Short-term and seasonal variability of mesozooplankton at two coastal stations (Gdynia, Sopot) in the shallow water zone of the Gulf of Gdańsk

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Abstract

The idea of the study was to describe short-term and seasonal variations in the composition and abundance of zooplankton in the coastal area of the Gulf of Gdańsk at two shore stations and the influence of selected environmental factors (temperature, salinity, wind velocity) on it. The studies were based on material collected in the shallow waters of the Gulf of Gdańsk from stations located by the Marine Promenade (Bulwar Nadmorski) in Gdynia and the pier in Sopot. Samples were collected in 2001 mainly at weekly intervals using an open-type plankton net. Environmental parameters were measured at the same time. The zooplankton at the Gdynia and Sopot stations consisted of 30 taxa; Rotatoria, Copepoda and meroplankton were dominants. There was a much higher percentage of Rotatoria and a lower percentage of meroplankton at Sopot than at Gdynia. Considerable differences were apparent in the numbers of particular groups of zooplankton at these stations in the same periods. Simpson's biodiversity index, here based on the zooplankton of the shallow waters off Gdynia and Sopot, was relatively high most of the time. Diversity of mesozooplankton was greatest in July and October. There was a significant correlation between the abundance of mesozooplankton and environmental factors in the case of cladoceran and polychaete larvae. Frequent studies at stations located close to each other illustrate the highly dynamic range of variations occurring in the coastal area: the concentrations of particular organisms

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fluctuated very considerably from one week to another, even by a factor of several dozen. Nevertheless, the statistically mean numbers of zooplankton at both stations are comparable.

1. Introduction

Zooplankton are animals kept in suspension by water turbulence and dispersed more by such water movements than by their own actions. Although the zooplankton consists of a great many taxa, in the Baltic Sea and in other seas and oceans, crustaceans make up by far the largest proportion.

It was Mańkowski (1937, 1938) who initiated studies of pelagic fauna in Poland in the 1930s. After World War II further papers on zooplankton were published, including those by Mańkowski (1951), Ciszewski (1962) and Siudziński (1977). Since 1977, the Institute of Oceanography of the University of Gdańsk has conducted comprehensive studies of zooplankton in the Gulf of Gdańsk, which have focused on identifying changes in the environment that have resulted largely from increasing water eutrophication (Szaniawska 1977, Wiktor et al. 1982, Wiktor & Żmijewska 1985). To date, the sampling stations have been scattered throughout the Gulf of Gdańsk at a minimum depth of 10 metres or deeper, and samples have been collected at monthly or quarterly intervals (Siudziński 1977, Szaniawska 1977, Wiktor et al. 1982, Wiktor & Żmijewska 1985, Żmijewska et al. 2000). Research of a similar nature, though usually focused on seasonal changes, has also been carried out on mesozooplankton in other parts of the Baltic Sea (Hernroth & Ackefors 1979, Heerkloss & Schnese 1991, Viitasalo et al. 1995, Dippner et al. 2000, Möllmann et al. 2000).

The first attempt to describe short-term variations in the coastal zone of the Gulf of Gdańsk was undertaken in 1991–92 at the Centre of Marine Biology (Kozakiewicz & Styczyńska-Jurewicz 1993). Similar studies have been carried out for three years now at the Institute of Oceanography UG, with the aim of determining the composition, abundance and dynamics of short-term variations in the pelagic fauna of this area (Bielecka et al. 2000).

Like the whole Baltic Sea, the Gulf of Gdańsk is very special in terms of hydrology and climate. The most important factor influencing its specificity is the salinity, which depends on the quantity of water entering from the river Vistula and currents from the open Baltic (Cyberska 1990, Matthäus & Schinke 1994).

The primary aims of the present work was to describe the short-term and seasonal variations in the composition and abundance of zooplankton in the coastal zone of the Gulf of Gdańsk at two shore stations located at

Gdynia and Sopot, and to find out to what extent these parameters are influenced by temperature, salinity and wind speed. A further aim was to assess the degree of homogeneity of the littoral zone at these two stations.

2. Materials and methods

The studies were based on material collected in the shallow waters of the Gulf of Gdańsk in 2001 from stations located by the Marine Promenade (Bulwar Nadmorski) in Gdynia and the pier in Sopot; the two stations are about 12 km apart. Samples were collected weekly, except in winter when they were collected every fortnight. A total of 90 surface hauls were made (the net was hauled for a distance of about 60 m) and 90 vertical samples were collected at a depth of 1 m (the depth at the sampling point was about 1.5 m).

The hauls were made using an open-type plankton net of diameter 0.22 m and mesh size 50 μm. A WT LF 340 probe was also used during sample collection to measure the water temperature and salinity.

Having been preserved in 4% formaldehyde solution, the samples were identified with a Nikon SMZ 800 stereoscopic microscope. Mesozooplankton specimens were identified to the smallest taxonomic unit; trochophore larvae were not identified to the species level. Since concentrations of organisms were not very great, all of them were accounted for, and no sub-samples were prepared. Not included in the results are the data from the surface hauls, since they merely confirmed the species composition in the water column. Rather, they were used to determine the abundance of particular organisms in the water and whether an organism had been collected accidentally.

The results were recalculated to the number of specimens in the water column, and Simpson's biodiversity coefficient D was derived on a weekly basis with the formula

$$D = 1 - \sum_{i=1}^{S} (p_i{}^2).$$

The value of Simpson's coefficient varied from 0 (low biodiversity) to the maximum 1–1/S, where S is the number of species in the group and p_i the proportion of individuals of species i in the group (Krebs 1989). This coefficient illustrates both the biodiversity of zooplankton and its average annual abundance.

