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Energy strategy of *Corophium volutator* (Pallas, 1766) (*Amphipoda*) population from the Gulf of Gdańsk ☆

Aldona Dobrzycka *, Anna Szaniawska

Institute of Oceanography, Gdańsk University, Al. Marszalka Pilsudskiego 46, 81-378 Gdynia, Poland

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Abstract

The goal of this paper is to determine seasonal changes in energy values and lipid levels in specimens of *Corophium volutator* from the Gulf of Gdańsk as an energy strategy under the conditions of the inhabited environment. Materials for the study were collected in the near-shore part of the Gulf of Gdańsk, at Swarzewo, between October 1991 and September 1992. Energy values were determined by means of a modified calorimetric microbomb of the Phillipson type. Lipids were determined by extraction using a mixture of chloroform, methanol and water.

Females generally predominate in the population of *Corophium volutator*. This population is characterized by a low energy value, $12.69 \pm (SD)3.49$ J mg^{-1} DW ($18.22 \pm (SD)2.49$ J mg^{-1} AFDW). The small mean lipid level in their bodies, $5.8 \pm (SD)$ 4.14% DW, explains their relatively low energy value.

It has been shown that, additional to such factors as food quality and availability, seasonal variation in the population has a significant influence on the nature of the changes in the energy value and lipid level in *Corophium volutator*.

Keywords: Corophium; Energy strategy; Gulf of Gdańsk; Lipid; Puck Bay

* Corresponding author.

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1. Introduction

The species *Corophium volutator* is relatively well known from the point of view of its biology and ecology. Studies of this organism, mainly dealing with its biology, have been made by Hart [1], Segerstråle [2,3], Watkin [4] and Jażdżewski [5,6]. Agrawal [7] studied the physiology of its digestion. In addition, its adaptation to various environmental factors has been investigated, e.g. salinity, McLusky [8,9], type of substrate, Fenchel and Kofoed [10], and oxygen concentration, Gamble [11,12]. In Poland, this species was investigated by Jażdżewski [5,6] whose work dealt with population problems. Other aspects of the importance of *Corophium volutator* are not yet known because no studies have been undertaken on, for instance, its biochemistry or bioenergetics.

The goal of this paper is to determine the seasonal changes in the energy values and lipid levels in specimens of *Corophium volutator* from the Gulf of Gdańsk. The analysis of energy values makes it possible to define the role of the species under the conditions of the inhabited environment and its usefulness as food.

All physiological processes taking place within organisms constitute energy transformations; therefore, the seasonal variability of the energy value tends to show the nature of these physiological processes.

The determination of lipid contents supplies information on the adaptation of the animal and the type of its metabolic processes. This reveals the role of lipids in the metabolism of the animal and shows in what way its habitat and manner of living determine its life strategy.

Corophium volutator constitutes an important and numerous component of the zoobenthos of Puck Bay (part of the Gulf of Gdańsk) together with such species as *Nereis diversicolor*, *Hydrobia sp.*, *Sphaeroma hookeri*, and *Oligochaeta*. In Inner Puck Bay it is a dominant species [13]. It is an important component of the food web and its source of food is organic matter deposited on the sea bed, mainly detritus, as well as *Bacillariophyceae*, bacteria and microalgae [14,10]. *Corophium volutator*, in turn, constitutes a food source for *Pleuronectidae*, *Perca fluviatilis*, *Anguilla anguilla*, *Gobiidae*, *Crangon crangon* and water fowl [14].

2. Experimental

The material for this study was collected once a month from 16 October 1991 to 29 September 1992. The site of sample collection was station S1, located 0.5 km from the site of sewage discharges at the purification plant at Swarzewo in the direction of the town of Puck (Fig. 1).

