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Meiobenthic communities of the Szczecin Lagoon

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Abstract

Based on data collected at 7 stations 4 times a year in 1985 and 1986, composition and distribution of meiobenthic communities in the Polish part of the Szczecin Lagoon, a eutrophic and polluted water body connected with the Baltic Sea, is presented. The data show a tendency to reduced total meiobenthos densities and diversity from the lower to upper reaches of the lagoon. The meiobenthic communities studied were dominated by nematodes, ostracods ranking second in numerical importance. Harpacticoid copepods were most abundant at the outer stations which are influenced by Baltic inflows. Most of the 10 harpacticoid species recorded in the lagoon were found at the outer stations (lower reaches) as well. Similarity analysis allowed to separate three zones within the lagoon: (1) the outer zone, its stations showing most abundant and diverse meiobenthic communities; (2) the innermost zone (upper reaches) with the least abundant and qualitatively impoverished communities; and (3) the intermediate zone.

Introduction

The Szczecin Lagoon is a semi-enclosed coastal water body communicating with the southwestern part of the Baltic Sea and thus affecting the hydrography and biota of the nearshore zone. Of the 687 km^2 surface area of the lagoon, 403 km^2 belong to Poland (MUTKO 1986). The area is shallow (4 m average depth) except for the artificially dredged navigation lane cutting through the lagoon approximately from north to south.

The lagoon is a polymictic water body with strong wind-driven turbulence (MAJEWSKI 1980). Depending on strength and direction of the prevailing winds, the water balance of the lagoon is governed either by drainage of its water to the Baltic via three outlets, the Peene to the west (GDR), the Swina and the Dziwna to the east, or by incoming Baltic water entering via the same three outlets. In this case the lagoon becomes slightly brackish (MUTKO 1986).

The lagoon constitutes a part of the river Odra estuarine system (MAJEWSKI 1980). The river enters from the south, discharging about 15 – 20 km^3 of water per year. At the same time, the Odra, having collected en route all types of urban, agricultural, and industrial pollutants, introduces this load to the lagoon, the pollution load being strongly augmented by the city of Szczecin with its industry, chemical plants in particular.

Over the recent decades, the Szczecin Lagoon has been subjected to growing eutrophication and pollution. The eutrophication is manifested by high nutrient loads (MUTKO 1986), accumulated mostly in the upper reaches of the lagoon (TADAJEWSKI, BIALY, KNASIAK, STASZCZUK, SZUREK and PAWŁOWSKA, unpubl.), which results in pronounced summer phytoplankton blooms, *Microcystis aeruginosa* being identified as the major responsible species (CHOJNACKA, unpubl., DWORCZAK, unpubl.).

The macrobenthos of the lagoon is qualitatively and quantitatively impoverished and dominated by oligochaetes and chironomid larvae (DRZYCIMSKI and MASŁOWSKI, unpubl.), organisms typical of sediments in polluted and eutrophic water bodies. *Dreissena polymorpha*, whose dense beds covered about 10 % of the bottom in the fifties and sixties (WIKTOR 1980), has been greatly restricted in its range (PIESIK, pers. comm.).

Environmental deterioration has also affected the lagoon fishery. The total catch has declined, as have the landings of commercially valuable fish species such as salmonids, pike, pikeperch (KOMPOWSKI and NEJA, unpubl.)

Unlike other biotic components of the lagoon ecosystem, the meiobenthos (defined here as benthic animals passing a 1 mm mesh size sieve) has not been previously studied, and there are no data on distribution and abundance of meiobenthic animals in the past. On the other hand, this group of organisms has been recognized as a valuable tool for environmental assessment (HEIP 1980). The purpose of the present work is therefore to give an overwiew of the current state of the meiobenthic communities of the lagoon from data collected during 1985 – 1986, the first stage of our ongoing project on the Szczecin Lagoon ecosystem. Our objective has been to form a basis from which inferences on the processes leading to observed patterns can be made in the future.

Material and methods

Meiobenthos was sampled in 1985 – 1986 at 7 stations located in various parts of the lagoon (Fig. 1). Station characteristics are given in Table 1 a/b.

Due to intensive mixing, the water overlaying the bottom is well-oxygenated throughout the lagoon; the outer (E, F) and open lagoon stations (D, G), however, show narrower dissolved oxygen ranges, the minimum oxygen contents being higher than those at the innermost stations (A, B, C). There is no trace of anoxia observed in other eutrophic Baltic coastal lagoons (BESCHNIDT and NOACK 1976).

