Energetic value and lipid content of the Baltic zooplankton*

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Lipid content
Zooplankton
Baltic Sea

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Abstract

The results of measurements of energetic value and lipid content in the zooplankton of the southern Baltic in 1974 are presented. Diel and seasonal changes in these parameters are illustrated. The energetic value of organic matter ranged from 25.5 to 33.2 J·mg^{-1}, while the lipid content of dry plankton matter fluctuated between 4.3 and 22.9%.

1. Introduction

In the previous biological investigations of the Baltic, zooplankton biomasses were expressed by fresh weight or dry weight (Mańkowski, 1975, 1978 a, b; Lindahl, 1977). In present day investigations, it is sometimes also necessary to express the biomass of zooplankton by means of its energetic value. Particularly in ecosystem investigations the comparison of various trophic levels requires the use of one common idex, which may be energy or content of carbon (Hagmeier, 1961; Beers, 1966; Cummins and Wycheck, 1971; Williams and Robins, 1979). The use of calorific values of the plankton published by various authors (Kreutzberg and von Oertzen, 1973; Bast and von Oertzen 1976; Chojnacki, 1976: a, b Griffiths, 1977; Williams and Robins, 1979) for converting the biomass of the Baltic zooplankton into energy values does not always give satisfactory results as they often refer to other ecosystems and other species. They also exhibit significant discrepancies (from 20 to 30 J·m^{-1}). Therefore, in order to convert multi-year data and very numerous biomasses of the Baltic plankton into energy values, direct measurements of energetic value of the Baltic zooplankton were made. Since the calorific value of plankton depends to a large degree on its fat content, measurements of lipid content in the zooplankton were also made.

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2. Material and methods

Zooplanktonic samples were collected during cruises of the r/v 'Birkut' in the Southern Baltic in 1974. Stations at which the zooplankton was sampled are presented in Figure 1. A Hensen plankton net with a mesh size of 333 μm was used; the column of water was filtered vertically from the bottom to the sea surface. Planktonic samples were immediately dried in a temperature of 333° K in an oven specially

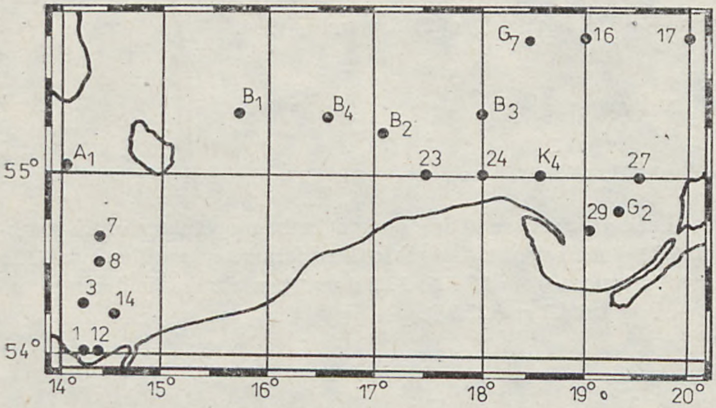

Fig. 1. Location of sampling stations

designed for this purpose and stored in an desiccator until the end of the cruise. Just before the samples were burned, tablets weighing from 10 to 25 mg were made from the plankton; these tablets were dried at a temperature of 333°K to a constant weight. Energetic value was measured by burning the tablets in a Phillipson (1964) microcalorimetric bomb (type Klekowski and Beczkowski, 1973). The energetic value was calculated with respect to benzoic acid, whose energetic value was assumed as 26.46 $J \cdot mg^{-1}$. From three to six measurements (burnings) were made from each planktonic sample. The results presented in the tables are the mean values from several measurements. High repeatibility of burning results was obtained; deviations of individual results from the mean value did not exceed 1% of the mean value. Ashes were determined by burning samples of dry plankton in a muffle furnace at a temperature of 773°K. Our experiences have shown that the process of drying and preparing the tablets for burning has to be carried out very carefully. Filter paper cannot be used for preliminary drying of samples since fat losses may occur there. The force applied for pressing the tablets cannot be too large since fat, very abundant in the Baltic plankton, may leak out.

Lipid content was determined by extraction-weighing method (Dowgiałło, 1975). The powdered dry material (about 0.1 g) underwent extraction while hot, but the solution consisting of methyl alcohol and chloroform was not allowed to reach the boiling point. After filtering, the extract was concentrated in a water bath with a temperature of 333−343°K and then in a vacuum desiccator over P_2O_5 in nitrogen atmosphere at a temperature of about 323°K. The preparations thus obtained were subjected to re-extraction with the help of the solution consisting of chloroform and petroleum ether. The solution obtained was filtered and concentrated in tared weighing bottles in a steam bath and then redried in a vacuum desiccator. By weighing bottles with settlings and taking into account the blank test with solvents, the weight of lipid (in per cent) was determined.

