Abundance and species composition of plankton in the Gulf of Gdańsk near the planned underwater outfall of the Gdańsk–Wschód (Gdańsk–East) sewage treatment plant

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Abstract

The aim of this paper is to determine the current biological state of life in the pelagic zone of the Gulf of Gdańsk in relation to the planned start-up of an underwater outfall which will discharge sewage from the Gdańsk–Wschód (Gdańsk–East) sewage treatment plant. The plankton material was collected during two research cruises in July and October 1998. The samples were taken at 15 stations in four profiles located near Wyspa Sobieszewska (Sobieszewo Island), perpendicular to the coastline. Both the taxonomic and numerical structure of phytoplankton and zooplankton were typical of the coastal area of the Gulf of Gdańsk. The species diversity depends on hydrological conditions, mainly input from the River Wisła (Vistula). The abundance and biomass of phytoplankton in 1998 were several times lower than in 1994 and 1995 in the area off Górki Wschodnie, the profile located closest to the planned construction site. This could have been caused by generally lower temperatures in 1998 in comparison to previous years. In the investigated area only traces of algal eutrophication indicator species were noted. However, potentially toxic species were confirmed and were most abundant near the Wisła mouth. The highest concentrations of pelagic fauna occur in the shallowest area closest to the shoreline. Long-term observations of the dynamics of the variations in abundance and species composition indicate the increasing significance of one particular species – *Acartia bifilosa*.

1. Introduction

The earliest Polish research into the plankton of the Gulf of Gdańsk dates back to the 1930s and to the years just after the Second World War and usually dealt with particular aspects of the pelagic fauna (Mańkowski 1937, 1938, 1948, 1951, Rzóska 1939). In the 1960s and 1970s numerous papers were published on the zooplankton of the southern Baltic, including the Gulf of Gdańsk (Ciszewski 1962, Mańkowski 1963, Siudziński 1977).

Comprehensive investigations were begun in 1977 by a team of marine biologists from the Institute of Oceanography, University of Gdańsk, under the direction of Professor Krystyna Wiktor. The principal goal, which has remained unchanged, was to determine whether and to what extent the eutrophication of the Baltic has modified particular elements of the ecosystem. Investigations so far, including those of the pelagic zone, have been carried out using the UG's small vessel, k/h 'Oceanograf–1' and 'Oceanograf–2', and have covered the shallow water area from 0 to 5 m (Żmijewska 1974, Szaniawska 1977, Pliński *et al.* 1982, 1985, 1994, Wiktor *et al.* 1982, Wiktor & Żmijewska 1985, Wiktor 1990, Pliński 1995).

Studies of phytoplankton in the Gulf of Gdańsk have been carried out in various areas with various sampling and data processing methods (Rumek 1948, 1950, Malewicz *et al.* 1975, Bralewska 1992, Niemkiewicz & Wrzołek 1998).

Extending down to a depth of about 20 m, the pelagic zone is an especially important element in the marine ecosystem since it is here that enhanced primary production occurs. Any adverse environmental changes, usually of anthropogenic origin, initially affect the phytoplankton in that the biomass is multiplied. This increase, in turn, influences the pelagic fauna, which is linked trophically to the phytoplankton. One symptom of adverse change is the previously unrecorded phenomena of overgrowth and the number of parasites occurring on a massive scale in copepods (Wiktor & Krajewska-Sołtys 1994). Another example is the impoverishment of pelagic fauna, where one species is continually gaining in significance at the expense of others (Szadkowska unpublished, Szostak unpublished).

The aim of this paper is to determine the current biological state of life in the pelagic zone of the Gulf of Gdańsk in relation to the planned underwater outfall that will discharge sewage from the Gdańsk–Wschód (Gdańsk–East) sewage treatment plant.

2. Materials and methods

This paper is based on plankton material collected during two research cruises of k/h 'Oceanograf–2' in July and October 1998. During each cruise, samples were collected at 15 stations in four profiles located near Sobieszewo Island, perpendicular to the coastline (Fig. 1). A total of 60 plankton samples were collected.

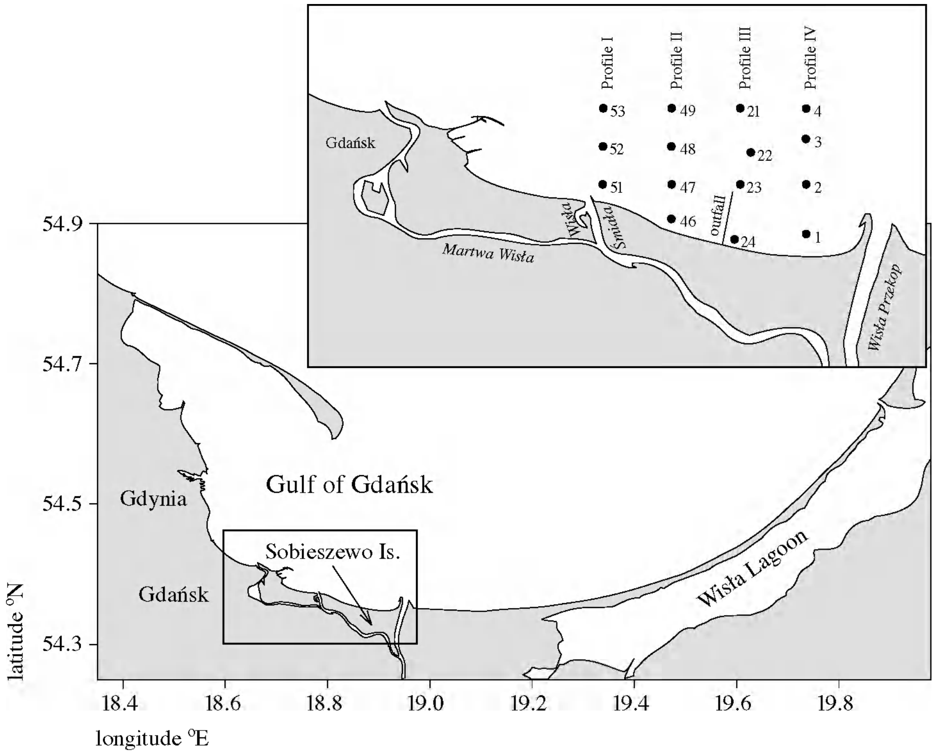

Fig. 1. Location of sampling stations in the vicinity of the outfall from the Gdańsk–Wschód sewage treatment plant (Nowacki 1999)

Plankton sample collection and analyses was carried out according to the methodology recommended in international monitoring investigations for the Baltic Sea (HELCOM 1988).

