# Seasonal changes in energy value and lipid content in a population of *Corophium volutator* (Pallas, 1766) from the Gulf of Gdańsk

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*Corophium volutator*
Bioenergetic energy values
Lipids
Gulf of Gdańsk

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**Abstract**

Materials for the study were collected in the near-shore zone of the Gulf of Gdańsk, at Swarzewo, between October 1991 and September 1992. The population of *Corophium volutator* (*Amphipoda*) from the Gulf of Gdańsk is characterized by a low energy value – 12.69 ± (SD) 3.49 J mg$^{-1}$ DW (18.22 ± (SD) 2.49 J mg$^{-1}$ AFDW). A small low mean lipid level in their bodies – 5.8 ± (SD) 4.14% d.w. – was also observed, which explains their relatively low energetic value.

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

## 1. Introduction

The species *Corophium volutator* is relatively well known from the point of view of its biology and ecology. Many workers have studied this organism: Hart (1930), Segerstråle (1940, 1959), Watkin (1941), Jażdżewski (1970, 1971) dealt mainly with the biology of this species; Agrawal (1963) studied the physiology of digestion. Others have explored its adaptation to various environmental factors, *e.g.* salinity (McLusky, 1967, 1970), the type of substrate (Fenchel and Kofoed, 1975) and oxygen concentration (Gamble, 1970, 1971).

In Poland this species was investigated by Jażdżewski (1970, 1971), who dealt with population problems. Other aspects of the importance of

*Corophium volutator* are so far not known because no studies have been undertaken on, for instance, its biochemistry or bioenergetics.

The object of this paper is to determine energy values and lipid levels in specimens of *Corophium volutator* from the Gulf of Gdańsk. The analysis of energy values makes it possible to assess the role of the species in the conditions of the environment it inhabits 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.

Determination of lipid content supplies information on the adaptation of the animal and the type of metabolic processes it has. This allows us to discover the role of lipids in the animal's metabolism and shows in what way its habitat and manner of living determine its life strategy.

*Corophium volutator* is interesting for a number of reasons. It has been observed that it constitutes an important and numerous component of the zoobenthos in Puck Bay (part of the Gulf of Gdańsk), apart from such species as *Nereis diversicolor*, *Hydrobia* sp., *Sphaeroma hookeri*, and *Oligochaeta*. In the Inner Puck Bay it is a dominant species (Wołowicz *et al.*, 1993). It is usually defined as a marine organism, a typical euryhaline one (Jażdżewski, 1971). It lives in waters with a salinity of 2–50 psu (McLusky, 1967), the most favourable salinity being 10–30 psu, especially 20 psu (McLusky, 1970). It occurs off the Atlantic coasts of North America between latitudes 40° and 50° N, and off the coasts of Europe: from the Mediterranean Sea to the Black Sea and the Sea of Azov, in the Baltic Sea, off the coasts of Norway, Great Britain and Ireland (Schellenberg, 1942; Guryanova, 1951). It prefers a loose, muddy or sandy-muddy bottom. Its food source is organic matter deposited on the bottom, mainly detritus, as well as *Bacillariophyceae*, bacteria and microalgae (Schellenberg, 1942; Fenchel and Kofoed, 1975). *Corophium volutator*, in turn, constitutes a food component of *Pleuronectidae*, *Perca fluviatilis*, *Anguilla anguilla*, *Gobiidae*, *Crangon crangon* and waterfowl (Schellenberg, 1942). The duration of its reproductive period is temperature-dependent. For instance, in the Dovey estuary in western Wales it lasts from January to October (Watkin, 1941), off the Baltic coast of Finland – from May to the beginning of October (Segerstråle, 1940), and in Puck Bay – from April to October (Jażdżewski, 1970).

## 2. Material and methods

The material for this study was collected once a month from 16.10.1991 to 29.09.1992. Samples were collected at station S1, located 0.5 km from the outfall of the sewage treatment plant at Swarzewo in the direction of the town of Puck.

The material was collected in the near-shore zone, about 20 m from the shore, with the aid 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 consecutive hauls. The material was strained through a sieve with a $1 \times 1$ mm mesh and taken to the laboratory. The smallest specimens of the population were washed away through the sieve meshes.

