *tridentatus* **(Crustacea, Decapoda) in relation to season, sex and size**

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**Abstract**

The energy value of male and female *Rhithropanopeus harrisii tridentatus* of various carapace width classes was determined. Crab samples were collected in the Vistula Lagoon from April to November 1995. The population of *R. harrisii tridentatus* from the Vistula Lagoon was characterised by a very low energy value 7.97 [SD] $\pm 1.5$ J mg$^{-1}$ DW, (12.69 [SD] $\pm 2.1$ J mg$^{-1}$ AFDW). The average amount of ash in this population was 37.66% of dry weight (organic matter was 62.44%). In each month (except September) the calorific value of the females exceeded that of the males; this value also varied seasonally. The calorific value of the population dropped to a minimum in August, whereas the maximum level was recorded in September.

## 1. Introduction

The mud crab *Rhithropanopeus harrisii* inhabits the brackish waters of the Atlantic coast of North America. A subspecies – *R. harrisii* (Gould) ssp. *tridentatus* (Maitland) – occurs in European waters (Buitendijk and Holthuis, 1949). Ballast water and sediment discharges have been recognised as major factors causing the introduction of undesirable aquatic organisms into ports around the world (Carlton and Geller, 1993), and it was in this way that the mud crab was probably introduced into Baltic waters. *R. harrisii tridentatus* is a permanent component of the demersal fauna there (Demel, 1953; Kujawa, 1957; Żmudziński, 1957; Filuk and Żmudziński, 1961; Szudarski, 1963). It inhabits the Dead Vistula and the Vistula Lagoon (the southern Baltic – eastern Polish coastal zone) at depths of 0–5 m (Żmudziński, 1961).

Although it has been the subject of ecophysiological investigations (Pautsch, 1957; Czeczuga and Czerpak, 1970; Turoboyski, 1973; Rychter, 1997), no data is available as to the energy value of the species. The crab is a link in the trophic chain of local fish *e.g.* eel *Anguilla anguilla* (L.) and flounder *Pleuronectes flesus* (L.), and birds *e.g.* cormorant *Phalacrocorax carbo* (L.) (Filuk and Żmudziński, 1961). The utility of *R. harrisii tridentatus* as a food resource and its role in the environment depend on the calorific value of individuals. Season, developmental stage, size, sex and conditions of individuals as well as period of reproduction are the factors influencing the calorific value of animals (Snow, 1972).

The aim of this research was to determine the calorific value of *R. harrisii tridentatus* (males and females) in the annual cycle as a function of the size of individuals. The data obtained has helped to describe its role in the Vistula Lagoon's ecosystem.

## 2. Materials and methods

The material for this study was collected at a station in the Vistula Lagoon near Frombork at a depth of 1.5 m. Samples were taken once a month throughout 1995 except in January, February, March and December, owing to the thick ice layer that covered the Lagoon during those months. The material was collected in special traps. Individual specimens of *R. harrisii tridentatus* were isolated and frozen, then taken to the laboratory. The following analyses were carried out:

- the sex was determined according to the sexual dimorphism traits listed by Rathbun (1930),
- both the wet and dry weights of individuals were determined,
- the carapace width of the individuals was measured to within 0.1 mm,
- the males and females were divided into 5 carapace width classes at 4.5-mm intervals, *i.e.* 0–4.5, 4.6–9, 9.1–13.5, 13.6–18 and 18.1–22.5 mm.

Immediately following the population biometry, the individual groups of males and females from each month were dried at 60°C to constant (dry) weight after prior formation of pellets from homogenised material. A modified Philipson KMB–2 type microbomb calorimeter, a detailed description of which is given by Klekowski and Bęczkowski (1973) and by Prus (1975), was used to determine the energy value of the material.

Prior to combustion of the samples, the microbomb calorimeter was calibrated with benzoic acid. After charring the samples from each month, the following parameters were determined: the total energy value expressed in J mg$^{-1}$ DW, the energy value of ash-free organic matter (J mg$^{-1}$ AFDW), and the percentage of ash obtained after oxidation (DW).

The abbreviations used in the paper stand for:
AFDW – ash free dry weight,
DW, d.wt. – dry weight,
SD – standard deviation.