The innermost stations, due to their distance from outlets, are much less affected by Baltic inflows (increased chloride content and increased conductivity) than the remaining sites.

Chlorophyll-a ranges at stations A through D are much narrower, and the maximum values are much lower than at the remaining stations, which indicates lower photosynthetic activity at the mouth of the river Odra.

Finally, the heavy metal content of the sediments at the river mouth indicates that the Szczecin Lagoon acts as a sink for these pollutants. The outer stations, however, had much lower contents. Zinc and lead levels at most stations exceed values reported by VAN DAMME et al. (1984) for sediments of Westerschelde, a heavily polluted North Sea estuary.

Meiobenthic collections were made 4 times in 1985 (April, June, September– October, and November) and 4 times in 1986 (April, June, August–September, and November). Samples were taken with a 22.4 mm i.d. corer (PŁOCKI and RADZIEJEWSKA 1980), 3 samples per station being collected on most sampling occasions. The samples were fixed with 4 % formaldehyde and Rose Bengal stained. After screening a sample through a 1 mm mesh size sieve, meiobenthic animals were extracted by decantation and sieving through a set of 3 sieves (0.200, 0.100, 0.040 mm apertures). Animals extracted were identified to major taxa and enumerated, harpacticoid copepods being identified to the species level.

The following parameters were determined for each station: mean density of each taxon and of total meiobenthos; mean contribution of each taxon (in %) to the mean total density; number of taxa; and mean taxon diversity index calculated according to the SHANNON-WIENER formula (PIELOU 1975): $H' = -\Sigma p_i \log p_i$, where p_i is the proportion of

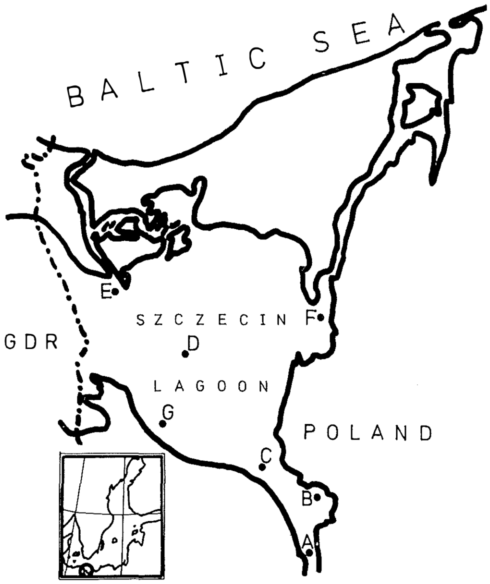

Figure 1

Investigation area and sampling sites

Table 1

Sampling stations characteristics (ranges of values)
A: bottom water*

Station	Temp. °C	Dissolved O_2/mg/dm^3	pH	BOD_5	mgCl/dm^3	Conductivity µs/cm	Chlorophyll-*a* mg/dm^3
A	5.80 – 20.70	5.10 – 13.60	7.71 – 8.50	2.70 – 5.10	89.25 – 159.00	0.51 – 0.67	20.90 – 22.70
B	5.80 – 21.10	4.90 – 12.90	7.84 – 8.40	2.90 – 4.90	81.65 – 235.40	0.51 – 0.66	22.70 – 44.80
C	4.00 – 21.90	4.80 – 13.10	7.74 – 8.31	1.80 – 5.00	85.20 – 319.00	0.52 – 0.92	12.90 – 72.40
D	4.20 – 20.80	7.00 – 12.30	8.01 – 9.01	3.20 – 4.80	81.65 – 639.00	0.48 – 1.53	29.40 – 93.40
E	4.00 – 20.60	8.00 – 12.10	8.28 – 9.08	1.80 – 5.00	88.75 – 2988.00	0.54 – 4.34	17.20 – 108.70
F	4.00 – 20.20	6.10 – 11.60	8.05 – 8.69	2.20 – 5.50	88.75 – 590.50	0.50 – 1.11	19.10 – 142.80
G	4.00 – 21.00	7.50 – 12.00	8.80 – 9.95	2.40 – 5.00	85.91 – 578.60	0.54 – 1.46	31.50 – 113.60

* data from TADAJEWSKI et al. (unpubl.)