Phytoplankton samples were collected using a bathometer at depths of 0, 2.5, 5, 10, 15 and 20 m (depending on station depth), after which the same water samples from each depth were mixed in order to obtain a single sample from each station. Each sample was preserved immediately with Lugol solution. Investigations of phytoplankton involved determining species composition, numbers, biomass and chlorophyll *a* concentration.

The following units were used in abundance analyses: cell, cenobium, colony or filament of 100 μm in length. Biomass was determined on the basis of stereometric formulae relating to particular phytoplankton taxa. The concentration of chlorophyll *a* was determined from spectrophotometric measurements of samples from various depths; these were then averaged for the whole water column at each station. 96% ethanol was used as extraction solvent.

Zooplankton was collected during the daytime with a WP–2 plankton net having the following parameters: mouth diameter – 40 cm, net length – 1 m, filter mesh size – 100 μm, depth of hauls varied from 4 to 19 m. The material collected was immediately preserved in 4% formaldehyde. In the laboratory, zooplankton counts were done of a known fraction of the total sample (from 1/2 to 1/128) using a Motoda box-splitter (Motoda 1959). Biological analyses covered all the animals in the samples or sub-samples and were intended to determine the species composition, quantitative relationships and the stage composition of the most abundant species (Copepoda: nauplii, copepodite and adult). Numerical data were expressed as the number of individuals m^{-3} of water and the number of individuals m^{-2}.

3. Results

Phytoplankton

Species composition

A total of 36 phytoplankton taxa were confirmed near Sobieszewo Island. In July 1998, blue-green algae were most abundant, while in October dinoflagellates and green algae were most frequently encountered (Table 1). Blue-green algae from the *Oscillatoriales* order, green algae *Pyramimonas* sp., flagellates and cryptophytes were common in summer and autumn. In July, in addition to the taxa already mentioned, blue-green algae *Cyanodyction* sp. and *Aphanizomenon* sp. as well as dinoflagellates *Dinophysis norvegica* and *Dinophysis acuminata* were noted at all stations. The diatom *Coscinodiscus granii* and green algae *Planctonema lauterbornii* were also common throughout the area in October. In both months potentially toxic species and eutrophication indicators were confirmed in the phytoplankton (Table 1).

In July, of seven potentially toxic species, the blue-green algae *Aphanizomenon* sp. was the most important in terms of numbers, and the dinoflagellate *D. norvegica* in terms of biomass. The abundance of both reached a maximum in the profile closest to the Wisła (River Vistula) mouth (Table 2).

Table 1. Species composition of plankton in the study area in July and October 1998

Phytoplankton taxa	July	Oct.	Zooplankton taxa	July	Oct.
Phylum: Cyanophyta (blue-green algae)			Type: Ciliata		
Class: Nostocophyceae			Suborder: Tintinnina	+	
Anabaena cf. lemmermannii P. Richter[pt]	+				
Aphanizomenon sp. Morren ex Bornet, Flahault[pt]	+	+	Type: Rotatoria		
Aphanothece sp.	+		*Keratella cruciformis* Levander	+	+
Cyanodyction sp.	+		*Keratella quadrata* Müller	+	+
Microcystis aeruginosa Kützing[ei, pt]	+		*Synchaeta* spp.	+	+
Nodularia spumigena Mertens[pt]	+	+	*Trichocerca marina* Daday	+	+
Oscillatoriales	+	+			
Snowella sp.	+		Type: Arthropoda		
			Phylum: Crustacea		
Phylum: Chromophyta			Order: Diplostraca		
Class: Dinophyceae (dinoflagellates)			Suborder: Cladocera		
Dinophysis acuminata Claparede Lachmann[pt]	+	+	*Bosmina coregoni maritima* Müller	+	+
Dinophysis norvegica Claparede Lachmann[pt]	+	+	*Evadne nordmanni* Loven	+	+
Dinophysis rotundata Claparede Lachmann[pt]	+		*Pleopsis polyphemoides* Leuckart	+	+
Ebria tripartita (Schumann) Lemmermann[h]	+	+	*Podon intermedius* Lilljeborg	+	+
Heterocapsa triquetra (Ehrenberg) Stein	+	+	*Podon leuckarti* Sars	+	
Heterocapsa rotundata (Lohmann) Hansen	+	+			
Diplopsalis sp.	+		Order: Copepoda		
Peridiniella catenata (Levander) Balech	+	+	*Acartia* spp. juv.	+	+
Prorocentrum minimum (Pavillard) Schiller[pt]		+	*Acartia bifilosa* Giesbrecht adult	+	+
Class: Bacillariophyceae (diatoms)			*Acartia longiremis* Lilljeborg adult		+
Asterionella spp.		+	*Acartia tonsa* Dana adult	+	+
Centric diatoms	+		*Acartia* sp. adult	+	+
Chaetoceros danicus Cleve		+	*Centropages hamatus* Lilljeborg*	+	+

Table 1. (continued)

Phytoplankton taxa	July	Oct.	Zooplankton taxa	July	Oct.
Chaetoceros spp.	+		*Eurytemora hirundoides* Nordquist*	+	+
Coscinodiscus granii Gough		+	*Eurytemora* spp.	+	+
Skeletonema spp.	+	+	*Temora longicornis* Müller*	+	+
Class: Cryptophyceae (cryptophytes)	+	+	*Pseudocalanus* sp.*		+
Class: Chrysophyceae			*Calanoida* – non ident.		+
Flagellata non def.	+	+			
			Order: Cyclopoida – nauplii	+	+
Phylum: Chlorophyta (green algae)					
Class: Chlorophyceae			Order: Harpacticoida*		+
Actinastrum hantzschii Lagerheim[ei]	+	+			
Pediastrum angulosum (Ehrenberg) Meneghini[ei]	+		Order: Cirripedia – nauplii, cypris		
Pediastrum duplex Meyen[ei]	+	+	*Balanus improvisus* Mandahl-Barth	+	+
Pediastrum tetras (Ehrenberg) Ralfs[ei]	+	+			
Planctonema lauterbornii Schmidle		+	Type: Mollusca		
Scenedesmus acuminatus (Lagerheim) Chodat	+	+	Phylum: Bivalvia veliger	+	+
Scenedesmus ecornis (Ehrenberg) Chodat	+		Phylum: Gastropoda veliger	+	+
Scenedesmus linearis Komarek		+			
Scenedesmus obliquus (Turpin) Kützing		+	Type: Annelida		
Coelastrum microporum Nägeli[ei]	+		Phylum: Polychaeta – metatrochofora	+	+
Class: Prasinophyceae					
Pyramimonas sp.	+	+			
Class: Euglenophyceae					
Eutreptiella sp.	+	+			

ei – eutrophication indicator (Tikkanen & Willen 1992),
pt – potentially toxic species (Larsen & Moestrup 1989, Edler *et al.* 1996),
h – heterotrophic species (not included in the quantitative phytoplankton analysis),
∗ – all growth stages of particular Copepoda species (juvenile and adult).