3. Results

The burned planktonic samples contained planktonic organisms which measured up to 2 mm when living. Dry plankton weight contained on the average 93.44% of organic substance and 6.56% of ash. The energetic value of the organic substance ranged from 25.5 to 33.2 J·mg^{-1}, while the lipid content in the plankton fluctuat-

Table 1. Energetic values and lipid content of the Baltic zooplankton

Date	Station	Energetic values				Lipid content [dry matter
		dry matter		organic matter		
		[cal/mg]	[J/mg]	[cal/mg]	[J/mg]	
22 IV	K_4	6.07	25.4	6.50	27.2	8.50
23	G_2	5.92	24.8	6.34	26.5	4.30
25	B_2	6.24	26.1	6.68	28.0	9.50
25	B_4	5.87	24.6	6.28	26.3	7.10
26	B_1	5.82	21.4	6.23	26.1	8.40
27	A_1	6.03	25.2	6.46	27.0	6.70
1 VI	G_2	6.80	28.5	7.28	30.5	21.80
2	B_3	6.73	28.2	7.20	30.1	17.30
3	B_1	6.57	27.5	7.03	29.4	18.10
5	A_1	6.35	26.6	6.79	28.4	12.90
14 VIII	G_2	7.24	30.4	7.76	32.5	.
15	B_3	6.75	28.3	7.22	30.2	17.90
17	B_1	7.00	29.3	7.45	31.2	.
18	A_1	6.56	27.5	7.02	29.4	.
18	7	7.39	30.9	7.92	33.2	.
18	8	6.42	26.9	6.87	28.8	14.80
18	26	6.55	27.4	7.02	29.4	15.50
19	1	7.31	30.6	7.83	32.8	.
19	12	7.10	29.7	7.59	31.8	.
20	14	7.34	30.7	7.85	32.9	.
26	G_7	5.70	23.9	6.10	25.5	5.60
26	16	5.71	23.9	6.11	25.6	.
26	17	7.05	29.6	7.55	31.6	.
27	23	5.89	24.7	6.31	26.4	5.70
27	24	5.92	24.8	6.34	26.5	6.30
29	27	7.28	30.5	7.79	32.6	.
29	29	6.73	28.2	7.20	30.1	18.60
7 XI	G_2	7.25	30.4	7.76	32.5	22.90
9	B_1	7.30	30.6	7.82	32.7	21.50

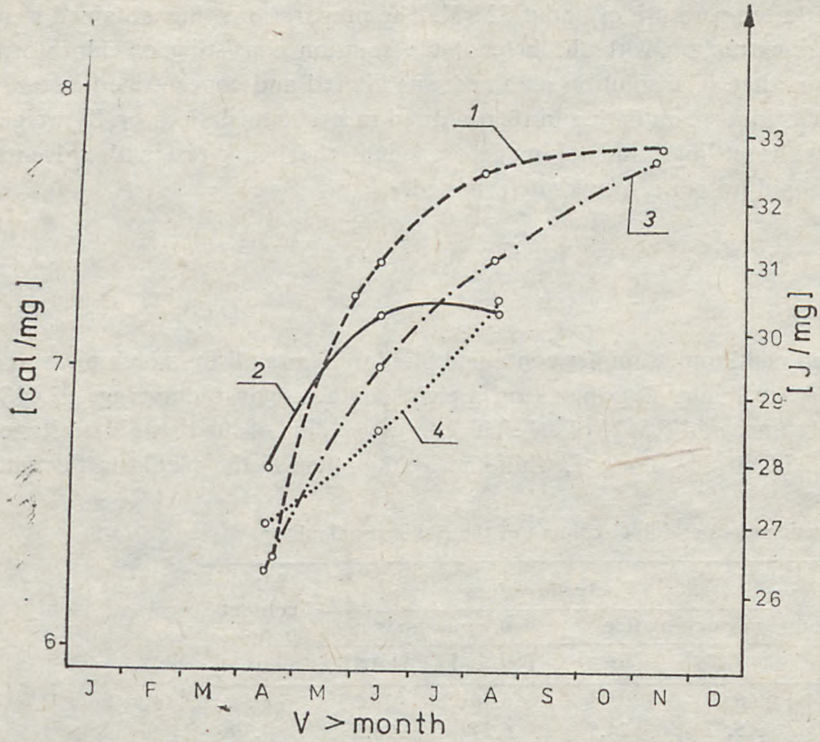

Fig. 2. Seasonal changes in the mean energetic value ([cal/mg] and [J/mg]) of the zooplankton in various areas of the Baltic Sea. *1*—Gdańsk Deep; *2*—Słupsk Furrow; *3*—Bornholm Deep; *4*—Arkona Deep