Sampling stations characteristics
B: Sediment*

Station	Type	% organic matter	Cu µg/g	Zn µg/g	Pb µg/g	Cd µg/g
A	muddy sand	2.53	nd	nd	nd	nd
B	sand	0.24	nd	nd	nd	nd
C	muddy sand	16.04	35.9	593.5	117.3	10.7
D	sandy mud	20.26	43.8	978.3	157.3	9.6
E	sand	0.37	24.7	291.2	87.8	9.0
F	muddy sand	9.81	6.1	298.1	111.1	8.4
G	mud	13.46	21.3	529.5	98.0	9.0

* data from TADAJEWSKI et al. (unpubl.)
nd = no data

the *i*th taxon. Statistical treatment of data involved testing for significance of differences in various parameters between stations by means of 1-way analysis of variance (ANOVA) (SOKAL and ROHLF 1981). Appropriate transformations to stabilize the variance were made when necessary: log(n + 1) on density data, and *arc sin* on proportions.

Station data were also subjected to similarity analysis (FIELD 1971, FIELD et al 1982). First, similarity coefficients were calculated for each pair of stations; the Czekanowski coefficient, $Cz = \frac{2W}{a+b}$, where a = sum of log (n + 1) transformed taxon scores for station a; b = sum of log (n + 1) transformed taxon scores for station b; W = sum of the smaller scores for each station, was used for the purpose. The resultant matrix of similarity coefficients was subsequently sorted by group-average technique, and the dendrogram obtained was plotted.

Results and discussion

Mean densities of the total meiobenthos were found to cover a broad range of 0 (periodically at stations A, B, C, G) to about 2540 ind./10 cm^2 (station F, April 1985). On the whole, densities at each station fluctuated rather widely during the period of study and high intrinsic variability was also found at all sampling occasions (cf. SD's in Table 2). A consistent pattern of temporal and spatial variations could not be possibly detected because of the low sampling frequency (4 times a year). Therefore, the densities and other community parameters are averaged at each station across the seasons and years for the purpose of the further analysis. The range of mean total densities thus arrived at is close to the values reported from other Southern Baltic coastal lagoons (ARLT 1973, ARLT and HOLTFRETER 1975, ARLT and SCHLUNGBAUM 1978, BESCHNIDT and NOACK 1976).

The highest mean densities were found at stations E and F (Table 2, Fig. 2), located near the connection of the lagoon with the Baltic Sea. The range of densities at these stations is basically within that observed at shallow stations of the Southern Baltic, except perhaps for the lowest values at station F (RADZIEJEWSKA 1984, RADZIEJEWSKA 1988, in press).

The lowest mean total densities were found at the inner stations C, B, A (Table 2, Fig. 2), the ones most influenced by the pollution- and nutrient-laden river water. Not infrequently,

Table 2

Mean densities (± SD) of meiobenthic taxa at Szczecin Lagoon stations (ind./10cm^2)

Station	A	B	C	D	E	F	G
% of empty samples	31.6	14.3	4.1	0	0	0	4.1
Taxon							
Hydrozoa	0	0.73 ± 2.82	0.21 ± 0.72	0	0	0.32 ± 1.15	0
Rotatoria	1.35 ± 2.75	1.46 ± 2.37	1.60 ± 2.70	3.09 ± 5.34	2.24 ± 3.14	7.36 ± 10.92	1.28 ± 2.39
Turbellaria	0.54 ± 1.37	5.36 ± 14.99	3.84 ± 5.90	3.09 ± 7.81	35.41 ± 31.36	10.67 ± 18.84	0.64 ± 1.73
Gastrotricha	0	1.22 ± 5.59	0.11 ± 0.52	0	50.88 ± 101.73	0	0
Nematoda	42.82 ± 93.72	99.72 ± 316.63	21.55 ± 29.18	88.00 ± 117.79	294.08 ± 288.84	492.48 ± 453.55	54.29 ± 85.49
Hirudinea	0.13 ± 0.59	0.12 ± 0.56	0	0	0	0.11 ± 0.52	0
Oligochaeta	1.08 ± 2.31	3.65 ± 9.90	6.19 ± 27.12	0	9.71 ± 20.41	11.09 ± 20.88	0
Ostracoda	1.35 ± 2.32	7.07 ± 17.02	3.84 ± 5.28	29.01 ± 58.47	140.37 ± 136.86	134.61 ± 190.76	70.40 ± 125.52
Harpacticoida	1.89 ± 3.99	10.00 ± 39.43	0.53 ± 1.06	3.31 ± 5.62	52.69 ± 55.20	65.81 ± 121.85	0.75 ± 2.32
Chironomidae larvae	0	0.24 ± 1.12	0	0.21 ± 0.72	0.32 ± 0.86	4.15 ± 7.42	0.64 ± 2.30
Insecta larvae	0	0	0	0	0	0.21 ± 0.72	0
Halacaridae	0	0.37 ± 1.68	0	0	1.39 ± 2.38	0.64 ± 1.36	0
Tardigrada	0.27 ± 1.17	0.24 ± 0.77	0.11 ± 0.52	0	0.64 ± 1.13	1.28 ± 2.14	0
Kinorhyncha	0	0	0	0	0.11 ± 0.52	0	0
Gastropoda juv.	0	0	0	0	0.11 ± 0.52	0.53 ± 2.13	0
Lamellibranchia juv.	0.27 ± 0.81	0.85 ± 1.87	0.43 ± 0.97	3.84 ± 7.59	10.24 ± 20.04	4.37 ± 9.41	16.43 ± 35.14
Total meiobenthos	49.06 ± 99.68	131.17 ± 400.52	38.61 ± 56.80	130.99 ± 156.70	616.11 ± 380.38	738.45 ± 602.43	144.96 ± 176.68