The percentages of the various zooplankton components in the Gulf of Gdańsk were calculated for the whole of 2001. Student's t-test (Łomnicki 1995) was used to compare the average abundance of particular components and all of the mesozooplankton at both stations. Using linear regression, the authors attempted to correlate the overall abundance of the mesozooplankton and its constituents with measured temperature, salinity and wind speed.

3. Results

The year-long measurements of water temperature and salinity enabled short-term variations in these very important marine environment parameters to be detected. The highest and lowest water temperatures were recorded at Gdynia on 19 January 2001 (0.8°C) and 6 July 2001 (24.5°C) (Fig. 1). The weekly water temperatures were similar at the two stations as these lie quite close to each other. One significant weekly water temperature increase (by 7°C) was recorded during the sampling period on 6 July 2001. In other months, the temperature variations were far less pronounced. Water salinity differences were even smaller, with annual variations lying between 6.0 and 7.3 PSU.

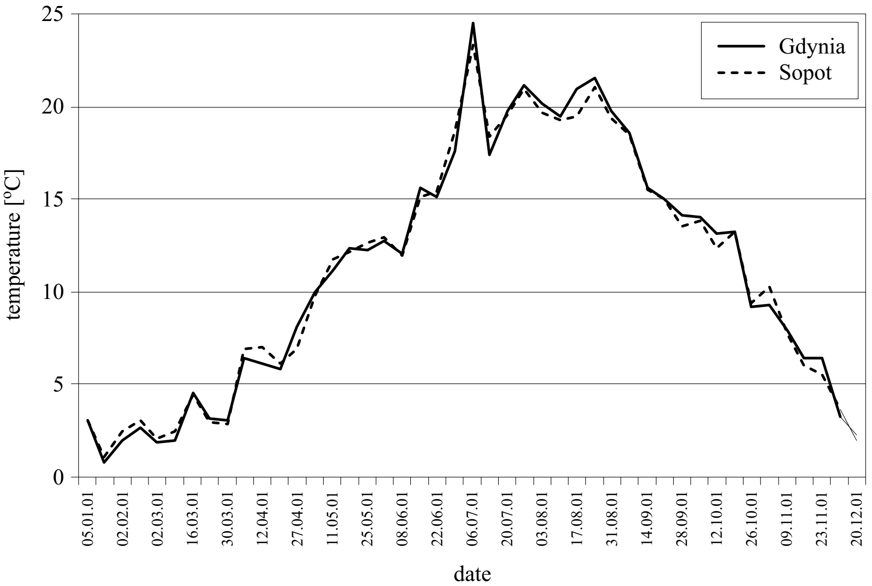

Fig. 1. The sea water temperature at two stations in 2001

The zooplankton at the Gdynia and Sopot stations comprised 30 taxa (Table 1), of which Rotatoria, Copepoda and meroplankton were dominant (Fig. 2). The meroplankton consisted of the larvae of Mollusca, Cirripedia, Polychaeta and trochophores. The larvae of trochophores and Appendicularia were not numerous, so these two groups were excluded from the detailed description of the results (Fig. 2).

Table 1. The occurrence of identified zooplankton taxa in Gdynia and Sopot

Taxon	Gdynia	Sopot	Taxon	Gdynia	Sopot
Keratella cochlearis	+	+	*Centropages hamatus*	+	+
Keratella cruciformis	+	+	*Pseudocalanus* sp.	+	+
Keratella quadrata	+	+	Unidentified Copepoda	+	+
Synchaeta baltica	+	+	Harpacticoida	+	+
Synchaeta monopus	+	+	*Balanus improvisus* nauplii	+	+
Synchaeta fenica	+	+	*Balanus improvisus* cypris	+	+
Synchaeta spp.	+	+	Bivalvia veliger	+	+
Trichocerca marina	+	+	Gastropoda veliger	+	+
Bosmina coregoni maritima	+	+	Trochofora	+	+
Evadne nordmanni	+	+	Polychaeta larvae	+	+
Podon polyphemoides	+	+	Insecta larvae	+	+
Podon intermedius		+	*Fritilaria borealis*	+	+
Acartia spp.	+	+	Polychaeta	+	
Temora longicornis	+	+	Isopoda	+	
Eurytemora spp.	+	+	*Zoea decapoda*		+

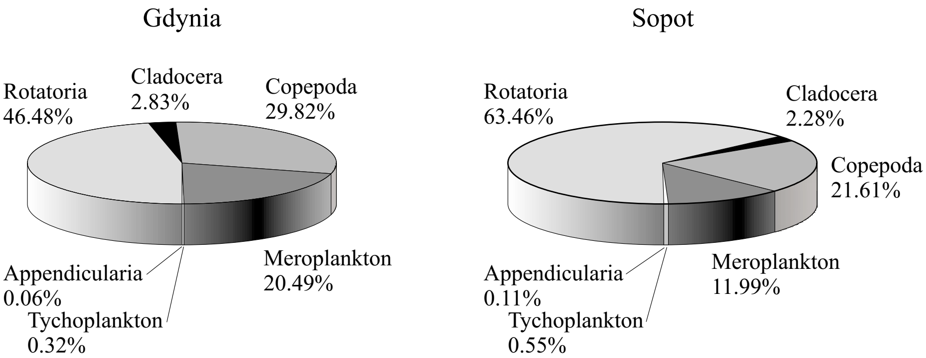

Fig. 2. The percentage of particular zooplankton components in 2001

The percentage of Rotatoria was much higher (63.56%) and that of meroplankton lower (11.99%) at Sopot in comparison with the figures from Gdynia (46.58% and 20.49%, respectively) (Fig. 2). At both stations small numbers of tychoplankton were netted; their presence, however, was accidental, since these waters are not their natural environment (Fig. 2). These organisms included specimens of Harpacticoida, mature Polychaeta, Isopoda and Insecta larvae.