The material was collected in the near-shore zone, about 20 m from the shore, with the help of an Ekman grab with a grabbing area of 61.8 cm^2. Two samples were taken each month, one sample consisting of the material taken in three subsequent hauls. The material was sieved through a sieve with a mesh size of

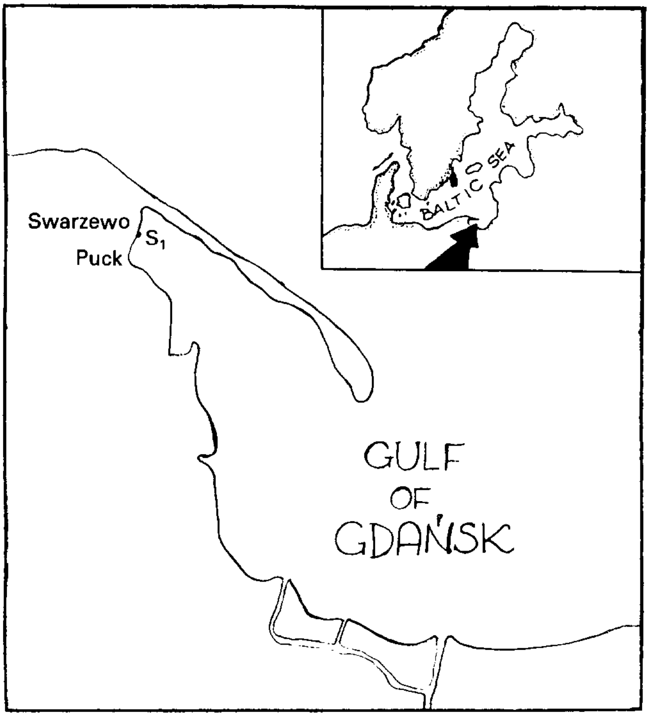

Fig. 1. Map showing the sample collection sites.

1 mm × 1 mm and taken to the laboratory. The smallest specimens of this population were washed away through the sieve meshes.

One sample from each month was preserved in 4% formalin solution and was used to determine the population composition. A second sample served to determine the energy values and lipid content.

Energy values of *Corophium volutator* specimens were determined by means of a modified calorimetric microbomb of Phillipson KMB type [15], after prior formation of pellets from the homogenized material. Following charring of the samples from each month, the following were determined: the total energy value, i.e. the ash value, expressed in J mg^{-1} DW, and the energy value of organic matter, i.e. ash-free, expressed in J mg^{-1} AFDW.

For lipid separation, a chloroform–methanol–water mixture was used, utilizing the method of Blight and Dyer [16]. When determining lipids, the method of Marsch and Weinstein [17] was used, consisting in the measurement of extinction and reading the lipid level from a model curve prepared on the basis of glycerol tripalmitin. Extinctions were read using a SPEKOL II Carl Zeiss Jena spectrophotometer at wavelength of 360 nm.

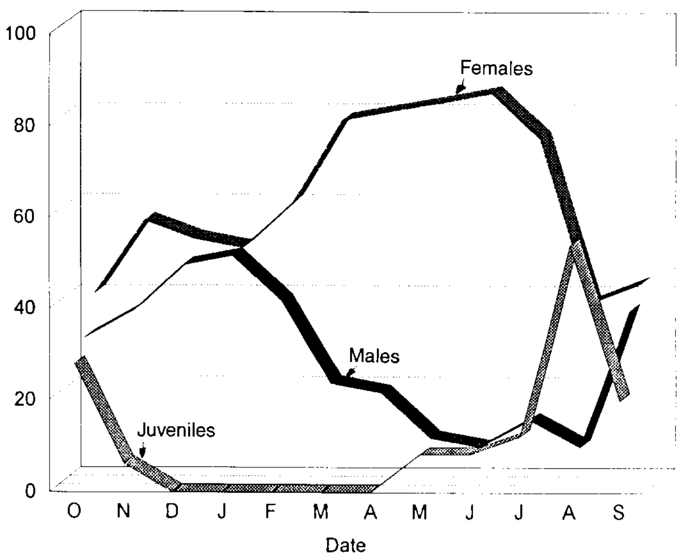

Fig. 2. Population changes throughout the year.