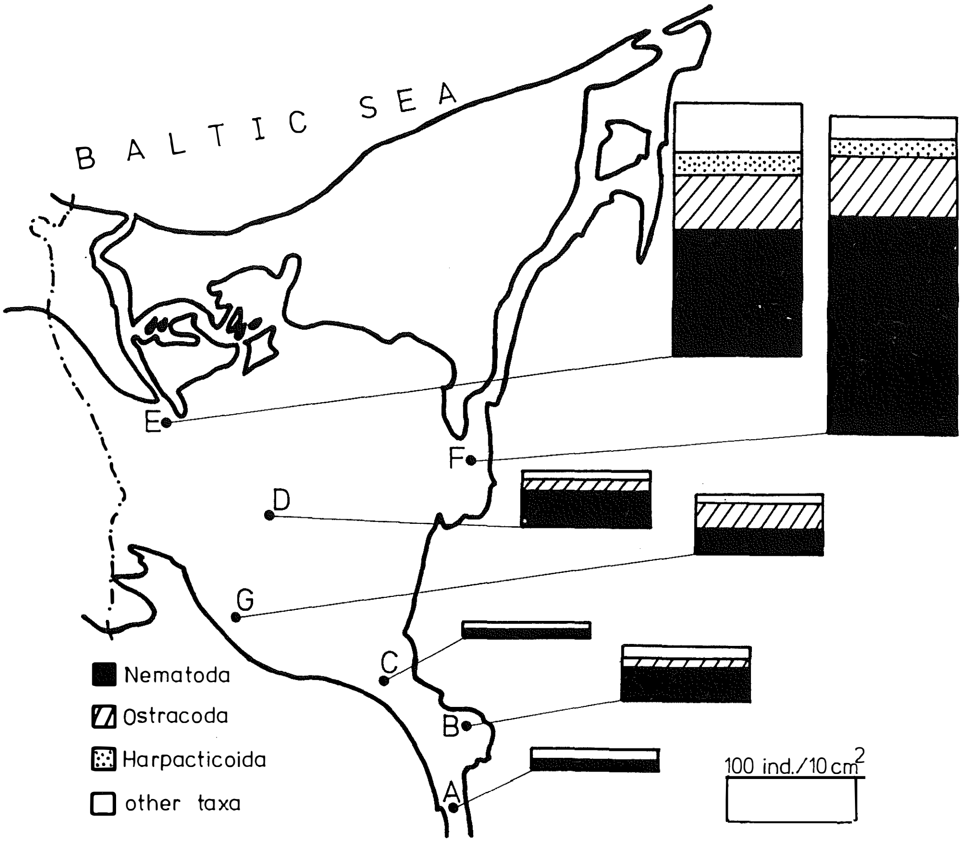

Figure 2

Distribution, abundance (averaged values), and composition of meiobenthic communities in the Szczecin Lagoon

samples devoid of meiofauna ("empty") were collected there (Table 2). A tendency toward reduced densities from the lower to higher reaches of the lagoon is thus seen. A similar tendency was observed by ARLT and HOLTFRETER (1975), ARLT and SCHLUNGBAUM (1979), and BESCHNIDT and NOACK (1976) in other Southern Baltic coastal lagoons, as well as by VAN DAMME et al. (1984) in polluted Dutch estuaries of the North Sea.