Table 2. Average abundance [10^6 units m^{-3}], biomass [mgC m^{-3}] and percentage of potentially toxic phytoplankton species (Larsen & Moestrup 1989, Edler *et al.* 1996) in the investigated area in July and October 1998

a) July 1998

Group	Species	N	Abundance ± SD	Contribution to abundance [%]	Biomass ± SD	Contribution to biomass [%]
blue-green algae	*Anabaena lemmermannii*	13	1.87 ± 1.09	0.10	0.58 ± 0.34	0.78
	Aphanizomenon sp.	15	55.33 ±43.56	3.18	6.19 ± 4.87	8.31
	Microcystis aeruginosa	4	0.44 ± 0.59	0.03	0.05 ± 0.08	0.07
	Nodularia spumigena	11	1.42 ± 0.9	0.08	1.76 ± 1.12	2.29
dinoflagellates	*Dinophysis acuminata*	15	2.49 ± 1.21	0.14	7.2 ± 3.51	9.67
	Dinophysis norvegica	15	4.01 ± 3.08	0.23	15.62 ±12.03	20.97
	Dinophysis rotundata	12	0.44 ± 0.41	0.03	0.76 ± 0.71	1.04

b) October 1998

Group	Species	N	Abundance ± SD	Contribution to abundance [%]	Biomass ± SD	Contribution to biomass [%]
blue-green algae	*Aphanizomenon* sp.	10	1.45 ± 1.2	0.18	0.14 ± 0.11	0.33
	Nodularia spumigena	1	0.77	0.17	0.96	2.64
dinoflagellates	*Dinophysis acuminata*	4	0.1 ± 0.04	0.01	0.28 ± 0.11	0.51
	Dinophysis norvegica	10	0.13 ± 0.08	0.01	0.51 ± 0.32	1.11
	Prorocentrum minimum	14	2.16 ± 1.46	0.22	1.9 ± 1.27	4.51

Table 3. Average abundance [10^6 units m^{-3}], biomass [mgC m^{-3}] and percentage of phytoplankton eutrophication indicators (Tikkanen & Willen 1992) in the investigated area in July and October 1998

a) July 1998

Group	Species	N	Abundance ± SD	Contribution to abundance [%]	Biomass ± SD	Contribution to biomass [%]
blue-green algae	*Microcystis aeruginosa*	4	0.44 ± 0.59	0.03	0.05 ± 0.08	0.07
	Actinastrum hantzschii	1	3.23	0.16	0.04	0.05
green algae	*Pediastrum angulosum*	2	0.15 ± 0.11	0.01	0.25 ± 0.18	0.38
	Pediastrum tetras	2	0.12 ± 0.05	0.01	0.04 ± 0.05	0.04
	Pediastrum duplex	12	0.46 ± 0.77	0.06	0.59 ± 1.23	3.12
	Coelastrum microporum	6	0.27 ± 0.36	0.01	0.05 ± 0.06	0.06

b) October 1998

Group	Species	N	Abundance ± SD	Contribution to abundance [%]	Biomass ± SD	Contribution to biomass [%]
green algae	*Actinastrum hantzschii*	2	1.42 ± 0.27	0.20	0.02 ± 0.004	0.04
	Pediastrum tetras	1	0.08	0.02	0.02	0.06
	Pediastrum duplex	4	0.1 ± 0.04	0.01	0.09 ± 0.03	0.21

In October, five potentially toxic species were found in the phytoplankton, but their numbers were generally smaller than in July. The dinoflagellate *Prorocentrum minimum* occurred throughout the area at this time, its biomass being highest in the vicinity of the Wisła mouth.

In both July and October 1998, species indicative of eutrophication made up only a small percentage of the total abundance and biomass of phytoplankton in the area (Table 3). In July, most species (five out of six) were recorded near the Wisła mouth. Of all the indicator species, the green algae *Pediastrum duplex* and *Coelastrum microporum* had the broadest range, occurring throughout the area. In October, three indicator species were found: *Actinastrum hantzschii*, *Pediastrum tetras* and *P. duplex*. Three species were also confirmed in the profile near the Wisła mouth, whereas only one species, *P. duplex*, occurred in two other profiles.

Simpson's biodiversity index based on the phytoplankton of the investigated area was 0.87 in July 1998; in October 1998 it was slightly higher at 0.90.

Phytoplankton abundance and biomass and chlorophyll *a* concentrations

Flagellates and cryptophytes were the most abundant phytoplankton at all stations in both July and October. In terms of biomass, the most important group were dinoflagellates (mainly *D. acuminata* and *D. norvegica*), while in October the diatom *C. granii* dominated at all stations (Figs. 2 a and 2 b).

In both months phytoplankton abundance and biomass varied at different stations. In July, phytoplankton numbers varied from 1.14 to 3.45×10^9 units m^{-3}, while in October they varied from 0.37 to 2.13×10^9 units m^{-3}. In July the biomass ranged from 46 to 112 mgC m^{-3}, in October from 16 to 71 mgC m^{-3}. In both months the greatest numbers of phytoplankton was confirmed in the area near the Wisła Śmiała mouth (profile I). In July the greatest phytoplankton biomass was noted in profile II, in October near the Wisła Śmiała mouth (profile I) (Figs. 3 and 4). The chlorophyll *a* concentration in July 1998 in the area ranged from 1.40 to 3.99 mg m^{-3}, in October from 1.70 to 2.02 mg m^{-3}. The maximum values in July were recorded in the profile closest to the Wisła mouth, while in October the maximum was noted near the planned construction project (profile III) (Fig. 5).