3. Results

3.1. Characteristics of the population

The determination of the population structure was aimed at revealing intrapopulation changes throughout the year. A distinct predominance of females over males was observed; only in January was there an equal percentage of males and females. An especially large share of females (Fig. 2) was observed in June (84% females, only 8% males, and 8% immature specimens). The minimum percentage of females in the population occurred in August (38%). The greatest percentage of males in the population (Fig. 2) was observed in January (50%), the smallest in June and August (only 8% in each of these months). Juvenile specimens began to appear in the population from May and were present in the samples until November (Fig. 2). In August, a peak in juvenile specimen abundance was visible (54%, with females 38%, and males 8%). The minimum percentage share of immature specimens was observed in June (only 4%).

3.2. Energy values

The mean energy value for all samples was $12.69 \pm (\mathrm{SD})3.48$ J mg^{-1} DW ($18.22 \pm (\mathrm{SD})2.49$ J mg^{-1} AFDW). The highest total energy value was obtained on 5 March 1992 (15.88 J mg^{-1} DW); the lowest on 29 September 1992 (5.38 J mg^{-1} DW). The highest energy value of organic matter reached by the population was on 26 May 1992 (20.45 J mg^{-1} AFDW); the lowest was on 25 August 1992 (11.89 J mg^{-1} AFDW) (Fig. 3).

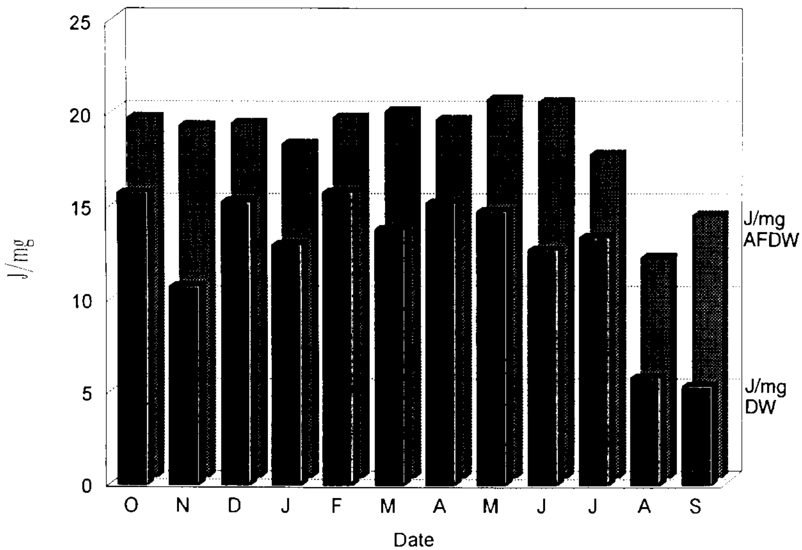

Fig. 3. Energy values of the samples.

3.3. *Lipid level*

The mean lipid level for all samples was 5.8 ± (SD)4.14% DW. The highest lipid level was attained by the population on 28 November 1991 (14% DW); the lowest on 5 March 1992 (0.35% DW). It may be stated in general that the highest lipid level was characteristic for the samples collected in the autumn, the lowest for those taken in the winter and early spring. The lipid level rose slightly with an improvement in trophic conditions in March and reached a local maximum on 26 May 1992 (7.4% DW) in the reproduction season. After a small decrease in the lipid level at the end of the summer, an upward trend prevailed until the autumn maximum (Fig. 4).

4. Discussion

The analysis of the population allowed seasonal changes and their scale to be observed. Females generally predominate in the population of *Corophium volutator* from the Gulf of Gdańsk. This predominance of females in this species has been pronounced by many researchers to be the rule. A prolongation of the reproduction season by one month (it lasted from April to November) was observed in comparison with earlier studies [5], which observed the reproduction season to run from April to October. This was a result of higher temperatures in the autumn. A larger share of females was observed in the pre-reproduction period: 60% females on 5 March 1992, 78% on 30 March 1992 and as much as 80% on 28 April 1992. The maximum level of females was observed in June. In the pre-reproduction period the number of males decreased, which was connected with their increased