One sample from each month was preserved in 4% formalin solution and used to determine the population composition.

The second sample served to determine the abundance, and the wet and dry weight of *Corophium volutator* specimens.

Population composition analyses were based on the sexual dimorphism features elaborated by Bousfield (1973).

The energy values of *Corophium volutator* specimens were determined by means of a modified Phillipson KMB calorimetric microbomb (Klekowski and Bączkowski, 1973), after prior formation of pellets from the homogenized material. After charring the samples from each month, the following were determined: the general energy value, *i.e.*, 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.

A chloroform-methanol-water mixture was used in the separation of lipids (Blight and Dyer, 1959).

Marsch and Weinstein's method (1966) was used to determine lipids. This involved measuring extinction and reading the lipid level on the basis of the model curve prepared on the basis of glycerol tripalmitin. Extinctions were read off using a SPEKOL II Carl Zeiss Jena spectrophotometer with a wavelength of 360 nm.

## 3. Results

### Characteristics of the population

The determination of the population structure aimed to reveal intrapopulation changes throughout the year. There was a distinct predominance of females over males; only in January was there an equal proportion of males and females. An especially large percentage of females (Fig. 1) was observed in June (84% females, 8% males, and 8% immature specimens). The minimum percentage of females in the population occurred in August (38%). The largest percentage of males in the population (Fig. 1) was recorded 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 onwards and were present in the samples until November (Fig. 1). In

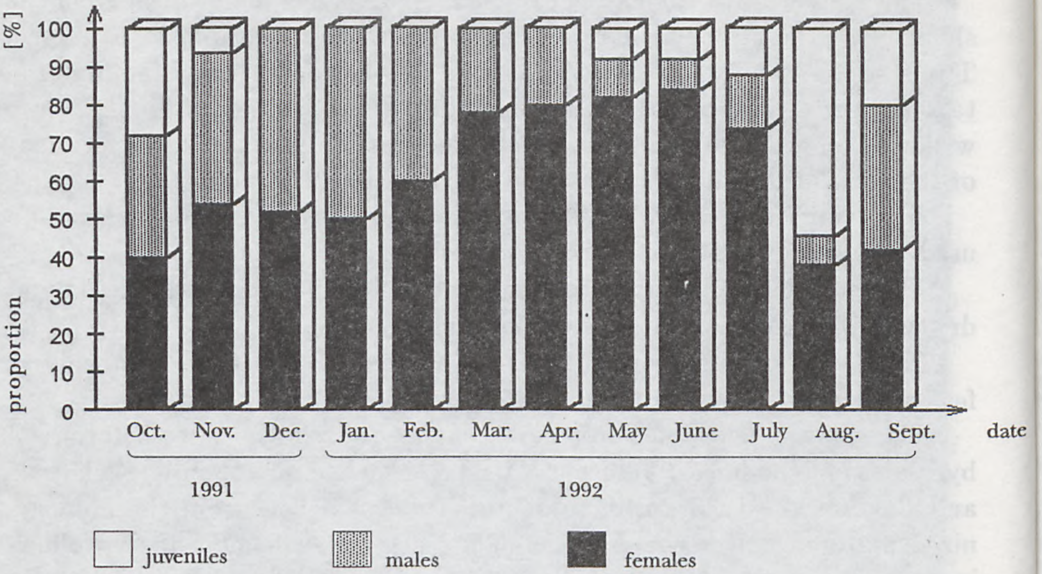


Fig. 1. Seasonal changes in the percentage of females, males, juveniles specimens of *Corophium volutator* in the period 16.10.1991–29.09.1992