The results of 1-way ANOVA showed the stations to differ significantly ($p<0.001$) in their overall meiofaunal densities (Table 3). Doubtless, the differences stem partly from differing sediment types encountered at the stations. This is particularly evident at station E with almost clean sand (cf. Tables 1, 2). Effects of sediment type on both the abundance and the composition of meiofauna have already been noted elsewhere (GRAY 1974, RADZIEJEWSKA 1988, in press). However, the stations differ not only with respect to the nature of their sediments, but also in other characteristics such as percentage of organic matter and heavy metal content of the sediment and susceptibility to Baltic inflows (Table 1). Periodic absence of meiobenthic animals at the innermost stations and at station G (Table 2) in spite of oxygen regimes far from anoxia (Table 1) suggests other forces affecting the meiobenthic communities, like accumulation of toxic substances (cf. high heavy metal content at stations C, G).

When present, meiobenthic communities on the average consisted of 2 to 7 taxa per station (Table 4). Mean numbers of taxa and diversity indices again showed the outer stations (E and F) to be the most diverse ones, occasionally containing such typically marine organisms as kinorhynchs (Table 2). The remaining stations were qualitatively impoverished (Table 4), and also proved to differ significantly ($p<0.001$) in terms of their numbers of meiobenthic taxa and diversity (Table 3).

Table 3

Analysis of variance tables

Parameter tested	Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	Among stations	6	59.71	9.95	24.88***
density	Within stations	153	61.74	0.40	
log/n+1/ transf.	Total	159	121.45		
	Among stations	6	488.74	81.46	21.16***
No. of taxa	Within stations	153	589.23	3.85	
	Total	159	1077.97		
	Among stations	6	2.0564	0.3427	12.6926***
H'	Within stations	153	4.1257	0.0270	
	Total	159	6.1821		
	Among stations	6	2366.83	394.47	$0.80^{n.s.}$
% Nematoda arcsin transf.	Within stations	142	62426.72	439.63	
	Total	148	64793.75		
	Among stations	6	7889.02	1314.84	3.68**
% Ostracoda arcsin transf.	Within stations	142	50694.81	357.01	
	Total	148	58583.83		
% Harpacticoida	Among stations	6	2439.20	406.53	4.66***
arcsin transf.	Within stations	142	12377.05	87.16	
	Total	148	14816.25		

n.s. = difference non-significant
** = difference highly significant /$p < 0.01$/
*** = difference very highly significant /$p < 0.001$/

Meiobenthic communities at most stations were dominated by nematodes (Tables 2, 4; Fig. 2). Their average contribution ranged from about 41 to about 68 %, which is lower than encountered in other eutrophic and/or heavily polluted estuaries and lagoons (ARLT and HOLTFRETER 1975, ARLT and SCHLUNGBAUM 1979, BESCHNIDT and NOACK 1976, VAN DAMME et al. 1984). The relative importance of nematodes seems to be similar at most stations, and 1-way ANOVA failed to show statistically significant differences ($p>0.05$) between stations with respect to the percentage of nematodes in the samples (Table 3).

Table 4

Meiobenthic community parameters (mean ± SD)

Station	No. of taxa	H'	% Nematoda	% Ostracoda	% Harpacticoida
A	1.9 ± 2.2	0.1120 ± 0.1594	62.15 ± 42.94	16.88 ± 32.19	4.78 ± 9.19
B	3.5 ± 2.2	0.3205 ± 0.2087	57.44 ± 29.12	18.23 ± 21.86	4.54 ± 8.64
C	3.1 ± 1.8	0.3334 ± 0.1975	55.65 ± 26.15	18.30 ± 23.08	2.27 ± 6.13
D	3.5 ± 1.4	0.3309 ± 0.1661	66.26 ± 20.82	22.06 ± 19.32	2.31 ± 2.88
E	7.0 ± 1.8	0.5253 ± 0.1062	48.73 ± 19.96	24.93 ± 16.25	8.79 ± 7.96
F	6.3 ± 2.6	0.3512 ± 0.1408	67.74 ± 20.40	20.02 ± 18.90	6.00 ± 8.74
G	2.8 ± 1.5	0.2306 ± 0.1550	40.57 ± 35.29	42.84 ± 35.48	2.57 ± 9.60