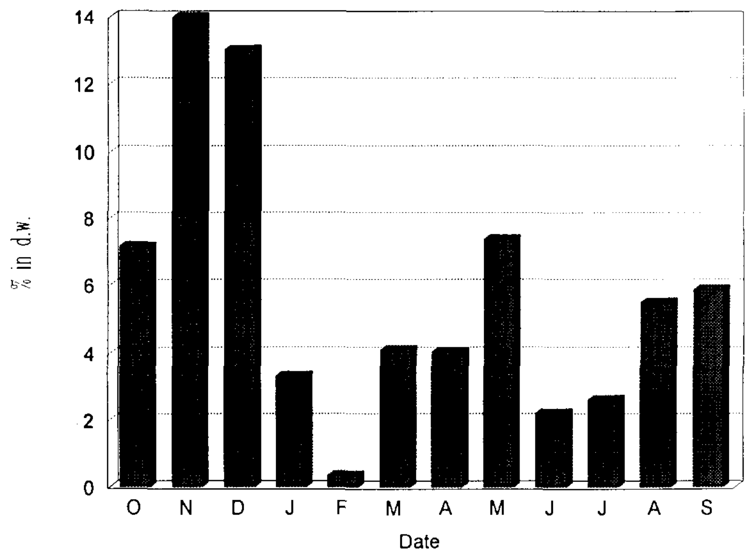

Fig. 4. Lipid levels of the samples.

mortality upon fulfilling their procreative function. This phenomenon has been observed previously by many scientists. Juvenile specimens began to appear after the first spawning, i.e. in May, and were present in the samples until November, when the reproduction season came to an end. The maximum number of juvenile specimens was noted in August and this had a visible impact on the energy value.

However, in comparison with Jażdżewski [5], the proportion of juvenile specimens in the samples from 1991/1992 was underestimated. Such disparities may be explained by the fact that the smallest specimens were washed away through the sieve meshes during the collection of materials for this study.

The energy value of the population studied depends on the share of females, males, and juveniles, the season of the year, and the trophic conditions (quality and quantity of available food). The energy value of the species *Corophium volutator* is relatively low ($12.69 \pm (SD)3.48$ J mg^{-1} DW). Autumn months are characterized by small fluctuations in energy values. It seems that the amount of food deposited on the bottom (Table 1) at that time is of considerable importance. Only in November was a decrease in the total energy value observed, which was most likely connected with stress following the end of the reproduction season. In autumn the specimens gather high-energy compounds in the form of lipids and this is responsible for the relatively high and stable level of energy values at that time. The plentiful food available allows for the assimilation of considerable amounts of energy. In addition, the process of development and growth favours storage and transformation of energy obtained in the form of food. Also, in autumn large, mature specimens predominate in the population, which accounts for quite high energy values at that time. In winter a small decrease in energy values was observed. In January there was a local minimum in the energy value of the organic matter

Table 1
The levels of organic matter at station S1 in the period December 1988–November 1989 (Kotwicki et al. [18])

Date	Organic matter (%)
12/88	0.61
01/89	–
02/89	3.41
03/89	0.36
04/89	–
05/89	1.22
06/89	–
07/89	1.95
08/89	–
09/89	1.43
10/89	2.35
11/89	4.51

(18.04 J mg^{-1} AFDW), as well as a reduction in the total energy value of the population (13.03 J mg^{-1} DW). In January 1989 (Table 1) no organic matter was observed in the substrate: so it may be inferred that there is a food deficiency in that winter month. However, the fact of fewer trophic components in the habitat did not significantly influence the reduction in the level of energy values. It may thus be expected that in winter months this species to a large degree lives on resources stored in their bodies in the autumn. Besides, metabolism is reduced so the animals do not react in such a drastic way to reduced food resources in the environment. An increase in the energy value is connected with an inflow of food substances to their habitat and the appearance of females with embryos in the population (5 March 1992). Directly after spawning, when the first juveniles start to appear, the energy values are lower. When reproduction intensifies, i.e. in May and June, females carrying eggs or juvenile specimens in their marsupia predominate. Especially high energy values of organic matter and higher total energy values are observed at that time. At the end of the reproduction season (in August) a kind of crisis may be observed: lowest energy values were found then. This moment of crisis is connected with the large number of juveniles, which are most abundant in August, in the population (54%). It may be expected that juvenile specimens have a narrow food spectrum as well as a high metabolic rate; hence, the low energy values. An important factor is undoubtedly food deficiency. In August 1989 no share of organic matter was observed in the sampling area [18]. This might suggest that in August 1992, there could be likewise insufficient amounts of food in the substrate or that the quality of deposited organic matter might have made it unassimilable as food, especially by young specimens. Besides, the predominance of females which have finished reproduction and have degenerated tissues considerably influences this state of affairs. The majority of females in the population have already given birth to the young (only for a few has the reproduction season not yet ended). The crisis shows how closely the energy expenditure is connected with spawning. It may also be expected that such low energy values at the end of the reproduction season are related to the high mortality of females (exhausted by reproduction), which until then contributed to the rather high energy value.