There were three genera of Rotatoria – *Synchaeta*, *Keratella* and *Trichocerca*, *Synchaeta* being distinctly dominant at both stations (Table 2). Rotatoria were present for most of the study period, and concentrations were highest in spring and late summer (Fig. 3). There were evident variations in Rotatoria concentrations in different weeks. Only in June and July did their concentrations remain stable from week to week at both stations. The maximum weekly increment was fifty-fold, from 1711 indiv. m^{-3} (11 May 2001) to 109 201 indiv. m^{-3} (18 May 2001) at the Sopot station. Two weeks later the number dropped to 632 indiv. m^{-3}. In Gdynia the greatest increase in Rotatoria concentration – from 711 indiv. m^{-3} to 19 820 indiv. m^{-3} – occurred between 9 March 2001 and 16 March 2001. Smaller but equally rapid variations in Rotatoria concentrations took place in April and August, when the concentration increased six- to eight-fold over a two-week period before returning to the initial value of approximately 1000 indiv. m^{-3} (Fig. 3).

Table 2. The percentage of Rotatoria taxa

Gdynia			Sopot		
Taxon	[indiv. m^{-3}]	[%]	Taxon	[indiv. m^{-3}]	[%]
Keratella spp.	36900	25.67	*Keratella* spp.	55509	24.39
Synchaeta spp.	106730	74.25	*Synchaeta* spp.	172053	75.59
Trichocerca marina	106	0.07	*Trichocerca marina*	53	0.02

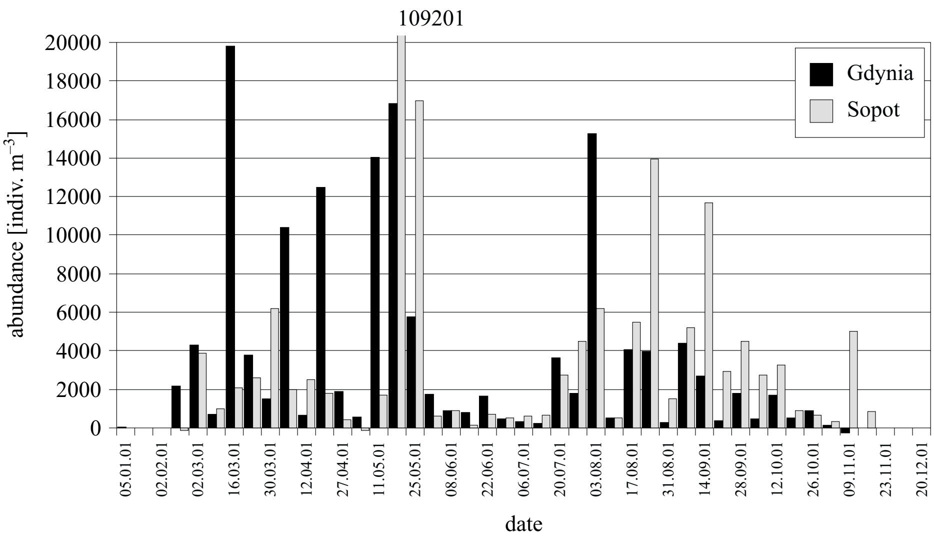

Fig. 3. The abundance of Rotatoria in successive weeks of the study

Table 3. The percentage of Cladocera taxa

Gdynia			Sopot		
Taxon	[indiv. m^{-3}]	[%]	Taxon	[indiv. m^{-3}]	[%]
Bosmina coregoni maritima	1341	15.35	*Bosmina coregoni maritima*	2316	29.33
Evadne nordmanni	578	6.62	*Evadne nordmanni*	869	11.00
Podon polyphemoides	6818	78.04	*Podon polyphemoides*	4922	62.33
			Podon intermedius	79	1.00

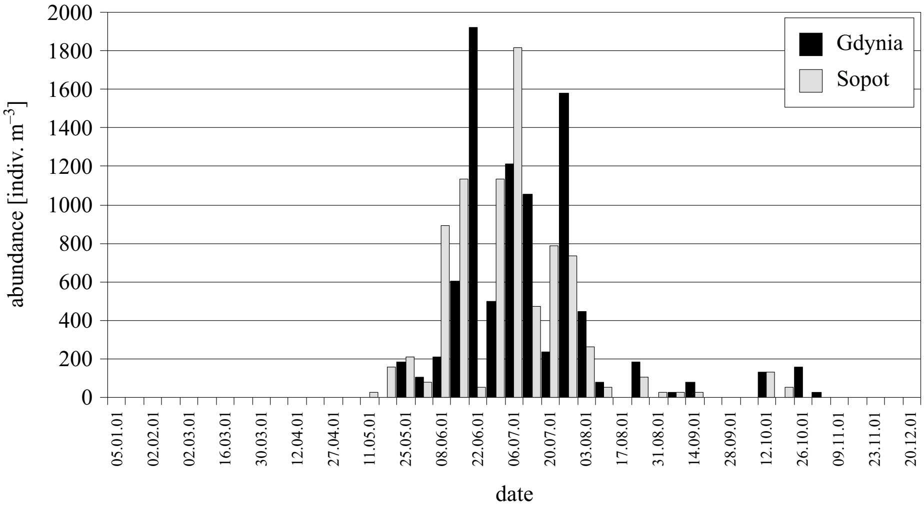

Fig. 4. The abundance of Cladocera in successive weeks of the study

Cladocerans at the Gdynia station were represented by three species – *Bosmina coregoni maritima*, *Evadne nordmanni* and *Podon polyphemoides* (Fig. 4). Along with another species, *Podon intermedius*, they were also netted at Sopot (Table 3). The maximum Cladocera concentration was noted on 22 June 2001 at Gdynia (1921 indiv. m^{-3}) and, as in the case of the Rotatoria, variations in abundance were considerable. Numbers achieved a maximum in June and July. On 15 June, the concentration fell from 1132 indiv. m^{-3} to 53 indiv. m^{-3}, only to increase two weeks later to 1816 indiv. m^{-3}, the highest value recorded at Sopot. At Gdynia, the Cladocera concentration dropped by a factor of four from the maximum value, but subsequently doubled to reach 1211 indiv. m^{-3} (Fig. 4).