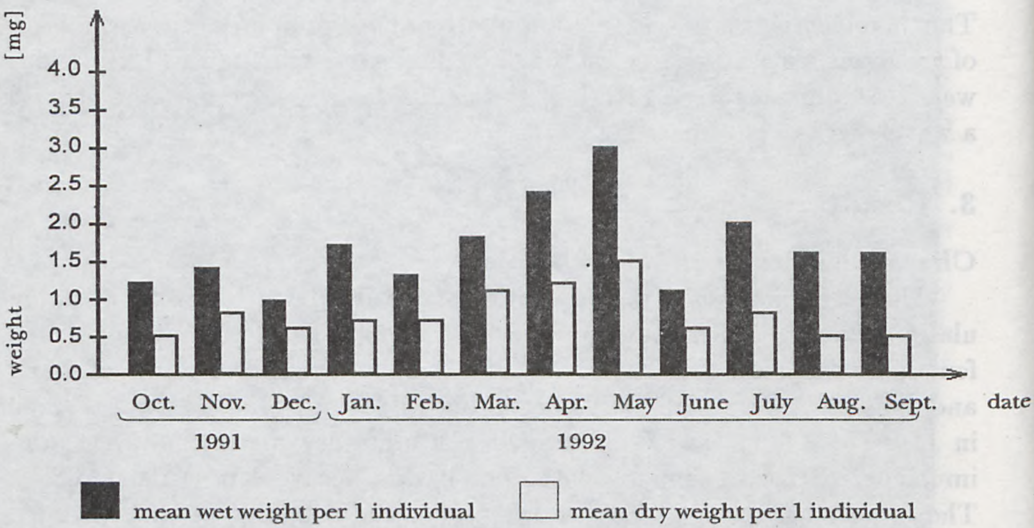


Fig. 2. Seasonal changes in mean wet and dry weight of one specimen (mg ind.$^{-1}$) in the *Corophium volutator* population in the period 16.10.1991–29.09.1992

August the juvenile abundance peaked – 54%, while there were only 38% females and 8% males. The minimum percentage of immature specimens was reported in June (4%).

The mean annual wet weight of a single specimen was 1.67 ± [SD] 0.55 mg and the mean annual dry weight of a single specimen was of 0.79 ± [SD] 0.32 mg. The highest mean wet weight of a specimen, recorded on 26.05.1992, was 3 mg, and the smallest mean wet weight of a specimen was equal to 1.1 mg (17.06.1992) (Fig. 2).

**Energy values**

The mean energy for all samples was 12.69 ± [SD] 3.48 J mg$^{-1}$ DW (18.22 ± [SD] 2.49 J mg$^{-1}$ AFDW). The highest total energy was obtained on 5.03.1992 (15.88 J mg$^{-1}$ DW), the lowest – on 29.09.1992 (5.38 J mg$^{-1}$ DW). The highest energy value of organic matter in the population was attained on 26.05.1992 (20.45 J mg$^{-1}$ AFDW), the lowest – on 25.08.1992 (11.89 J mg$^{-1}$ AFDW).

**Lipid level**

The mean lipid level for all samples was 5.8 ± [SD] 4.14% d.w. The highest lipid level was attained by the population on 28.11.1991 (14 % d.w.), the lowest – on 5.03.1992 (0.35% d.w.). It may be generally said that