## 3. Results

### 3.1. Description of the individual specimens

The *R. harrisii tridentatus* population structure was characterised by the significant domination of males over females (Fig. 1). In particular classes, greater average carapace widths were recorded in males than in females (except classes 1 and 2). The average carapace width in females was 7.76 [SD] $\pm 3$ mm, in males it was 10.38 [SD] $\pm 5.3$ mm. The largest male, with a carapace 21.9 mm wide, was found in June, whereas the largest female, with a carapace width of 16.1 mm was found in October.

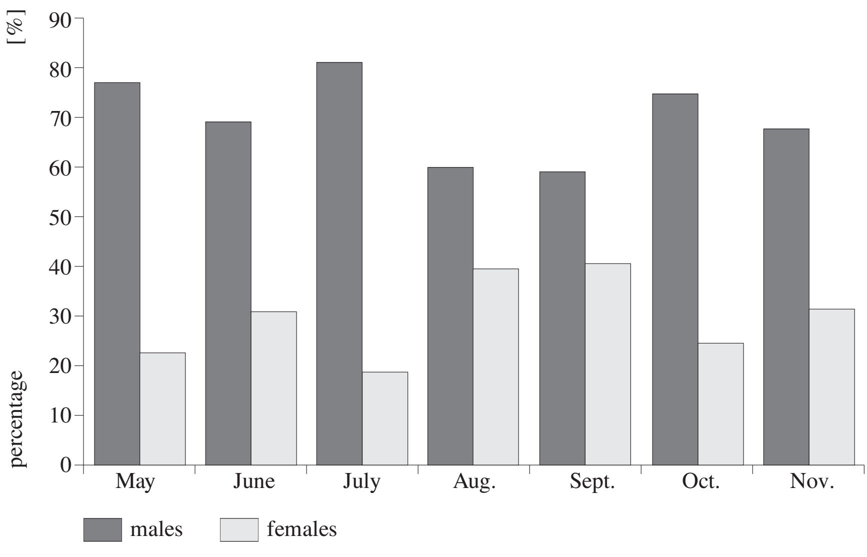


**Fig. 1.** Monthly percentage of males and females in the population of *R. harrisii tridentatus* (May–November, 1995)

During the research period the 3rd length class (9–13.5 mm) was found to be the most numerous. The average wet weight of males was 0.68 [SD]

$\pm 0.9$ g, that of females was 0.19 [SD] $\pm 0.2$ g. The average body weight of males exceeded that of females by 27.68%.

### 3.2. Energy value

The average total energy value of *R. harrisii tridentatus* was 7.97 [SD] $\pm 1.5$ J mg$^{-1}$ DW, that of organic matter was 12.69 [SD] $\pm 2.1$ J mg$^{-1}$ AFDW. Females displayed higher average energy values than males: females – 8.41 [SD] $\pm 1.5$ J mg$^{-1}$ DW (13.53 [SD] $\pm 2$ J mg$^{-1}$ AFDW), males – 7.67 [SD] $\pm 1.5$ J mg$^{-1}$ DW (12.14 [SD] $\pm 1.83$ J mg$^{-1}$ AFDW).

The total energy value of male and female *R. harrisii tridentatus* with respect to body size is set out in Fig. 2. The following energy changes were recorded in the various width classes in males: an increase from 7.49 [SD] $\pm 0.3$ J mg$^{-1}$ DW in the 2nd class to 9.02 [SD] $\pm 0.6$ J mg$^{-1}$ DW in the 3rd class, and then a decrease to 7.22 [SD] $\pm 2.1$ J mg$^{-1}$ DW in the 4th class and 6.27 [SD] $\pm 0.9$ J mg$^{-1}$ DW in the 5th class. However, in females from classes 2 and 3, the energy value was about 8.21 [SD] $\pm 1.6$ J mg$^{-1}$ DW, while in class 4 it decreased to 7.23 [SD] $\pm 1.2$ J mg$^{-1}$ DW.