Copepoda was the only zooplankton component in the coastal area of the Gulf of Gdańsk present throughout the year, *Acartia* spp. being dominant (Table 4, Fig. 5). Copepoda concentrations were highest in March

Table 4. The percentage of Copepoda taxa

Gdynia			Sopot		
Taxon	[indiv. m^{-3}]	[%]	Taxon	[indiv. m^{-3}]	[%]
Acartia spp.	78987	85.67	*Acartia* spp.	64326	82.93
Temora longicornis	3000	3.25	*Temora longicornis*	1184	1.53
Eurytemora spp.	5764	6.25	*Eurytemora* spp.	8686	11.20
Centropages hamatus	2131	2.31	*Centropages hamatus*	1606	2.07
Pseudocalanus sp.	1290	1.40	*Pseudocalanus* sp.	1395	1.80
Unidentified Copepoda	1026	1.11	Unidentified Copepoda	442	0.48

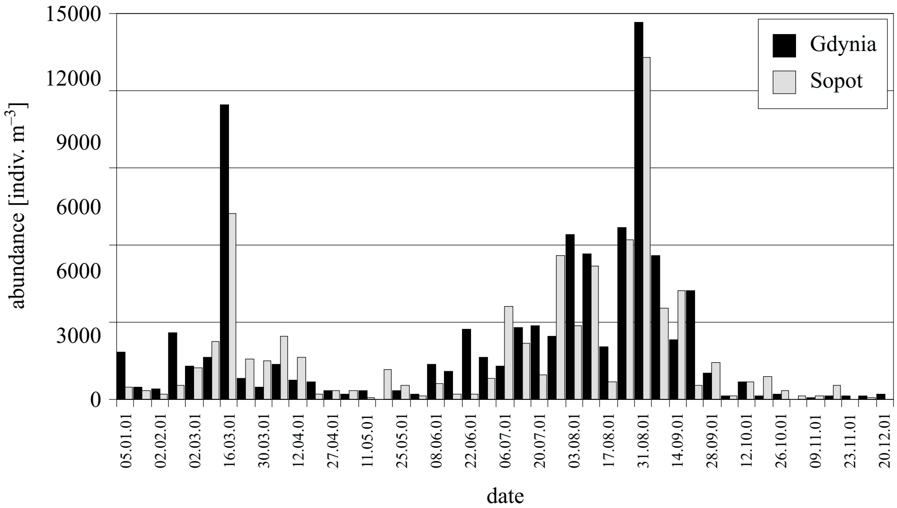

Fig. 5. The abundance of Copepoda in successive weeks of the study

and August, peaking at 14 634 indiv. m^{-3} on 31 August 2001 in Gdynia. Although the water temperature was higher, the abundance of Copepoda in May was closer to the figure from the winter months. The week-to-week differences between Copepoda numbers at the two stations were very small. Only in March and in summer were the weekly changes rather more dynamic. A one-off seven-fold increase in abundance occurred on 16 March in Gdynia, while in Sopot there was a three-fold increase in comparison with the previous week. The greatest increase in abundance at Sopot took place in the second half of August (17 August – 31 August 2001), when copepod numbers rose by a factor of nineteen to 13 265 indiv. m^{-3}. In the first week of September their numbers fell to 3580 indiv. m^{-3}. Although a similar situation occurred at Gdynia, the amplitude of changes was not as high, the abundance increasing only seven-fold (Fig. 5).

There were marked differences in the numbers of particular meroplankton components at both stations. Mollusca veliger were more common at Sopot (Fig. 7), whereas *Balanus improvisus* nauplii were present in greater numbers at Gdynia (Fig. 6). Representatives of both Mollusca and Cirripedia were present in summer, whereas Polychaeta larvae were noted in the colder months.

Cirripedia larvae (*B. improvisus* nauplii) occurred at both stations in the middle of May; however, only at Gdynia in June did their numbers exceed 10 000 indiv. m^{-3}, at which level they remained for the next three weeks. A maximum of 14 739 indiv. m^{-3} was reached on 8 June, prior to which their concentration had risen twelve-fold during one week. In the same week their numbers at Sopot had increased by a factor of ten; the maximum (3658 indiv. m^{-3}), however, was much smaller. In subsequent weeks *B. improvisus* nauplii were either recorded in small numbers (< 2000 indiv. m^{-3}) or were not recorded at all (Fig. 6).

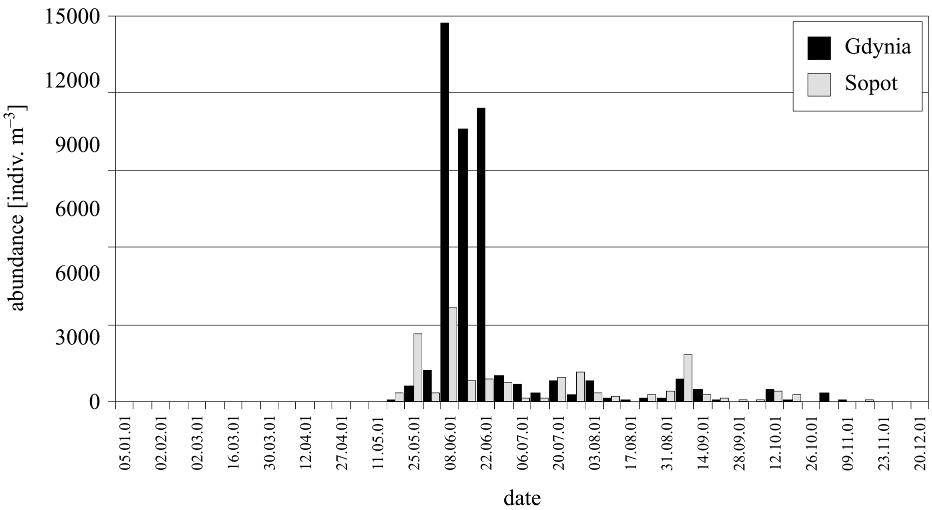

Fig. 6. The abundance of Cirripedia larvae (*Balanus improvisus* nauplii) in successive weeks of the study