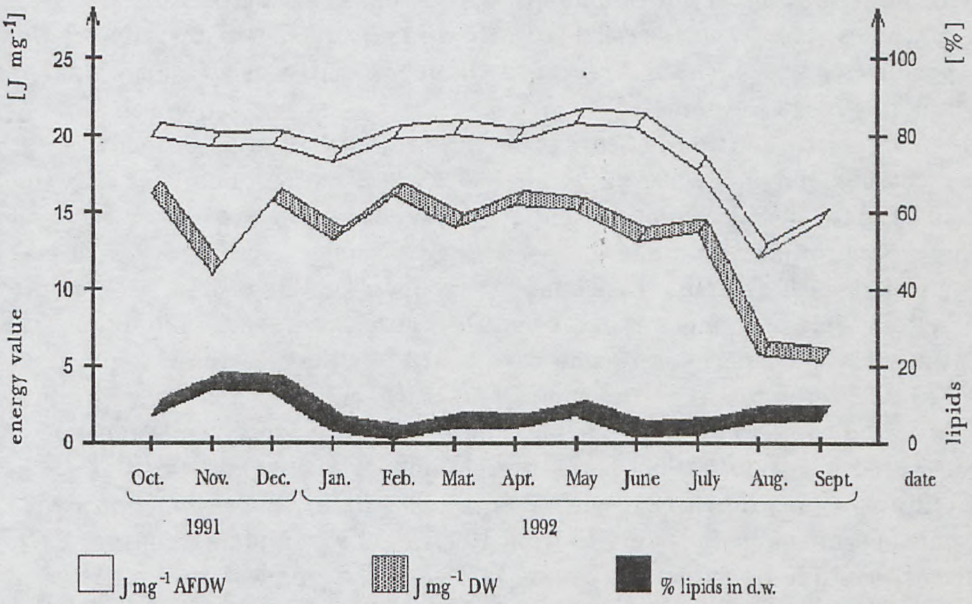


Fig. 3. Changes in lipid level (% d.w.) us, the changing energy value of organic matter (J mg$^{-1}$ AFDW) and total energy value (J mg$^{-1}$ DW) in the population of *Corophium volutator* in the period 16.10.1991–29.09.1992

the highest lipid level was characteristic of the samples collected in autumn, the lowest – of those taken in winter and early spring. The lipid level rose slightly with the improvement in trophic conditions in March and in the reproductive season reached a local maximum on 26.05.1992 (7.4% d.w.). Apart from a slight decrease in the lipid level at the end of summer, the upward trend prevailed until the autumn maximum (Fig. 3).

The ash remaining after charring allowed the energy value of organic matter and organic matter content in dry body weight to be determined. The mean ash content from all samples was 31.63 ± [SD] 13.37% d.w. The largest quantity of ash remained after the charring of a sample from 29.09.1992 (61.52% d.w.). A large quantity of ash was also left from a sample from 25.08.1992 (51.1% d.w.) and 28.11. 1991 (43.4% d.w.). The smallest quantity of ash remained from a sample from 5.03.1992 (18.4% d.w.).

## 4. Discussion

The population analysis revealed the scale of seasonal changes. Females generally predominate in the population of *Corophium volutator* from the Gulf of Gdańsk.

The predominance of females in this species was also considered by many researchers rule. A prolongation of the reproductive season (lasting from April until November) by one month was observed in comparison with earlier studies, *e.g.* by Jażdżewski (1970), who observed the duration of the reproductive season (from April until October). This was a result of higher temperatures in autumn.

A larger proportion of females in the pre-reproductive period was observed: 60% on 5.03.1992, 78% on 30.03.1992, and as many as 80% on 28.04.1992. The maximum percentage of females was observed in June. In the pre-reproductive period the percentage of males decreased, which was connected with their increased mortality upon fulfilling their procreative function. This phenomenon had been previously observed by numerous scientists. Juvenile specimens began to appear after the first spawning, *i.e.*, in May, and were present in the samples until November when the reproductive season came to an end. The maximum percentage of juvenile specimens was noted in August, which had a visible impact on the energy value.

However, in comparison with Jażdżewski (1970), 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 paper.

The values of both wet and dry weight were highest at the beginning of the reproductive season (in April and May), when females with embryos and eggs prevailed in the population. Already in the months preceding the reproductive period (from 5.03.1992) a distinct upward tendency in mean wet and dry weight of a single specimen had been reported, which was connected with the increasing predominance of females in the population and with the increasingly important biological role of females (resulting from giving birth to the young). From June onwards a reduction in the mean wet and dry weight of a specimen was observed, caused by the appearance of juvenile specimens in the population. The lowest mean dry weights occurred in August, September, and October (0.5 mg ind.$^{-1}$) and were due to the large percentages of juveniles at that time.

The energy value of the population studied depends on the percentage of males, females, and juveniles, the season of the year, and the trophic conditions.