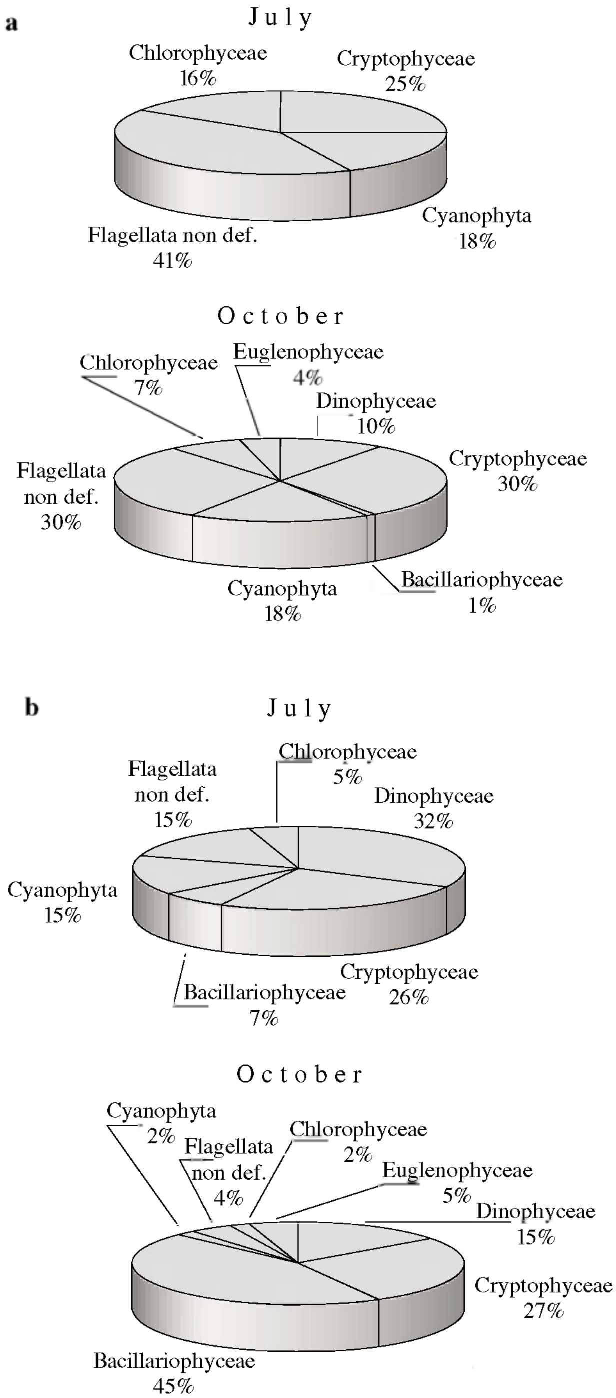

Fig. 2. Percentage of the principal taxa in the total phytoplankton abundance (a) and biomass (b) in the study area in 1998

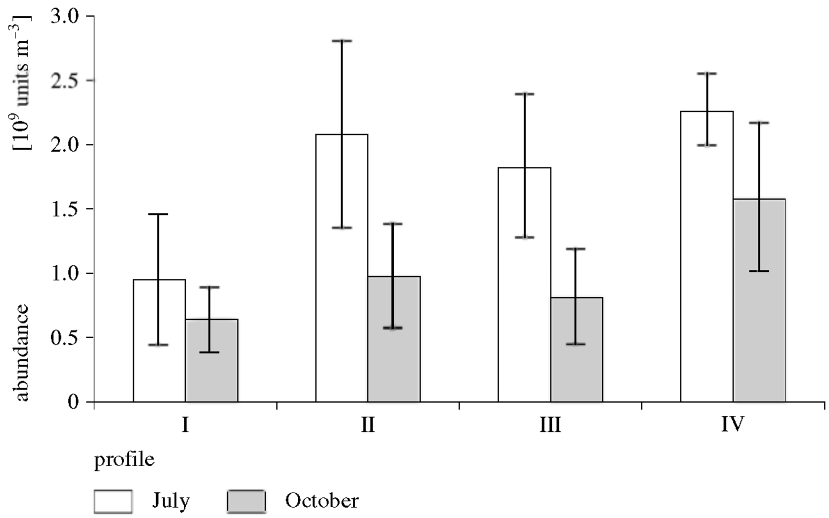

Fig. 3. Average abundance of phytoplankton (with standard deviation) along particular profiles in the study area in 1998

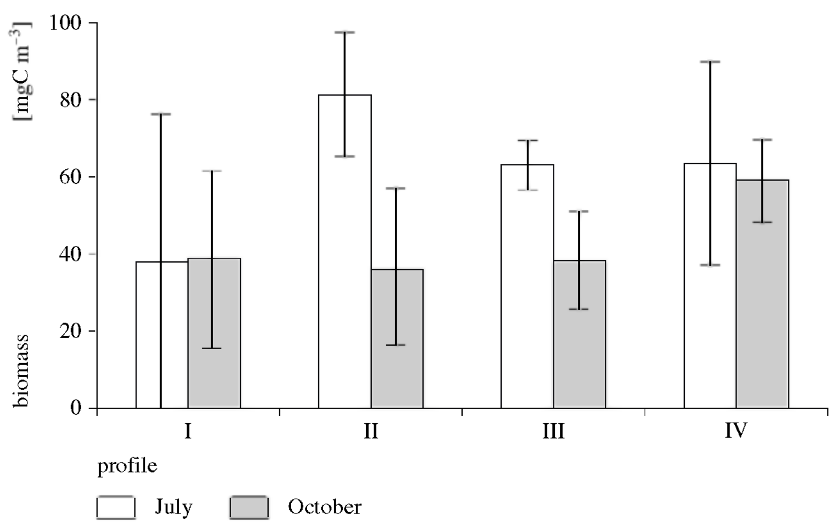

Fig. 4. Average phytoplankton biomass (with standard deviation) along the profiles in the investigated area in 1998

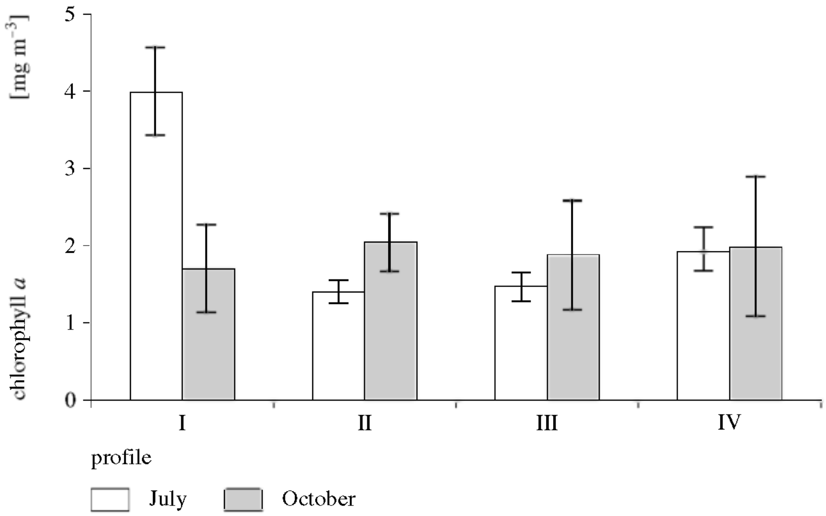

Fig. 5. Average chlorophyll *a* concentration (with standard deviation) along the profiles in the investigated area in 1998

Zooplankton

Species composition

The animal composition in the pelagic zone of the study area consisted of elements typical of the coastal areas of the Baltic Sea. Both in July and October representatives of freshwater fauna, such as Cyclopoida nauplii, were noted only sporadically (Table 1).