The situation was different with regard to Mollusca veliger: numbers were larger at the Sopot station, peaking at 7580 indiv. m^{-3} on 6 July 2001 (Fig. 7). At Gdynia, specimens of this taxon were much less abundant, and only in July did its numbers increase rapidly from 105 indiv. m^{-3} (29 June 2001) to 5238 indiv. m^{-3} (13 July 2001). The following week saw an equally abrupt fall, by a factor of 25. At Sopot, the first dynamic changes in Mollusca veliger abundance were recorded as early as May, when during a single week the number of Mollusca larvae rose from zero to over

3000 indiv. m^{-3}. A subsequent, equally high amplitude of change occurred in late June and early July, when a rise by 7369 specimens was followed by a fall by 7238 specimens in the following two weeks (Fig. 7). Bivalvia veliger was almost the only representative of Mollusca in the coastal waters of the Gulf of Gdańsk (Table 5).

Table 5. The percentage of particular taxa of Mollusca veliger

Gdynia			Sopot		
Taxon	[indiv. m^{-3}]	[%]	Taxon	[indiv. m^{-3}]	[%]
Bivalvia veliger	9212	90.67	Bivalvia veliger	23188	93.8
Gastropda veliger	947	9.33	Gastropda veliger	1079	6.2

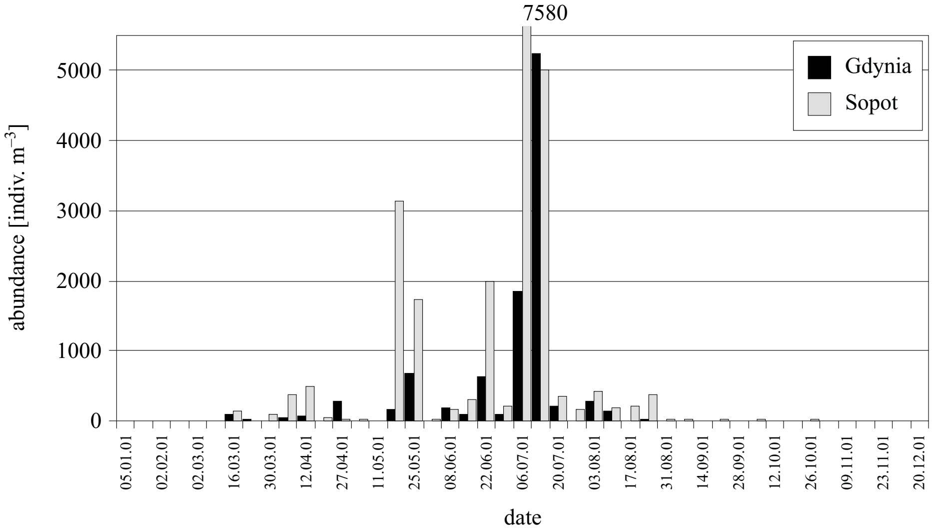

Fig. 7. The abundance of Mollusca veliger in successive weeks of the study

Polychaeta larvae occurred sporadically and then only in very small numbers (Fig. 8). Only on 16 March 2001 at Gdynia was their concentration relatively high at 3000 indiv. m^{-3}. This was, however, an isolated event; throughout their period of occurrence, numbers were no higher than 400 indiv. m^{-3}, and frequently less than 100 indiv. m^{-3} (Fig. 8). These values may not fully reflect the true situation, since trochophore larvae were recorded in the water column but were not assigned to any taxonomic unit; they could well have been the larval stages of Polychaeta.

Simpson's zooplankton biodiversity coefficient D reached a maximum (0.85) for the coastal zone of the Gulf of Gdańsk on 20 July 2001 at Sopot (Fig. 9). The mean value for the entire study period was 0.54. On five