**Table 1.** The proportion of organic matter at station S1 in the period 12.1988–11.1989 (Kotwicki *et al.*, in press)

| 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 |

The energy value of the species *Corophium volutator* is relatively low (12.69 ± [SD] 3.48 J mg$^{-1}$ DW). The autumn months are characterized by small fluctuations in energy values. It seems that the quantity of food on the bottom (Tab. 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 post-reproductive stress. In autumn the animals take in high-energy compounds in the form of lipids and this is responsible for the relatively high and stable energy values at that time. The plentiful food available allows considerable amounts of energy to be assimilated. In addition, development and growth favour the storage and transformation of energy obtained in the form of food. Also, in autumn large and mature specimens predominate in the population, which accounts for the quite high energy values at that time. Winter energy values decreased slightly. In January the energy value of organic matter fell to a local minimum (18.04 J $mg^{-1}$ AFDW), and the total energy value of the population was reduced (13.03 J $mg^{-1}$ DW). In January 1989 (Tab. 1) there was no organic matter in the substrate, so it may be inferred that food is deficient in that winter month. However, the fact that there were fewer trophic components in the habitat did not significantly influence the reduction of energy values. It may thus be expected that in the winter months specimens of this species to a large extent live on resources stored in their bodies in the autumn. Besides, metabolism is reduced, so the specimens do not react in such a drastic way to reduced food resources in the environment. The increase in the energy value is connected with the inflow of food substances to their habitat and the appearance in the population of females with embryos (5.03.1992). Directly after spawning, when the first juveniles start to appear, 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 reproductive season (in August) a kind of crisis may be observed – the lowest energy values were observed then. This moment of crisis is connected with the large percentage of juveniles, 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 such low energy values. An important factor is no doubt food deficiency. In August 1989 no organic matter was observed in the sampled area (Kotwicki *et al.*, in press). This might suggest that in August, 1992 there could likewise have been insufficient food in the substrate, or 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 reproductive season not yet ended). The crisis shows how great the energy expenditure connected with spawning is. It may also be expected that such low energy values at the end of the reproductive season are related to the high mortality in females (exhausted by reproduction) which until then contributed to the rather high energy value.

The differences in the lipid level in the *Corophium volutator* population during the season suggest that the role of this component undergoes 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 autumn. This is connected with the low temperatures at that time. Under unfavourable environmental conditions lipid intake becomes a necessity as it allows reserve materials to be secured and may constitute a protective layer for the organism. Favouring lipid intake is the large availability of food. The autumn months, as shown by the studies conducted then, abound in food (Tab. 1). This 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 this material was consumed during the winter. In spring, despite the low level of lipids, energy values remain 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 the seasonal changes of only one biochemical component – lipids – have been dealt with in this paper. It may be expected that at that time *Corophium volutator* specimens switch to a protein-type of metabolism, as is the case with other crustaceans at a time when they do not take in lipids (Szaniawska, 1991). Before the reproductive season (March, April) the lipid level may increase gradually, owing to a biological transformation of the female organism: adaptation for giving birth to the young. Large quantities of lipids must be utilized for forming eggs and embryos. When a large proportion of reproducing females is observed in the population (26.05.1992), the lipid content attains a local maximum. In June, the lipid level decreases, due to the appearance of juveniles in the population. The subsequent autumn increase is caused by the beginning of another reproductive cycle in females and energy storage before winter.

The detritus-feeding *Corophium volutator* feeds on low-energy food resources. Detritus is the dominant component of its diet. Bacillariophyceae, with an energy value of 15.97 J $mg^{-1}$ DW (Cummins and Wuycheck, 1971), constitute a negligible part of its food, together with bacteria and microalgae. This is not a high-energy food either. Schindler (1968) emphasizes that detritus has 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 *Corophium volutator* population 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 the inflow of food substances to their habitat and the appearance of females with embryos in the population.
- There was a low mean lipid level in their bodies – $5.8 \pm$ (SD) 4.14% d.w. – which explains their low energy value.
- The highest lipid levels were observed in autumn (low temperatures and the securing of reserve materials): in November it was 14% d.w.
- The seasonal variability in population composition significantly influences the nature of changes in the seasonal energy-value and lipid-level changes in the *Corophium volutator* population.
- *Corophium volutator* is a dominant species in the 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.

## References

Agrawal U. P., 1963, *Studies on the physiology of digestion in Corophium volutator*, J. Mar. Biol. Ass. U. K., 43, 125–128.

Blight E. G., Dyer W. J., 1959, *A rapid method of total lipid extraction and purification*, Physiology, 37, 911–917.

Bousfield E. L., 1973, *Shallow-water Gammariean Amphipoda of New England*, Proc. of the United States National Museum, 125, 159–239.