Analysis of the zooplankton species composition showed that between July and October its structure changed. Tintinnina disappeared from the species composition in the autumn. Noteworthy additions to the autumn fauna, however, were Harpacticoida, typical zoobenthic Copepoda and the marine species *Pseudocalanus* sp. (Table 1). Simpson's biodiversity index based on the zooplankton of this area in 1998 was 0.47 in July, but higher in October – 0.67.

Time-space variability

The plankton sampling stations were situated along four profiles (Fig. 1). In summer 1998 (July) the average abundance of zooplankton increased from east to west. In the west (profile I), the average zooplankton abundance was 5 times higher than in the east (profile IV), (Fig. 6). In November 1998 the average abundance of planktonic fauna was much lower than in summer, no significant changes being found among the four profiles (Fig. 6).

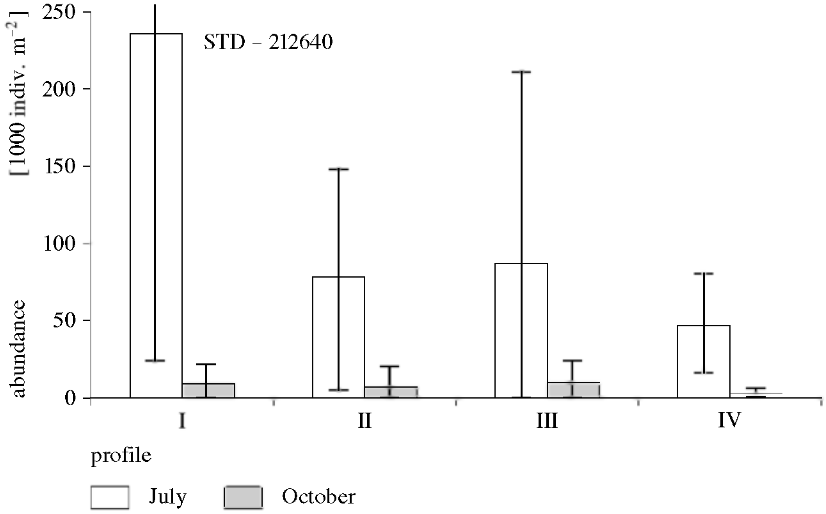

Fig. 6. Average abundance of zooplankton along the profiles in the study area in 1998

Independently of season, the average zooplankton abundance was several times higher at stations located nearest the coast (Fig. 7). In the summer, the zooplankton was dominated by meroplankton taxa, consisting principally of Mollusca larvae, mainly Bivalvia veliger, with an average abundance of 179 806 indiv. m^{-2} in shallow water (maximum abundance – 223 467 indiv. m^{-3} at station 51 near the Wisła Śmiała mouth). Additionally, Cirripedia larvae were present in numbers not exceeding 800 indiv. m^{-3}. Significant concentrations of Copepoda were also confirmed in July with an average abundance at coastal stations of 22 549 indiv. m^{-2}; in October this number was lower.

Rotatoria were dominant in the autumn (av. 11 113 indiv. m^{-2}) and especially high concentrations were reported from stations situated nearest the shore. At the same time, the abundance of Copepoda decreased four-fold in comparison with that of summer. The density of barnacle larva dropped abruptly, and the abundance of Cladocera was also several times lower (Fig. 7). It should be noted that there was a species succession among the Rotatoria: *Keratella quadrata*, dominant in summer, was replaced in October by representatives of the genus *Synchaeta*.

Only a few species are responsible for the large copepod stocks in the study area. Regardless of season and along all profiles, the dominant copepod was the genus *Acartia*; however, its high density decreased with water depth (Fig. 8). The most characteristic *Acartia* species was *Acartia bifilosa*, but in the autumn the genus *Acartia* was accompanied by a typically

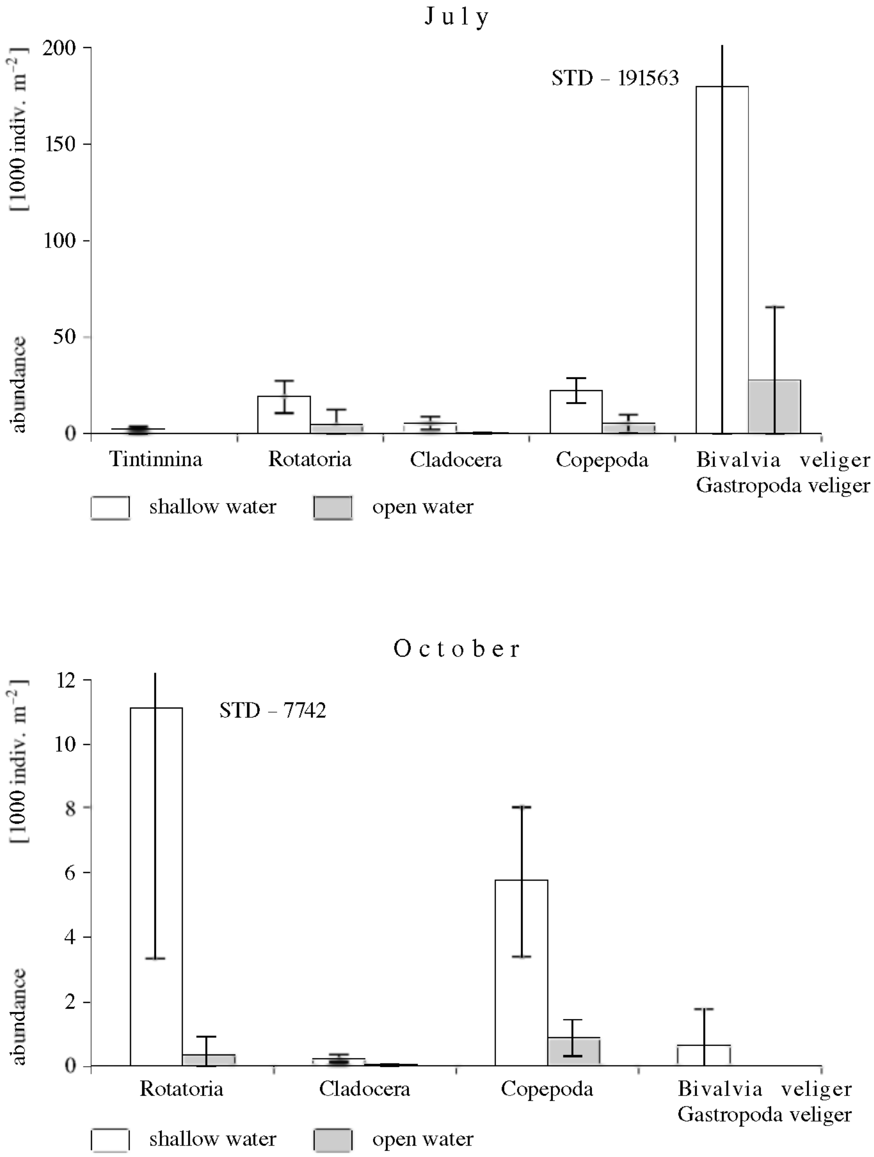

Fig. 7. Average abundance of the main group of zooplankton in the study area in 1998