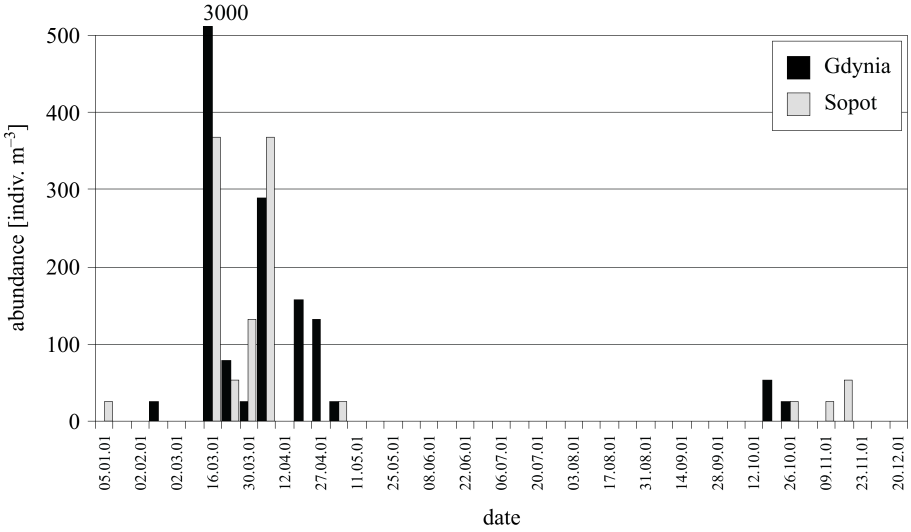

Fig. 8. The abundance of Polychaeta larvae in successive weeks of the study

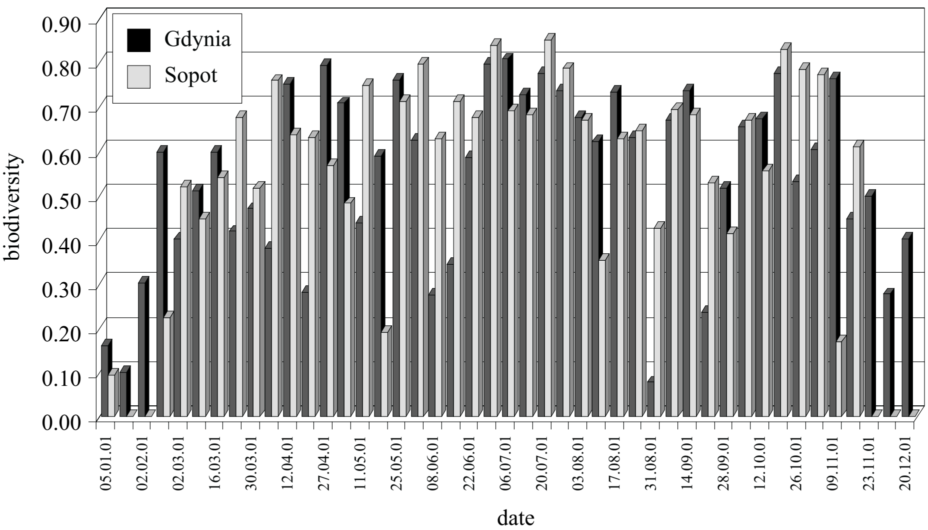

Fig. 9. The biodiversity of zooplankton in successive weeks of the study (Simpson's biodiversity index)

occasions at Sopot during the winter, D was equal to zero, when *Acartia* spp. was the only component of the zooplankton present. In the other months the value of D varied significantly, through rarely dropping below 0.3 (Fig. 9). At both stations D reached a maximum in July (av. 0.76) and October (av. 0.69).

Table 6. The dependence of the total number of mesozooplankton and its components (y) on salinity (x_1), water temperature (x_2) and wind velocity (x_3). Correlation coefficients of the equation of linear regression. $^*p = 0.05$; $^{**}p = 0.001$

Station	Sopot		
Mesozooplankton components	(x_1)	(x_2)	(x_3)
Rotatoria	$y = 4 \times 10^{-5}x + 10.916$ $r = -0.1475$	$y = -2 \times 10^{-6}x + 6.8593$ $r = 0.0926$	$y = -2 \times 10^{-5}x + 5.4527$ $r = -0.0889$
Cladocera	$y = 0.0087x + 9.5173$ $r = 0.2312$	$y = 0.0001x + 6.8245$ $r = 0.5225^{**}$	$y = -0.0029x + 5.8546$ $r = -0.2598$
Copepoda	$y = 0.001x + 9.3085$ $r = -0.3235^{*}$	$y = -3 \times 10^{-5}x + 6.9224$ $r = 0.4001$	$y = 0.0004x + 5.9907$ $r = -0.2217$
Balanus improvisus nauplii	$y = -0.0005x + 16.366$ $r = 0.2148$	$y = 6 \times 10^{-5}x + 6.7454$ $r = -0.1109$	$y = 0.0002x + 3.8565$ $r = 0.0524$
Mollusca larvae	$y = -0.0022x + 10.654$ $r = 0.1999$	$y = 5 \times 10^{-5}x + 6.9224$ $r = 0.2701^{*}$	$y = -0.0006x + 5.467$ $r = -\ 0.1126$
Polychaeta larvae	$y = -0.0034x + 6.3184$ $r = 0.6030$	$y = 0.0008x + 6.7162$ $r = -0.1808^{**}$	$y = -0.0179x + 11.033$ $r = -0.3634^{*}$
Total zooplankton	$y = 8 \times 10^{-5}x + 10.49$ $r = -0.1656$	$y = -2 \times 10^{-6}x + 6.8662$ $r = -0.2040$	$y = -4 \times 10^{-5}x + 6.6248$ $r = -0.1465$

Table 6. (*continued*)

Station	Gdynia		
Mesozooplankton components	(x_1)	(x_2)	(x_3)
Rotatoria	$y = –1 \times 10^{-5}x + 11.105$ $r = 0.0509$	$y = 2 \times 10^{-6}x + 6.9264$ $r = 0.0106$	$y = –8 \times 10^{-5}x + 5.6045$ $r = –0.0974$
Cladocera	$y = 0.0076x + 9.6761$ $r = 0.2045$	$y = 0.0001x + 6.9139$ $r = 0.4867^{**}$	$y = –0.0023x + 5.7859$ $r = –0.2317$
Copepoda	$y = 0.008x + 9.4346$ $r = –0.0989$	$y = –7 \times 10^{-6}x + 6.9476$ $r = 0.3728^{*}$	$y = –0.0003x + 6.0011$ $r = –0.2251$
Balanus improvisus nauplii	$y = 0.0001x + 15.643$ $r = 0.4586^{*}$	$y = 2 \times 10^{-5}x + 6.8781$ $r = –0.0823$	$y = –0.0002x + 5.5267$ $r = –0.1552$
Mollusca larvae	$y = 0.0018x + 10.149$ $r = 0.1890$	$y = 3 \times 10^{-5}x + 6.8324$ $r = 0.2701$	$y = –0.0006x + 5.6639$ $r = –0.1126$
Polychaeta larvae	$y = –0.0008x + 6.934$ $r = 0.252891$	$y = 8 \times 10^{-5}x + 6.8677$ $r = –0.2192$	$y = 0.0003x + 4.598$ $r = 0.1233$
Total zooplankton	$y = 0.0003x + 9.3949$ $r = 0.1459$	$y = 4 \times 10^{-6}x + 6.9049$ $r = 0.2819$	$y = –0.0001x + 6.3258$ $r = –0.2472$

Statistical analysis (Student's t-test) did not show up any significant differences in average abundance for particular components and the zooplankton as a whole between Gdynia and Sopot. Only in the case of Mollusca larvae was the difference statistically significant ($t = 1.99$; $df = 44$; $p = 0.05$) (Łomnicki 1995).