Table 2. Energetic values and lipid content of zooplankton in Gdańsk Deep in June 1974

Date	Time	Lipids [% of dry matter]	Energetic value [J/mg]	
			dry matter	organic matter
23 VI	4^{00}	21.8	29.0	31.1
	12^{00}	17.3	28.2	30.3
	20^{00}	22.6	30.2	32.1
	24^{00}	22.9	30.0	31.9
24 VI	4^{00}	19.2	28.3	30.1
	12^{00}	18.8	28.5	30.4
	16^{00}	21.1	29.1	31.3
	20^{00}	21.2	29.3	31.1
	24^{00}	23.6	30.4	32.3
25 VI	8^{00}	19.9	28.1	30.3
	12^{00}	20.6	28.6	30.7
	20^{00}	23.9	30.0	31.9
26 VI	16^{00}	14.3	28.1	30.9
	20^{00}	22.0	29.1	30.9

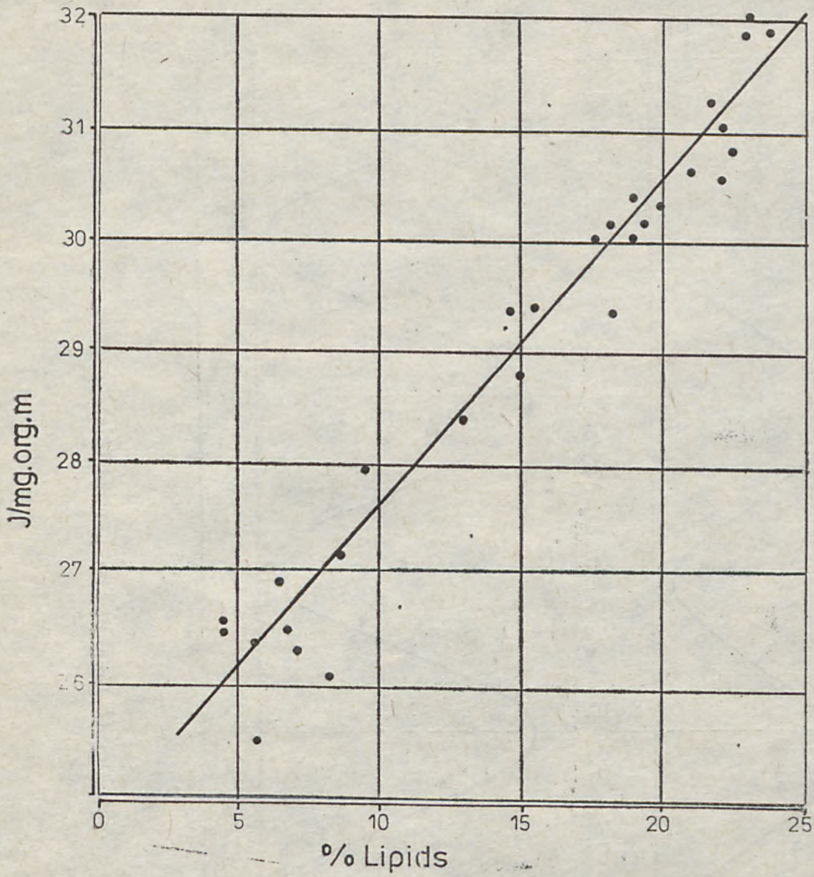

Fig. 3. The dependence of the energetic value of the organic plankton matter on the lipid content (per cent of dry plankton matter) of the Baltic zooplankton

ed between 4.3 and 22.9%. The results of energetic values and lipid contents in the zooplankton are presented in Table 1. The seasonal changes and regional differences in the plankton energetic value are presented in Figure 2. The points in Figure 2 represent the average values from the measurements made at the stations of a given area (*eg* the Gdańsk Deep—stations K_4, G_2, 27 and 29; the Arkona Deep—A_1, 7 and 8). It can be seen in Figure 2 that the energetic value of plankton in Gdańsk Deep was greater than in the Bornholm Deep. It can also be said that energetic value of the plankton increased from April to November. Figure 3 shows that the energetic value is proportional to the lipid content in the plankton. The equation for the relationship, determined by the least squares method, is:

$$E_n = 24.80 + 0.30L, \qquad (1)$$

where:

E_n—energetic value of plankton expressed in $J \cdot mg^{-1}$ (org. matter),

L—lipids expressed in per cent of the dry matter.