open-water species – *Acartia longiremis* (Fig. 8). Owing to the relatively high numbers in both periods, *Temora longicornis* was predominant (from 30% to 42% of the Copepoda). It was half as abundant in the summer, especially in the surface layer (Fig. 8). *Centropages hamatus*, making up from a few per cent to over 30% in the autumn, was also a typical representative of the autumn fauna, its concentration tending to rise conspicuously with

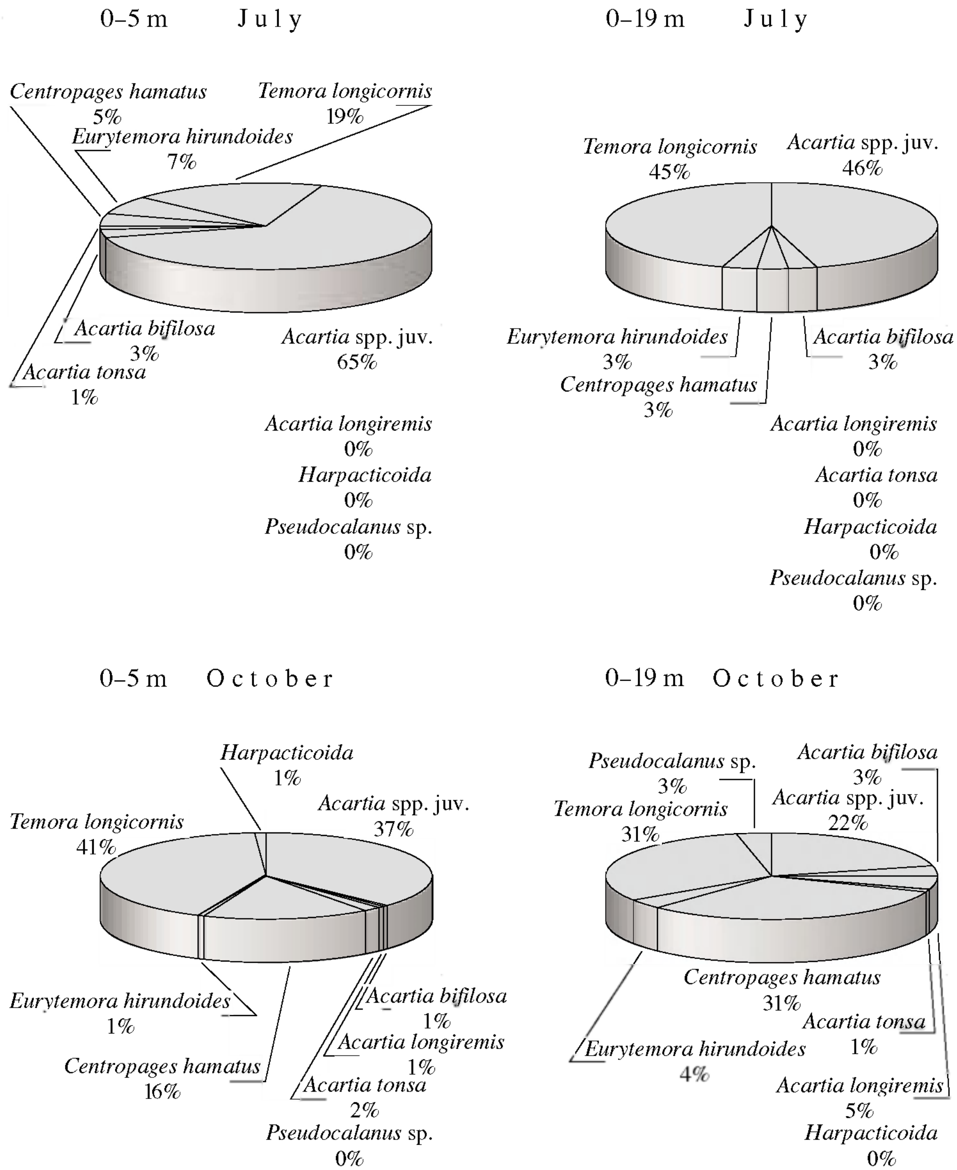

Fig. 8. Species structure of Copepoda [%] in the easternmost profile (IV) in the investigated area in 1998

increasing depth, in much the same way as the distribution pattern of *T. longicornis* (Fig. 8).

Two dominant Copepoda taxa, *Acartia* spp. and *T. longicornis*, occupy different levels in the water column, the former preferring surface waters, the latter deeper waters (Fig. 9).