The correlation between the abundance of particular components of the mesozooplankton and selected environmental factors (temperature, salinity, wind speed) was examined. In the case of cladocerans there was a strong positive correlation between their numbers and the water temperature at both stations (Table 6). At Sopot, the abundance of polychaete larvae and water temperature were strongly correlated: numbers increased with temperature decrease. There was a similar though weaker correlation with respect to wind speed. A similarly weak correlation was found for Copepoda. At Sopot the numbers of copepods increased with a drop in salinity, but at Gdynia with a rise in temperature. The statistical results also suggest that the abundance of *B. improvisus* nauplii at Gdynia was positively affected by salinity, whereas the number of Mollusca larvae in Sopot was closely related to temperature (Table 6).

4. Discussion

The Gulf of Gdańsk is inhabited mainly by euryhaline, freshwater and Baltic organisms. This area is characterised by a relatively low species diversity, and differences can only be seen through investigations of the distribution of species numbers and their percentage in the zooplankton (Wiktor et al. 1982, Wiktor 1990). Rotatoria, Copepoda, and meroplankton larvae of benthic organisms were dominant in the shallow waters of the coastal zone of the Gulf of Gdańsk, both at Gdynia and Sopot. Other researchers have reported similar compositions of zooplankton species from the southern Baltic Sea (Siudziński 1977, Wiktor et al. 1982, Wiktor & Żmijewska 1985, Postel et al. 1995, Heerkloss & Schnese 1999, Żmijewska et al. 2000). The numbers of specimens from these systematic groups reported by Bielecka et al. (2000) in studies of the Gulf of Gdańsk zooplankton carried out at the Gdynia station in 1998–99 were the highest ever recorded. Although the set of dominants at Gdynia and Sopot was similar, the percentages were not. Rotatoria made up the principal component of the zooplankton at both stations, although they were more significantly dominant in Sopot. Likewise, Kozakiewicz & Styczyńska-Jurewicz (1993) attempted to determine the short-term variability in mesozooplankton composition at stations at Sopot and Gdynia–Oksywie in the Gulf of Gdańsk in 1991–92. According to their results, Copepoda were dominant percentage-wise at both stations. However, any further comparisons with that work are impossible because its authors summed their data and presented them in the form of seasonal variations.

Rotatoria concentrations were greatest in spring, for example, at Sopot in May 2001. Dippner et al. (2000) reported a similar tendency in the central Baltic Sea: numbers of Rotatoria decreased in early summer and then began to rise again between August and September. Wiktor & Żmijewska (1985), who conducted studies of pelagic fauna in the Gulf of Gdańsk in 1981, reported the highest numbers of Rotatoria in July and August. Wiktor et al. (1982) also reported a decrease in Rotatoria numbers in summer and an elevated concentration in early autumn in the shallow waters of the Gulf of Gdańsk in 1977–78. The reverse was the case at Gdynia in 1998–99 (Bielecka et al. 2000), when Rotatoria were dominant in summer. The maximum concentration was, however, only half that recorded by this author in 2001. Although the tendencies are similar, there are distinct differences in the numbers of Rotatoria at particular periods of time. Except for one unusual maximum in May, Rotatoria numbers were generally much higher at Gdynia in spring and at Sopot in autumn. The genus *Synchaeta*, which Siudziński (1977) regards as cold-water dwelling, was responsible for the highest Rotatoria numbers at both stations. A similar dominance of *Synchaeta* among the Rotatoria has been reported from the southern (Viitasalo et al. 1995) and central (Dippner et al. 2000) Baltic Sea.

Cladocera are the most characteristic element of the coastal zooplankton in the Gulf of Gdańsk in summer. They are found in the greatest abundance in the well-warmed surface and subsurface water layers (Żmijewska 1974, Wiktor et al. 1982, Wiktor & Żmijewska 1985, Bielecka et al. 2000). The Cladocera abundance recorded in 2001 was lower than that noted by Siudziński (1977) (approx. 4300 indiv. m^{-3}), by Szaniawska (1977) (5000 indiv. m^{-3}) and by Bielecka et al. (2000) (8526 indiv. m^{-3}). As in the coastal zooplankton studies carried out in Gdynia three years earlier (Bielecka et al. 2000), cladoceran abundance varied significantly in the summer months. During the period when their concentrations were at a maximum, the rule was that during the weeks when they were abundant at Gdynia they were scarce at Sopot, and vice versa. *P. polyphemoides*, which prefers shallow waters (Siudziński 1977), was the most common and abundant cladoceran species. Similar observations were made by Wiktor & Pliński (1992), Bielecka et al. (2000) and Żmijewska et al. (2000).