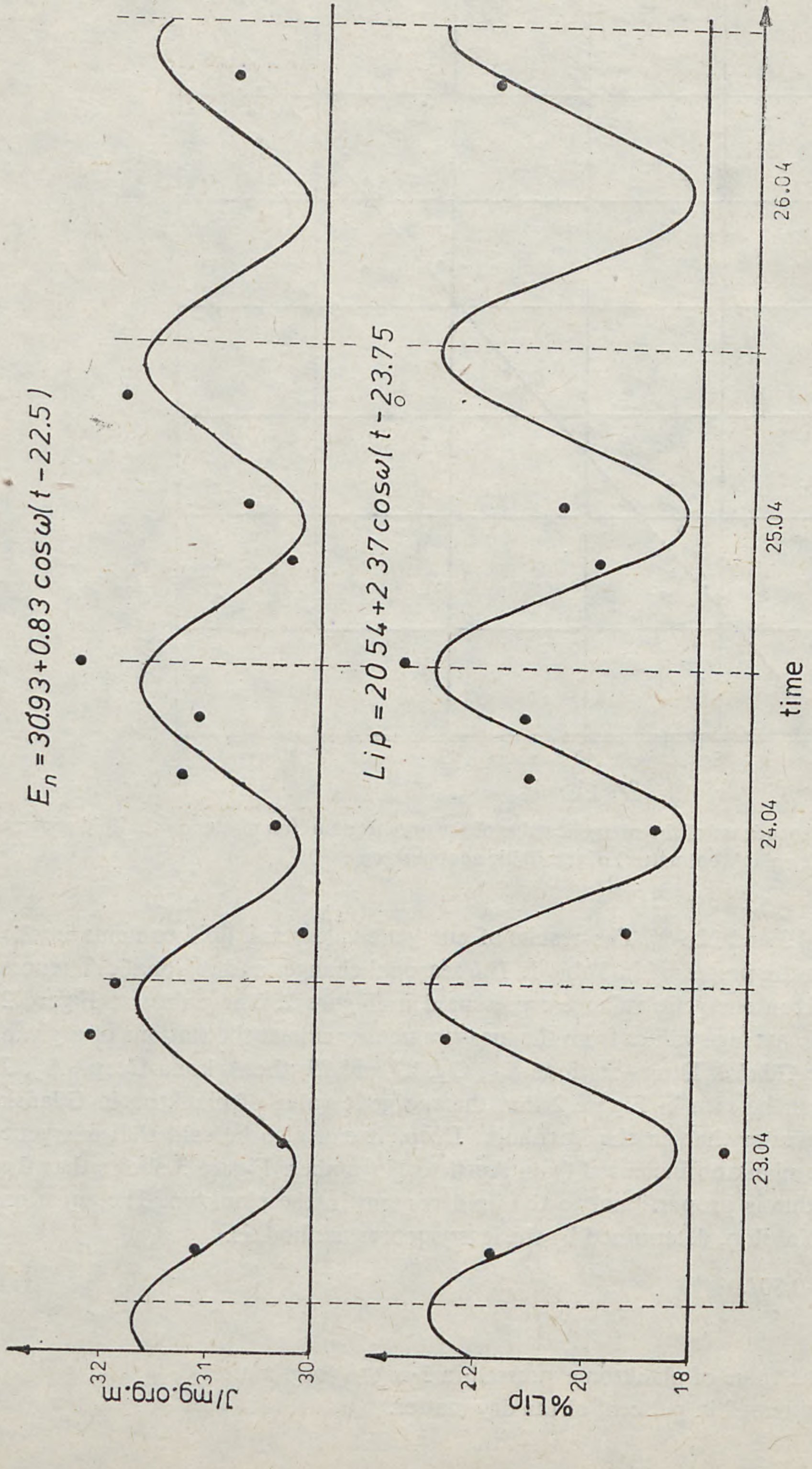

Fig. 4. Diel fluctuations of the plankton energetic value of the zooplankton (E_n) and its lipid content (*Lip*)

Between June 23 and 26, 1974 diel measurements of the plankton energetic value and lipid content were made (Table 2). It appeared from these observations that the plankton energetic value and lipid content increased during the night and dropped during day-time. The diel fluctuations in the plankton calorific value were described by mean of the following trigonometric function:

$$E_n = E_{n0} + E_{n1} \cos \omega (t - t_0)_1 \quad (2)$$

where:

E_{no} – mean value for the 24-hour period,
E_{o1} – amplitude of energetic value fluctuations,
t_0 – time when the maximum energetic value occurs,

ω $-\frac{2\pi}{T}$, ($T=24$ hours),

The diagram of the above function and the results of measurements of diel energetic values of the plankton are presented in Figure 4. The coefficients of equation (2) were determined by the least squares method on the basis of the diel measurements of energetic values. Figure 4 also presents diel fluctuations in lipid content in the plankton, which can be presented by means of the following function:

$$Lip = Lip_0 + Lip_1 \cos \omega (t - t_0). \quad (3)$$

Like in equation (2), the coefficients of this equation were calculated by least squares. In terms numerical values of the coefficients, the equations for variations of plankton energetic value in 24 hours, and for diel fluctuations of lipid content may be rewritten as follows:

$$E_n = 30.93 + 0.83 \cos \omega (t - 22.5), \quad (4)$$

$$Lip = 20.54 + 2.37 \cos \omega (t - 23.75). \quad (5)$$

4. Discussion

No detailed analysis of species composition of our planktonic samples was made. After our rough estimation it may be said, however, that species composition of the plankton underwent substantial changes during the year. In spring, about 90% of the zooplankton biomass were comprised of *Copepods*, especially *Temora longicornis* (Müller), *Acartia longiremis* (Liljeborg) and *Pseudocalanus elongatus* (Boeck); the rest belonged to *Cladocerans*. During the round-the-clock (June 23–26) investigations, *Temora longicornis* was the dominant species in the samples. *Cladocerans* were the most abundant in August (60–70%), the dominant species being *Bosmina coregoni maritima* (Müller). In autumn, the same species as in spring were most abundant but *Acartia longicornis* predominated. A more detailed description of the species composition of the Baltic plankton at that time may be found in the papers by: Chojnacki (1975, 1976b), Chojnacki and Drzycimski (1976) and Ciszewski and Witek (1977).

Mean energetic values (30.5 $J \cdot mg^{-1}$) of the Baltic zooplankton are relatively high when compared with the values quoted in the literature, *eg* in: Bast and von Oertzen (1976), Kreutzberg and von Oertzen (1973), Ostapenya and Shushkina (1971), Shushkina and Sokolova (1972), Musaeva and Sokolova (1979), Williams and Robins (1979), Zagorodnyanya and Pastukhova (1981), Shushkina and Musaeva (1982). The most likely reason for such discrepancies is the difference in methods of sample preparations for further counts. In some of the studies quoted above, formalin solution was applied for plankton samples preservation (Ostapenya and Shushkina, 1971; Shushkina and Sokolova, 1972, Zagorodnyaya and Pastukhova, 1981). Energetic values of zooplankton approximating the ones estimated in the Baltic Sea were counted for *Copepods* by Phillipson (1964) and Okołowicz (1980).

Seasonal changes in the energetic values of plankton may be due to alternations in species composition of plankton during the year, as well as to variations in fat content in plankton individual species. Seasonal changes in energetic value of plankton may also result from varying participation of juvenile forms in the total plankton matter. According to Petipa (1964), Williams and Robins (1979), the increasing participation of older development stages and of mature *Copepods* in plankton samples will be accompanied by an increase of specific energetic value of zooplankton. The high calorific value of the Baltic plankton is connected with its high fat content. Large amounts of fat were observed when the tablets for the burnings were prepared as well as during direct measurements of lipid content. These values are in the same order of magnitude as the values of lipid contents in zooplankton and other marine animals observed by Fisher (1962), Falk-Petersen (1981), Falk-Petersen *et al* (1981), Sargent and Falk-Petersen (1981), Handerson *et al* (1982), Falk-Petersen and Sargent (1982), Falk-Petersen *et al* (1982).

The reason for diel fluctuations in the calorific value of the plankton are probably related with the diel feeding rhythm of the plankton. Planktonic species occurring in the investigated samples feed mostly during night-time (Wimpenny, 1938; Detalo, 1964; Petipa, 1964a; Zagorodnyaya, 1974; 1975; Pawlowskaja and Peczen-Finenko, 1975; Petipa *et al* 1975).

Such diel fluctuations in the fat content in the zooplankton were also observed by Petipa (1964b), according to whom they may exceed 10% of the fresh plankton weight. It appears from our results (Fig. 4) that diel changes in the lipid content in the plankton may equal about 23% (with respect to the mean value).

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