The differences in the lipid levels in the *Corophium volutator* population during the season leads to the supposition that the role of this component changes depending on the season of the year and on the physiological processes taking place within the organisms. The highest lipid levels were observed in the autumn. This is connected with the low temperatures at that time. Under unfavourable environmental conditions, gathering of lipids becomes a necessity; this ensures reserve materials and may constitute a protective layer for the organism. The gathering of lipids is favoured by the large availability of food. The autumn months, as shown by studies conducted then, are very rich in food (Table 1). The autumn period is characterized by a lipid type of metabolism. In winter, lipid levels exhibit a downward trend; stored reserves are being utilized. In early spring, lipid contents drop to a very low level, which shows that lipid was consumed during the winter. In spring, despite the low level of lipids, the energy value remains at a relatively high level. It may be expected that at that time *Corophium volutator* specimens switch from a winter lipid-type metabolism to some other type. It is difficult to point to the biochemical factor responsible at that time for the high energy value as here we considered the seasonal changes of only one of the biochemical components of the organism, the lipids. It may be expected that *Corophium volutator* switchers to a protein type of metabolism, as is the case with other crustaceans, at a time when they do not gather lipids [19]. Before the reproduction season (March, April), a gradual increase in lipid levels may be observed, connected with a biological transformation in the female organisms, namely adaptation for giving birth to the young. Large amounts of lipid must be utilized to form eggs and embryos. When a large number of reproducing females is observed in the population (26 May 1992), local maxima in lipid contents are visible. In June, the lipid level decreases, which is connected with the appearance of juveniles in the population. The subsequent autumn increase is caused by the beginning of another reproduction cycle in the females and storing energy before winter.

Detritus-feeding *Corophium volutator* consumes food resources poor in energy. Detritus is the dominant component of its diet. *Bacillariophyceae* with an energy value of 15.97 J mg^{-1} DW [20] constitute a negligible part of its food, together with bacteria and microalgae. This is not a high-energy food either. Schindler [21] emphasizes that detritus is characterized by a low energy value. When it constitutes the main source of food, it has a significant impact on the low energy value of the organism, low lipid level, and a large proportion of mineral compounds in the body.

5. Conclusions

Females generally predominate in the population of *Corophium volutator* from the Gulf of Gdańsk.

The mean energy value of the *Corophium volutator* population between October and September is relatively low: 12.69 $\pm$ (SD)3.49 J mg^{-1} DW (18.22 $\pm$ (SD)2.49 J mg^{-1} AFDW).

The highest total energy value was obtained in February (15.88 J mg^{-1} DW) with an inflow of food substances to their habitat and the appearance in the population of females with embryos.

The low mean lipid level observed in their bodies, 5.8 $\pm$ (SD)4.1.% DW, explains their low energy value.

The highest lipid levels were observed in the autumn (low temperatures and adequate reserve materials); in November it was 14% DW.

The seasonal variability in the composition of the population has a significant influence on the nature of the changes in the seasonal energy values and lipid levels in the *Corophium volutator* population.

Corophium volutator is a dominant species in Inner Puck Bay, so it is an important component of the food web for *Pleuronectidae*, *Perca fluviatilis*, *Anguilla anguilla*, *Gobiidae*, *Crangon crangon* and water fowl.

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