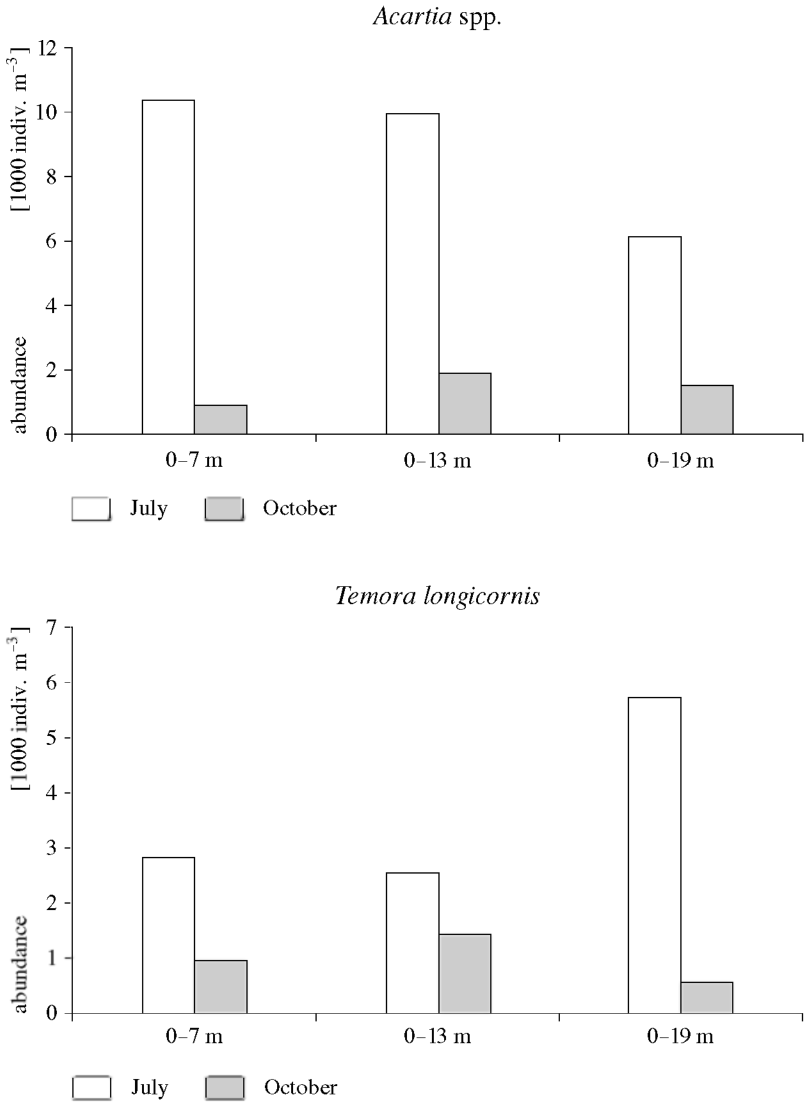

Fig. 9. Abundance [indiv. m^{-3}] of dominant Copepoda along the easternmost profile (stations 1–4) in 1998 (in July the water layers were: 0–7 m, 0–13 m, 0–19 m; in October: 0–5 m, 0–10 m, 0–19 m)

4. Discussion

A review of the available materials indicates that investigations of phytoplankton in the Gulf of Gdańsk are hardly comparable as far as time and sampling frequencies in a particular growing season are concerned. This is because of the different range of parameters, the diversity of methodologies and the variety of areas studied (Rumek 1948, 1950, Malewicz *et al.* 1975, Pliński *et al.* 1982, 1985, 1994, Pliński & Picińska 1985, Bralewska 1992, Pliński 1995, Niemkiewicz & Wrzołek 1998). These differences generally make it difficult to compare results and to determine long-term variations in the phytoplankton. None of the previous studies of phytoplankton in the Gulf of Gdańsk covered the area of the planned outfall of the Gdańsk–Wschód sewage treatment plant. Therefore, the results of the 1998 investigations, presented in this paper, are compared with the results obtained from studies carried out in autumn 1994 and summer 1995 along a profile near Górki Wschodnie (Niemkiewicz & Wrzołek 1998), as this profile is located closest to the planned construction site.

Flagellates and cryptophytes, the most abundant phytoplankton in both study periods in 1998, confirm the increasing significance of groups of small-celled phytoplankton that has been observed since the 1970s (Pliński 1995). The intensive growth of blue-green algae in summer and the autumnal domination of diatoms noted near Sobieszewo Island in 1998 were typical of the seasonal variations in phytoplankton in the Gulf of Gdańsk. This has also been mentioned in other sources, based on the 1986–87 and 1992–93 data (Pliński *et al.* 1994, Pliński 1995).

The phytoplankton abundance as well as the biomass and chlorophyll *a* concentration in July and October 1998 were several times lower than the 1994 and 1995 figures (Niemkiewicz & Wrzołek 1998) (Fig. 10). The lower values in 1998 may have been caused by lower summer temperatures since this is the period when stenothermal blue-green algae increase.

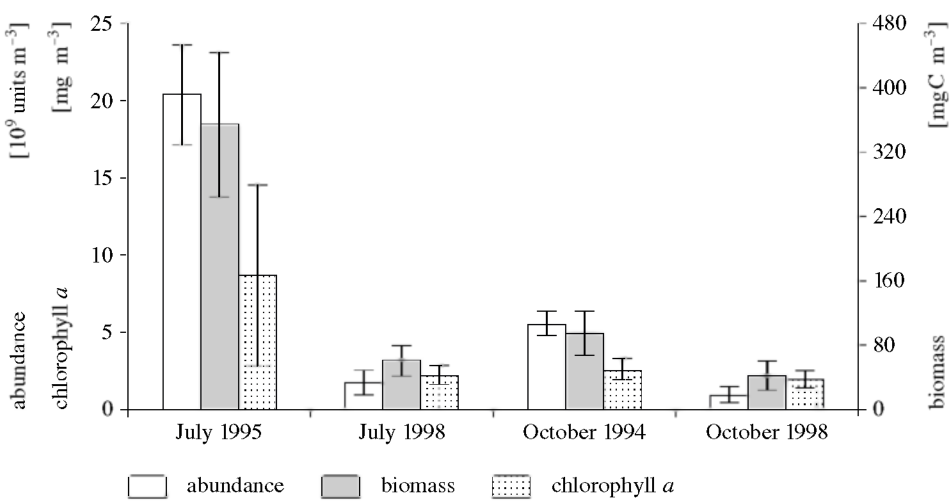

Fig. 10. Abundance and biomass of phytoplankton and chlorophyll *a* concentration in 1998 in comparison to the 1994 and 1995 figures (with standard deviation)

The results of chlorophyll *a* concentrations obtained in July and October 1998 were several times lower in comparison with those obtained in summer and autumn 1981 along the profile at Świbno (Latała 1985). However, they do lie within the 5–10 mg m^{-3} range found by Renk *et al.* (1992) in the Wisła mouth area on the basis of research done in 1987–90. The fact that the majority of potentially toxic species have been inhabiting waters of the Gulf of Gdańsk for many years is confirmed by Rumek (1948), Pliński *et al.* (1982, 1985), Pliński & Picińska (1985) and Ringer (1990). Significant adverse effects of their presence have yet to be confirmed, however. Nevertheless, phytoplankton blooms in the marine environment must be monitored constantly, especially where sewage is discharged and in recreational beach areas. It should be assumed that, owing to the potential mass growth of algae, the recreational value of coastal areas may decrease periodically, and that blooming algae may migrate with the currents to other parts of the Gulf of Gdańsk. Another adverse effect of increased blooming could be the degradation of the local environment of benthic sediments as a result of excessive sedimentation of plankton matter.

While the salinity is not likely to change following the opening of the sewage outfall, a slight increase in water temperature is to be expected (Nowacki 1999). This will probably boost local phytoplankton growth. A nutrient concentration several times higher in the discharge area in comparison to that in the Wisła will also accelerate biological production.