Table 5

Frequency of ocurrence (%), mean density, and density ranges (ind./10cm^2) of harpacticoid copepod species in the Szczecin Lagoon

$\left(\frac{\text{mean/frequency}}{\text{range}}\right)$

Species	Station A	B	C	D	E	F	G
Halectinosoma curticorne	0	2.59/14.3 / 0 – 21.3	0.08/ 8.3 / 0 – 2.56	1.28/25.0 / 0 – 15.36	18.97/83.3 / 0 – 102.40	5.65/16.7 / 0 – 89.60	0.11/ 4.2 / 0 – 2.56
Microarthridion littorale	0	0.61/14.3 / 0 – 5.12	0	0.32/12.5 / 0 – 5.12	8.96/37.5 / 0 – 79.36	0.11/ 4.2 / 0 – 2.56	0.32/ 8.3 / 0 – 5.12
Paraleptastacus spinicauda	0	0	0	0	0.32/12.5 / 0 – 2.56	0	0
Nitocra spinipes	0	0	0.11/12.5 / 0 – 2.56	0	0.32/12.5 / 0 – 2.56	0.43/16.7 / 0 – 2.56	0
Nitocra hibernica	0	0	0	0.21/ 4.2 / 0 – 5.12	2.24/ 8.3 / 0 – 48.64	8.53/37.5 / 0 – 94.72	0
Nitocra lacustris	0	0	0	0	0.43/ 8.3 / 0 – 7.68	0.32/ 4.2 / 0 – 7.68	0
Bryocamptus minutus	0	0.37/12.5 / 0 – 2.56	0.11/12.5 / 0 – 2.56	0	0	43.4/25.0 / 0–404.48	0
Bryocamptus echinatus	0	0	0	0	0	0.11/ 4.2 / 0 – 2.56	0
Canthocamptus staphylinus	0.67/4.2 / 0 – 12.8	0.37/ 9.5 / 0 – 5.12	0	0.11/ 4.2 / 0 – 2.56	0	0.32/ 8.3 / 0 – 5.12	0
Attheyella crassa	0.27/5.3 / 0 – 5.12	0	0	0	0	0.11/ 4.2 / 0 – 2.56	0

Second in importance were the ostracods (Tables 2, 4; Fig. 2) which occurred most abundantly at stations E, F, G (Table 2). Ostracods contributed, on the average, from about

17 % of the total meiobenthos at station A to about 43 % at station G (Table 4), the stations differing significantly ($p<0.01$) in percentage of ostracods (Table 3). The prominence of ostracods seems to be a typical feature in eutrophic and polluted Baltic coastal lagoons (ARLT and HOLTFRETER 1975, ARLT and SCHLUNGBAUM 1979, BESCHNIDT and NOACK 1976). As shown by BESCHNIDT and NOACK (1976), ostracods found in the Saaler Bodden were not deterred from living under adverse conditions and seemed to surpass other taxa, except nematodes, in their ability to withstand environmental stress. Moreover, KANSANEN (1981) found *Cypria ophthalmica* and *Candona* spp., the species most common also in the inner part of the Szczecin Lagoon (RADZIEJEWSKA, unpubl.) to be typical of polluted lacustrine areas.

In contrast, harpacticoid copepods are commonly regarded as a vulnerable group, very sensitive to habitat deterioration (HEIP 1980, RAFFAELLI 1982, VAN DAMME et al. 1984). Their abundance, as well as certain structural parameters of harpacticoid taxocene, have even been suggested as a valuable tool in environmental monitoring (HEIP 1980). Moreover, WARWICK and GEE (1984) state that harpacticoid copepods, by virtue of their high susceptibility to passive transport over the bottom, are less subjected to local predation pressures and their community structures reflect a larger measure of physical control. Over the two years of study, a total of 10 harpacticoid species were recorded (Table 5). Harpacticoids were concentrated mainly at stations E and F, *Halectinosoma curticorne, Microarthridion littorale,* and also *Bryocamptus minutus* being the most abundant and common species (Table 5). The first two, euryhaline brackish epibenthic animals, are known to live in detritus- and mud-enriched sands (NOODT 1970, VAN DAMME et al. 1984). Perhaps their tolerance of wide salinity fluctuations, adaptation to life in the bottom floc (NOODT 1970) and ability to perform active vertical migrations above the bottom (ARLT et al. 1980) facilitate their dispersal over the lagoon with changing currents and turbulence, and enable them to exploit favourable local conditions.