Copepoda are present all the year round, only their numbers vary. They are also one of the few members of the zooplankton present in the water in winter (Siudziński 1977). In 2001, there were two concentration maxima: one in March, and a second, larger one in August at Gdynia

(6396 indiv. m^{-3}). Although the August maximum is typical and has been reported by many authors (Szaniawska 1977, Wiktor et al. 1982, Heerkloss & Schnese 1999, Szymborska 2000, unpublished data), the March maximum was recorded in this area for the first time. The substantial contribution of *Pseudocalanus* sp., regarded as a zooplankton species preferring colder, open waters of a higher salinity (Wiktor et al. 1982, Wiktor & Żmijewska 1985), may indicate that there was an inflow of open-sea organisms. The were no significant differences in Copepoda abundance at the two stations in the same weeks. The genus *Acartia* was dominant in the material from both the Gdynia and Sopot stations. The decrease in Copepoda concentration in late April and early May noted in the current study was atypical in the sense that it had not been reported previously by other authors (Siudziński 1977, Wiktor et al. 1982, Wiktor & Żmijewska 1985). During this same period, no rapid changes in temperature or species composition were recorded. Similar observations were made by Bielecka et al. (2000) and Szymborska (2000, unpublished data) during their research in Gdynia.

The meroplankton in the coastal waters of the Gulf of Gdańsk in 2001 was represented mainly by the larvae of Cirripedia (*B. improvisus* nauplii and cypris), Mollusca (Bivalvia and Gastropoda veliger), Polychaeta (metatrochophore) and sporadically by trochophore larvae. The taxonomic composition of meroplankton in the Pomeranian Bay was similar (Postel et al. 1995).

Cirripedia larvae appeared in late May and concentrations reached a maximum in June; this was also reported by Siudziński (1977) and Bielecka et al. (2000). These larvae were, however, present in small numbers in autumn. This taxon appears to occur in the coastal waters of the Gulf of Gdańsk in much larger numbers, i.e. 115 790 indiv. m^{-3} (Bielecka et al. 2000), 37 795 indiv. m^{-3} (Szymborska 2000, unpublished data), 14 739 indiv. m^{-3} in 2001, than in open waters – 3000 indiv. m^{-3} (Szaniawska 1977), 318 indiv. m^{-3} (Wiktor et al. 1982). Cirripedia larvae were represented almost exclusively by the nauplius form. Their dominance at the Gdynia station may indicate that its maternal form is to be found in the vicinity.

As was the case with Cirripedia, the occurrence of Mollusca larvae in the spring and summer months is typical, and, according to Siudziński (1977), they prefer shallower waters. In July they reached their maximum concentration (7580 indiv. m^{-3}) at the Sopot station. Three years earlier and also in July, a figure of 14 1269 indiv. m^{-3} had been recorded at Gdynia (Bielecka et al. 2000). Unlike the situation in 1998–99, this taxon achieved a much higher concentration as early as May, and beginning in August, when Bielecka et al. (2000) noted its abundance as being in excess of 35 000 indiv. m^{-3}, it almost disappeared from the mesozooplankton composition. Bivalvia veliger was dominant among the Mollusca larvae, and the contribution of Gastropoda veliger was small, just as it had been in 1998–2000 (Gaj 1999, unpublished data; Szymborska 2000, unpublished data). Their much higher numbers and greater frequency of occurrence in the shallow waters at Sopot may indicate that the habitat there is suitable for parental organisms. Similar observations were made by Wiktor & Żmijewska (1985).

Polychaete larvae (metatrochophore) were a typical zooplankton component in the colder months. Both Żmijewska (1974) and Siudziński (1977) reported that they prefer deeper, colder waters with higher salinity. With the exception of March, when their concentration reached a maximum (16 March 2001 at Gdynia), they were noted in very small amounts and usually at only one station.

Simpson's coefficient D was relatively high for much of 2001 with an average of 0.54 and maximum values of 0.76 in July and of 0.69 in October. These figures indicate a high biodiversity in these waters. During her studies of the impact of pollution on zooplankton near the mouth of the Wisła Śmiała, Żmijewska et al. (2000) recorded much lower values of D –0.47 in July and 0.67 in October. The latter was similar to the value in the current study.

According to Kostrichkina et al. (1992), who has studied the zooplankton of the Gulf of Riga, the most important environmental factors influencing zooplankton abundance are temperature and the availability of food. These results are confirmed by the significant dependence between temperature and Cladocera and Polychaeta abundance found by the present authors. A positive correlation between the number of Cladocera and the water temperature was also noted in the northern (Viitasalo et al. 1995) and central (Dippner et al. 2000) Baltic Sea. In the work of Różańska et al. (1988) the correlation between the abundance of *Eurytemora affinis* and the NO_3 content took a different value from one year to another. This suggests that such an analysis does not fully answer the question regarding the dependence of the number of organisms on the state of the environment.

The considerable changes in the abundance of certain groups of mesozooplankton from one week to another may be due to predatory pressure. This water zone is inhabited by fish that may graze zooplankton, principally Copepoda, their preferred food (Thiel 1996). Similarly, the stability of the water column may give rise to unpredictable changes in the quantity and quality of zooplankton, because some groups prefer stable conditions, others mixed conditions (Viitasalo at al. 1995). The rapid pace of change in zooplankton abundance could also be caused by the non-linear nature of population growth processes (Heerkloss 1999).

Studies which are conducted at frequent intervals at stations located close to each other highlight the extremely dynamic range of variations occurring in the coastal zone. This is true not only of zooplankton but also of phytoplankton, as was confirmed by Witek & Pliński (1998), who collected samples at the same two stations in Gdynia and Sopot. With reference to the analyses by Bielecka et al. (2000), it is clear that such studies are meaningful, since the coastal zone is very important as an environment in which numerous organisms mature and their populations develop. The coastal zone is inhabited by fish larvae, juvenile and small fish (e.g. Gobidae) that prey on plankton larvae (Żmijewska et al. 2000). According to Wiktor (1990), the main energy flux flows from the phytoplankton to plankton crustaceans, to planktivorous fish and then to predators. The abundance of plankton organisms depends on the water purity, and the Gulf of Gdańsk is highly susceptible to environmental degradation (Wiktor 1982, Wiktor & Żmijewska 1985, Wiktor & Pliński 1992).

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