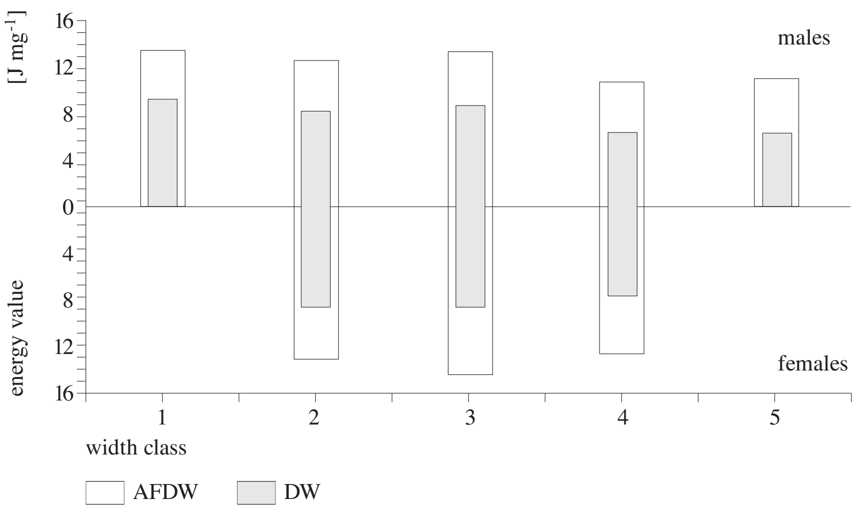


**Fig. 2.** Energy value of *R. harrisii tridentatus* with respect to body size

The total energy value in both males and females was found to vary seasonally and continuously (Fig. 3). The average energy value of males varied from 8.09 [SD] $\pm 0.9$ J mg$^{-1}$ DW in May, through 7.44 [SD] $\pm 1.9$ J mg$^{-1}$ DW in June and 7.09 [SD] $\pm 1.7$ J mg$^{-1}$ DW in July, to a minimum of 7.29 [SD] $\pm 1.6$ J mg$^{-1}$ DW in August. The highest energy value in males (9.61 [SD] $\pm 1.6$ J mg$^{-1}$ DW) was recorded in September, dropping to a minimum (6.53 [SD] $\pm 1.56$ J mg$^{-1}$ DW in November.

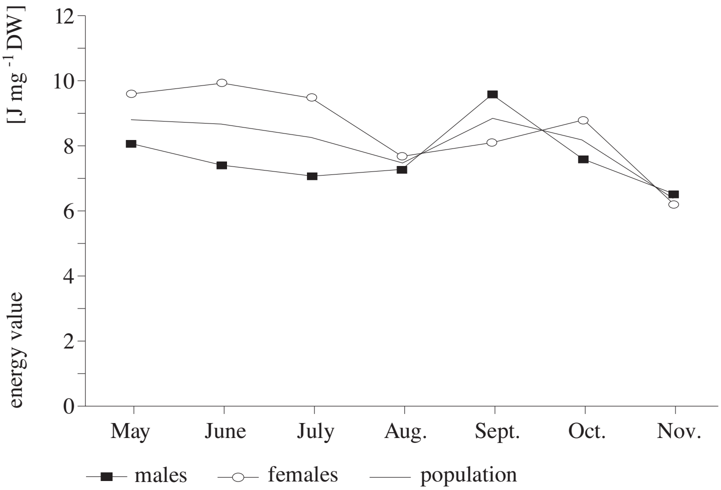


**Fig. 3.** Seasonal changes in the total energy value (DW) of *R. harrisii tridentatus*

In females the variations in energy value were not as significant as in the males during the seven-month study period. During the first three months values were similar – 9.7 J mg$^{-1}$ DW. In August, however, they dropped to 7.71 [SD] ± 0.6 J mg$^{-1}$ DW; they rose again to 8.13 [SD] ± 0.5 J mg$^{-1}$ DW in September, peaking at 8.41 [SD] ± 1.02 J mg$^{-1}$ DW in October, before falling to the minimum value of 6.22 [SD] ± 0.4 J mg$^{-1}$ DW in November.