The occurrence of harpacticoids in the lagoon to some extent followed seasonal succession patterns; e.g. certain species like *Canthocamptus staphylinus* occurred in cold seasons only (cf. SARVALA 1986). These patterns, however, are not easy to recognize due to the low sampling frequency. Successional differences notwithstanding, the stations differed markedly in the frequency of harpacticoid occurrence, total number of species recorded (from 2 at station A and G to 9 at station F), abundance (Table 5), and percental contribution to the mean meiobenthic density at a station (Table 4; Fig. 2). The role of harpacticoid copepods as expressed by their contribution to total density differs significantly ($p<0.001$) between stations (Table 3). As can be seen from the tables, harpacticoids were most common, abundant and diverse at the outer stations. This, coupled with scarcity of these animals at the remaining stations, particularly the innermost ones and G, shows the group to be indeed sensitive to polluted habitats. VAN DAMME et al. (1984) already concluded that harpacticoid copepods are good indicators of heavy metal pollution.

The dendrogram resulting from the similarity analysis (Fig.3) distinctly separates the three groups of stations. The first group is formed by the two outer stations E and F, with the richest and most abundant meiofauna communities. The second consists of the innermost stations A, B, C, in the area that bears the brunt of the pollution carried into the lagoon by the Odra, while stations D and G form the third, intermediate group in the dendrogam. Thus the lagoon, with respect to its meiobenthic communities, may be divided into three zones: outer, affected most by the inflowing Baltic water; innermost, heavily polluted, at the mouth of the Odra; and intermediate, covering the central and western part of the area.

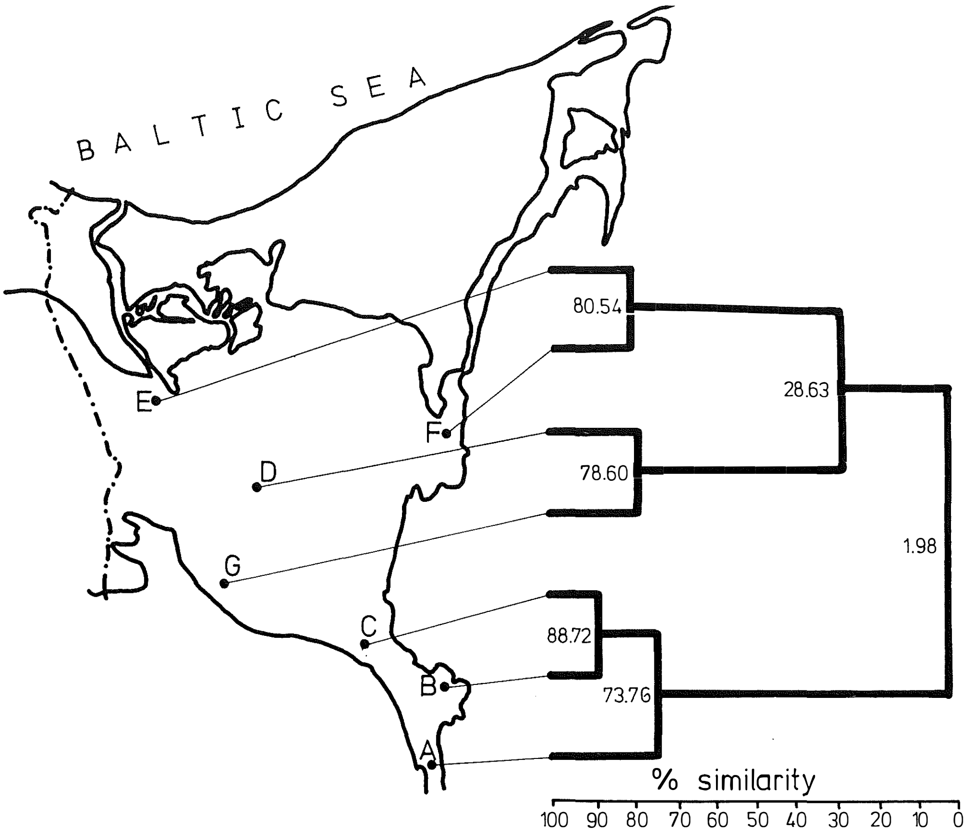

Figure 3

Similarity dendogram of the Szczecin Lagoon meiobenthic communities

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