Cummins K. W., Wuycheck J. C., 1971, *Caloric equivalent for investigation in ecological energetics*, Mitt. Inl. Ver. Limnol., 18, 1–158.

Fenchel T., Kofoed L. H., 1975, *Particle size-selection of two deposit feeders: the Amphipod Corophium volutator and the Prosobranch Hydrobia ulvae*, Mar. Biol., 30, 119–128.

Gamble J. C., 1970, *Anaerobic survival of crustaceans Corophium volutator, C. arenaria and Tanais cherreuxi*, J. Mar. Biol. Ass. U. K., 50, 657–671.

Gamble J. C., 1971, *The responses of the marine Amphipoda Corophium arenarium and volutator to gradients and choices of different oxygen concentrations*, J. Exp. Biol., 54, 275–290.

Guryanova E. F., 1951, *Bokoplawy morey SSSR*, USSR Academy of Sciences, Proc. of the Zoological Institute, Moskva, 974–983.

Hart T. J., 1930, *Preliminary notes on the bionomics of the Amphipod Corophium volutator*, J. Mar. Biol. Ass. U.K., 16, 761–789.

Jażdżewski K., 1970, *Biology of Crustacea Malacostraca in the Bay of Puck, Polish Baltic Sea*, Zool. Pol. Arch. Soc. Pol., 20, 423–480.

Jażdżewski K., 1971, *Ecology of crustaceans from Puck Bay*, Acta Biol. et. Med. Soc. Sc. Gedan., 16, 44–45, (in Polish).

Klekowski R. Z., Bączkowski J., 1973, *A new modification of the microbomb calorimeter*, Ekol. Pol., XXI, 16, 229–236.

Kotwicki S., Miłosek A., Szymelfenig M., Witkowski A., Wołowicz M., *Structure and dynamics of benthic communities in the coastal zone of Puck Bay near Swarzewo purification plant*, Arch. Ochr. Środ., (in press), (in Polish).

Marsch J. B., Weinstein D. B., 1966, *Simple charring method for determination of lipids*, J. Lipid Res., 7, 574–576.

McLusky D. S., 1967, *Some effects of salinity on the survival, moulting and growth of Corophium volutator (Amphipoda)*, J. Mar. Biol. Ass. U.K., 47, 607–616.

McLusky D. S., 1970, *Salinity preference in Corophium volutator*, J. Mar. Biol. Ass. U. K., 50, 747–752.

Schellenberg A., 1942, *Die Tierwelt Deutschlands und der angrenzenden*, Meeresteibe, 40 (IV), 252.

Schindler D. W., 1968, *Feeding, assimilation and respiration rates of Daphnia magna under various environmental conditions and their relation to production estimates*, J. Anim. Ecol., 37, 369–385.

Segerstråle S. G., 1940, *Studien über die Bodentierwelt in südfinlandischen Küstengewässern IV. Zur Biologie des Amphipoden Corophium volutator, nebst Angaben über die Entwicklung und Rückbildung der Oostegitenborsten bei dieser*, Art. Soc. Fen. Com. Biol., 7 (XVI), 40.

Segerstråle S. G., 1959, *Synopsis of data on crustaceans Gammarus locusta, G. oceanicus, Pontoporeia affinis, and Corophium volutator (Amphipoda, Gammaridea)*, Soc. Sci. Fen. Com. Biol., 20 (5), 23.

Szaniawska A., 1991, *Energy management of benthic invertebrates from the Gulf of Gdańsk*, Ph. D. thesis, University of Gdańsk, Gdańsk, (in Polish).

Watkin E. E., 1941, *The yearly life cycle of the Amphipod Corophium volutator*, J. Anim. Ecol., 10 (I), 77–93.

Wołowicz M., Kotwicki S., Geringer d'Oedenberg M., 1993, *The long-term biocenotic changes near sewage discharge in the water treatment plant at Swarzewo in Puck Bay*, [in:] *Puck Bay*, K. Korzeniewski (ed.), Fundacja Rozwoju Uniwersytetu Gdańskiego, Gdańsk, 510–519, (in Polish).