The energy value of organic compounds was found to remain constant at about 13.5 J mg$^{-1}$ AFDW in males from classes 1–3; in class 4 it was lower (11.63 [SD] ± 2.2 J mg$^{-1}$ AFDW), and lowest in class 5 (10.83 [SD] ± 1.3 J mg$^{-1}$ AFDW) (Fig. 2). In females, changes in the energy values of organic compounds between the classes were significant. In class 2 the energy value was 12.05 [SD] ± 1.1 J mg$^{-1}$ AFDW, in class 3 it was 15.25 [SD] ± 1.4 J mg$^{-1}$ AFDW, and in class 4 it was lowest at 11.87 [SD] ± 1.1 J mg$^{-1}$ AFDW (Fig. 2).

The energy value of organic matter in males and females varied from month to month (Fig. 4.). In May the energy in males was 12.87 [SD] ± 1.1 J mg$^{-1}$ AFDW; this fell to 11.5 J mg$^{-1}$ AFDW, a figure that remained constant during the next 3 months. In September the value increased to 13.68 [SD] ± 1.2 J mg$^{-1}$ AFDW, but fell again in the following months, reaching a minimum of 12.22 [SD] ± 1.9 J mg$^{-1}$ AFDW in November. The character of the variations in females is different. In May the energy value was 14.51 [SD] ± 0.4 J mg$^{-1}$ AFDW, increasing in June to 16.01 [SD] ± 1.7 J mg$^{-1}$ AFDW and remaining unchanged throughout July. In August it dropped sharply to 12.87 [SD] ± 2.1 J mg$^{-1}$ AFDW. The next increase in

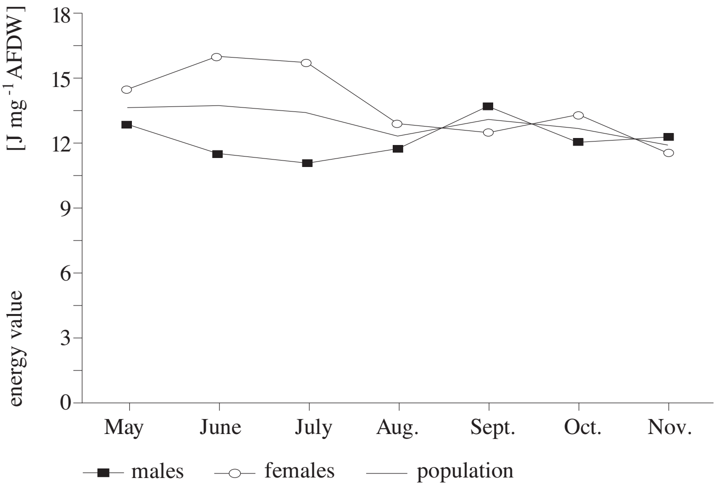


**Fig. 4.** Seasonal changes in the energy value of organic matter (AFDW) of *R. harrisii tridentatus*

energy value – to 13.25 [SD] $\pm$ 1.2 J mg$^{-1}$ AFDW – was recorded in October, after which it fell again to below 11.3 [SD] $\pm$ 1.7 J mg$^{-1}$ AFDW.

## 3.3. Quantity of organic matter

The quantity of organic matter varied from 50.77% d.wt. (November, 4th width class in males) to 70.3% d.wt. (September – 2nd class in males). The