The diversity of pelagic fauna in the coastal area of the Gulf of Gdańsk as presented in Table 1 is relatively poor. It is represented mainly by typically brackish forms with but a small contribution from freshwater and marine species. Only an insignificant number of freshwater animals, such as Cyclopoida nauplii, can be linked with the significant decrease of the Wisła input in 1998 (Nowacki 1999), the effects of which were limited to areas east of the river mouth; these are beyond the scope of the present investigation. In earlier studies, freshwater cladocerans (*Alona* spp., *Chydorus sphaericus*) and Copepoda (*Eudiaptomus* sp., *Eucyclops* sp.) were recorded quite regularly (Siudziński 1977, Wiktor & Żmijewska 1985). Wiktor & Żmijewska (1985) reported an especially diverse composition of Rotatoria – 15 species, the majority of which were freshwater forms.

Rotatoria are a group of exceptionally diverse animals in the coastal area of the Baltic Sea in terms of both taxa and numbers. Siudziński (1977), Wiktor *et al.* (1982), Wiktor & Żmijewska (1985) confirmed the domination of two genera: *Synchaeta* was typical in spring and autumn, *Keratella* typical in summer. High fluctuations in the abundance of dominant representatives is observed among the Rotatoria. Maximum numbers may reach over 1 million indiv. m^{-3} in spring to 8.5 thousand indiv. m^{-3} in autumn (Wiktor *et al.* 1982). In 1962, the average numbers of Rotatoria were six times lower than in 1958 (Siudziński 1977). During investigations in 1998 the variation in abundance was not so significant and the maximum concentrations were several times lower than those observed earlier. In general, Rotatoria are most abundant at the shallowest stations, a fact confirmed by the present study.

During long-term investigations, the abundance dynamic of Cladocera whose maximum numbers vary only two to three-fold, is significantly smaller (Siudziński 1977, Wiktor *et al.* 1982, Wiktor & Żmijewska 1985). This is confirmed by the authors' current data. However, significant changes have been noted with respect to the species composition of Cladocera. Nine species were found in 1978 (Wiktor *et al.* 1982), including significant numbers of immigrants from the Wisła. Siudziński (1977), and later Wiktor & Żmijewska (1985) and Szadkowska (unpublished), reported that Cladocera are represented mainly by two species *Bosmina coregoni maritima* and *Pleopsis polyphemoides*. Our data showed that *P. polyphemoides* was the dominant cladoceran in both summer and autumn, its numbers being much higher than those of other representatives of these crustaceans.

Unlike the animals above, Copepoda are common and occur in high densities. They are also a very important trophic component of the zooplankton. Represented by seven basic species (excepting freshwater forms), they inhabit the whole water column, but their biodiversity varies with depth. In the Gulf of Gdańsk the most common genus is *Acartia*, which is represented by three species: *A. bifilosa*, *A. tonsa* and *A. longiremis*. According to Siudziński (1977) and Wiktor & Żmijewska (1985), *A. bifilosa* and *A. tonsa* are prevalent and their numbers can vary over time. In the 1990s, the temporary numerical dominance of *A. bifilosa* was noted (Szadkowska unpublished, Szostak unpublished, Rakowski unpublished). Other copepod species (*T. longicornis*, *Eurytemora* spp., *C. hamatus*) occur regularly, though far less abundantly (Siudziński 1977, Wiktor *et al.* 1982, Wiktor & Żmijewska 1985, Szadkowska unpublished). In 1998 *A. bifilosa* was dominant among the Copepoda; however, in autumn, along with decreasing surface layer temperature and higher salinity water input (Nowacki 1999), a greater proportion of *A. longiremis* was recorded, as was the appearance of *Pseudocalanus* sp.

Copepod concentrations do not fluctuate as distinctly during a cycle of several years as do those of the Rotatoria. The spatial stratification in the water column is specific in that the near-surface layers are dominated by *Acartia* spp., while the deeper layers are occupied mostly by *T. longicornis*. This is an important aspect of the functioning of these crustaceans, which are present in vast numbers. Since they occur in the water column in this manner, territorial or trophic competition can be ruled out.

Mollusc and cirriped larvae are specific elements of the summer composition of the zooplankton, occurring mainly at shallow stations. The nearshore zone is important for trophic reasons. This zone is occupied by fish larvae, young fish and small fish (*e.g.* Gobidae), which feed on meroplankton (M. Sapota, personal communication). The larvae of benthic animals are most common from May or June until September (Siudziński 1977, Wiktor *et al.* 1982, Wiktor & Żmijewska 1985, Szadkowska unpublished). 1998 saw an especially intensive growth of Lamellibranchiata, with maximum concentrations of over 200 000 indiv. m^{-3}. This trend is reversed in the other representative of the meroplankton, Cirripedia larvaes. In the 1950s and 1960s, nauplii and cypris larvae of *Balanus improvisus* occurred only in summer, the abundance peaking in July at 15 000 indiv. m^{-3} (Siudziński 1977). In 1977–78 they were not very frequent, and were not recorded at all near the Wisła mouth (Wiktor *et al.* 1982). At the beginning of the 1990s (Szadkowska unpublished, Białczak unpublished) the density of Cirripedia larva decreased significantly, a fact also confirmed by the present authors' data.

5. Conclusions

1. Both the taxonomic and numerical structure of phytoplankton and zooplankton in July and October 1998 were typical of the coastal area of the Gulf of Gdańsk. The species diversity depends on hydrological conditions, mainly input from the River Wisła.
2. In 1998 the abundance and biomass of phytoplankton were several times lower than in 1994 and 1995 in an area off Górki Wschodnie, the profile located closest to the planned sewage outfall. This could have been caused by generally lower temperatures in 1998 in comparison to previous years.
3. Only traces of algal eutrophication indicator species were noted in the study area. However, potentially toxic species were recorded – these were most abundant near the Wisła mouth.
4. The highest concentrations of pelagic fauna congregate in the shallowest area closest to the shoreline. The impoverishment of the zooplankton is on-going, with the *Acartia* genus principally *A. bifilosa*, gaining the upper hand at the expense of other crustaceas.
5. An elevated abundance of phytoplankton is expected near the Gdańsk –Wschód sewage outfall because of the anticipated higher water temperatures and nutrient concentrations.

6. Phytoplankton monitoring is essential since potentially toxic species may become active as a result of local changes in the environmental properties in the vicinity of the outfall.
7. The opening of the outfall and increase in the water temperature, even locally, may affect the zooplankton, whose replenishment, in terms of structure and abundance, will be a long-term process and not one which will be detectable over the course of just a year or two.

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