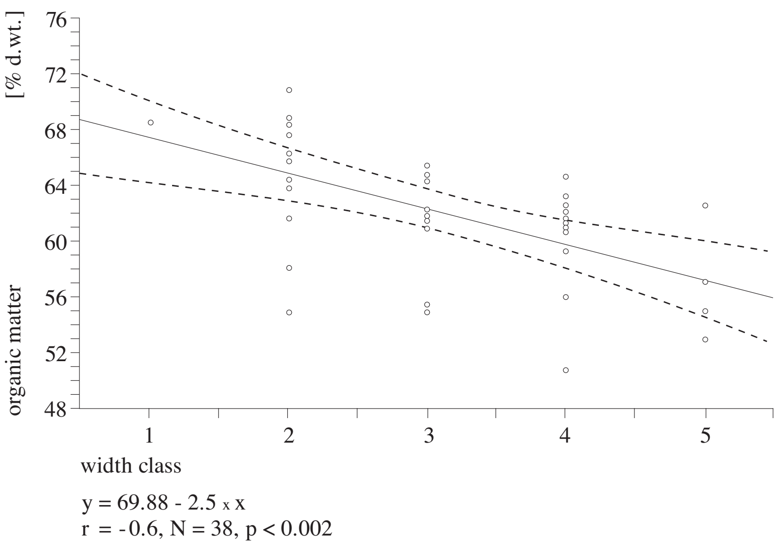


**Fig. 5.** Correlation between the organic matter and the carapace width of *R. harrisii tridentatus*

respective differences between males and females were very small: 61.73 [SD] $\pm$ 6.99% d.wt. and 61.54 [SD] $\pm$ 5.77% d.wt. From the average amounts of organic matter in males and females in the same width classes it can be seen that the quantity of organic compounds in males decreased with carapace width increase from 68.42% d.wt. (class 1) to 53.08% d.wt. (class 5). In the case of females, the quantities of organic matter vary between classes, the largest being recorded in class 2 (66.14 [SD] $\pm$ 6.41% d.wt.), the lowest in class 3, 59.61 [SD] $\pm$ 5.91% d.wt. In general, the amount of organic matter in males and females decreases with increase in size (Fig. 5.).

## 4. Discussion

The numbers of males and females in particular samples varies to a statistically significant extent ($p < 0.05$). Throughout the study period, the majority of individuals were males (67.7%). According to Murina and Reznichenko (1952), the significantly larger number of males shows that the process of acclimatisation of this species in the basins investigated is nearing completion. Significant differences between males and females were observed in larger individuals, owing to the fact that in males the body weight increased at a higher rate (Turoboyski, 1973). Moreover, the greater pincer size in males is important. The largest individual in the whole sample was a male with a carapace width of 21.9 mm; the width of the largest female was 16.1 mm. According to Turoboyski (1973) the greatest male ever found was 26.1 mm wide.

May 1995 was a relatively warm month, coming in the wake of a prolonged, very cold spell, and the animals started growing rapidly; in September large numbers of young individuals were present.

No statistically significant relationship between the total energy value and the energy value of organic matter, and the carapace width of crabs could be found. Individuals with carapaces from the 13.5–18 mm width range displayed the highest energy values, while greater individuals showed a decreasing tendency. Lower energy values were recorded in the youngest and, therefore, smallest individuals, which have a characteristically rapid metabolism, when the body concentrates on increasing protein structures and not on building up an energy surplus.

The sex of individuals may be a factor influencing the energy value of an individual. The average total energy value of females (8.41 [SD] $\pm$ 1.5 J mg$^{-1}$ DW) was slightly higher than that of males (7.67 [SD] $\pm$ 1.56 J mg$^{-1}$ DW). The difference between the two groups (0.75 J mg$^{-1}$ DW) was not significant. The average energy values of organic matter in males and females were very similar: 13.53 [SD] $\pm$ 2 J mg$^{-1}$ AFDW and 12.14 [SD] $\pm$ 1.83 J mg$^{-1}$ AFDW respectively. This small difference means that the amount of ash in males made up 37.83% of DW, *i.e.* 0.32% DW more than in females.

The energy value of this species varied seasonally, which was probably due to the seasonal variations in water temperature influencing the structure and dynamics of the crab population, their gametogenetic activity and metabolic level, and the abundance of food (Dobrzycka and Szaniawska, 1993). Values were lowest in late autumn (no data from winter months), and highest in summer. The cyclical storage and utilisation of high-energy organic matter is linked to the reproductive cycle. The physiological state of the animals and the trophic conditions influence energy values during the year (Prus, 1970). The crabs' diet in the Vistula Lagoon is made up largely of the polychaete *Nereis diversicolor* and dead organic matter from plants and animals (Mordukhay-Boltovskoy, 1952). In spring, the amount of energy assimilated by the organism increases and high-energy matter is stored, which is reflected in an increase in the total energy value prior to the reproductive season. This is the first spring increase in the energy value. After this time males show the first signs of their energy resources diminishing. This energy is used up in the formation of spermatophores and the fertilisation of females. Female energy values increase as a result of the storage of the high-energy compounds necessary for reproduction. This occurs between June (Turoboyski, 1973) and August, when the water temperature is $> 19°$C.

In August energy values in both sexes decrease (females 7.71 [SD] $\pm 0.83$ J mg$^{-1}$ DW, males 7.29 [SD] $\pm 1.6$ J mg$^{-1}$ DW); this is caused by the end of reproductive period and postreproductive stress manifested by physiological degeneration of tissues and metabolic changes (Ławiński and Węglarska, 1959). Immediately after breeding, young individuals occur in the population whose energy values are lower than those of mature individuals. The second increase in energy values is due to the abundance of food following the largest algal bloom during summer and autumn (Latała, 1978, 1994), which enables the crabs to build up significant reserves of energy (Szaniawska, 1990). In early spring, energy reserves recover from the losses incurred during the reproductive period (females 8.13 [SD] $\pm 0.7$ J mg$^{-1}$ DW, males 9.61 [SD] $\pm 1.3$ J mg$^{-1}$ DW), and those due to tissue regeneration and the slowing down of the metabolic rate.

In October the total energy value decreases, probably because of the smaller amount of food available. Under such conditions, the metabolism of individual crabs remains at a constant level, with the animals' own stored energy being consumed. The increase in energy values of organic matter is illustrated by the assimilation of high-energy compounds before the adverse winter period.

The quantity of organic matter is maintained at a level of 60–70% DW, an amount comparable for both males and females during the study period. The average value for all individuals is 62.34% d.wt. The greatest quantity of organic matter was recorded in September, when trophic conditions are optimum (Pliński, 1989). The average amount of ash for all *R. harrisii tridentatus* individuals was 37.83% d.wt. A greater amount of ash was recorded in mature individuals owing to the greater carapace size.

**Table 1.** Average energy values in Baltic benthic species

| Species | References | Energy value $[\mathrm{J\,mg^{-1}DW}] \pm \mathrm{SD}$ | Energy value $[\mathrm{J\,mg^{-1}AFDW}] \pm \mathrm{SD}$ | Organic matter [% d.wt.] |
|---|---|---|---|---|
| *Rhithropanopeus harrisii tridentatus* | Wiszniewska (unpubl.) | $7.97 \pm 1.59$ | $12.68 \pm 2$ | 62.34 |
| *Saduria entomon* | Czubek (1992) | $10.88 \pm 1.29$ | $18.94 \pm 3.36$ | 60.99 |
| *Crangon crangon* | Szaniawska (1990) | $16.98 \pm 1.78$ | $20.06 \pm 2.34$ | 85.09 |
| *Palaemon adspersus* | Szaniawska (1990) | $19.81 \pm 1.79$ | $22.52 \pm 1.75$ | 87.4 |

This research has shown that *R. harrisii tridentatus* belong to a group of organisms with characteristically low energy values. These values suggest the existence of species-specific changes in the biochemical composition, mainly the amount of glycogen, which is an important component accumulated by benthos species (Griffiths, 1977). Up to now, research has shown that Baltic crustacea are characterised by higher energy values than *R. harrisii tridentatus* (Tab. 1.). The energy differences between the benthos and planktonic crustacea are also due to the kind of stored organic compounds (Lee and Hirota, 1973; Griffiths, 1977).

## 5. Conclusions

- The average, total energy value of *R. harrisii tridentatus* is 7.97 $\mathrm{J\,mg^{-1}}$ DW, and the average energy value of organic matter is 12.69 $\mathrm{J\,mg^{-1}}$ AFDW. These values are the lowest of the Baltic crustacea that have been investigated.

- The total energy value and the energy value of organic matter of *R. harrisii tridentatus* vary seasonally. The highest values were obtained in spring (May) and early autumn (September), the lowest ones in summer (August) and late autumn (November).
- The highest organic matter energy values in females were recorded in July, since this was the reproductive period, when high-energy compounds were accumulated.
- The difference between the average energy values in males and females for the seven-month period is statistically insignificant at a confidence level of 95%. The energy value of *R. harrisii tridentatus* does not depend on the sex of individuals.
- The amount of organic matter (in % d.wt.) for males and females decreases with increase in size, and the amount of ash increases with increase in carapace width.

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