Small-scale vertical distribution of zoobenthos in the sandy littoral of the Gulf of Gdańsk

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Abstract

Three sites in the Gulf of Gdańsk were analysed for the presence of zoobenthos in 0–10 cm sediment cores, collected at 1 m depth in the course of the year. 80% of the macrobenthos biomass was distributed in the top 5 cm of the sediment at Osłonino, while at Jurata 50% of the biomass was found below 5 cm. At Mikoszewo macrofauna was found in the intermediate 3–5 cm layer only. Meiofauna was most abundant in the upper sediment layers at Jurata and Osłonino, while at Mikoszewo most of the biomass was found below 5 cm. The upper 5 cm layer was the richest in taxa, as regards both meio- and macrobenthos. Below 5 cm Polychaeta dominated the macrofauna, Nematoda and Oligochaeta the meiofauna. The vertical distribution of meio- and macrofauna changes slightly in the course of the year. The spring and autumn samples revealed more fauna in the upper sediment layers, while the deeper sediment strata were rich in biomass in the winter months. The mean size of individual zoobenthos specimens increased with the depth of the sediment layer.

1. Introduction

The present paper is the third in a series dealing with the sandy littoral of the Polish coast. The previous two covered the open-coast zoobenthos (Haque *et al.*, 1996) and seasonal changes in the abundance and biomass of zoobenthos in the Gulf of Gdańsk (Haque *et al.*, 1997). The high biomasses and the diversity of taxa found in the sandy littoral of the Gulf of Gdańsk are indicative of the significance of this ecological zone in terms of energy transfer and carbon production. The aim of this paper is to describe the small-scale vertical distribution of the sandy-littoral zoobenthos, to discover how the fauna is distributed within the upper 10 cm of sediment and how it varies in the course of the year.

2. Material and methods

Samples were collected at three stations situated in the Gulf of Gdańsk, 10 m from the water line, at 1 m depth, from January to December 1993 (Fig. 1). A manual sediment corer was used for sampling (tube 10 cm

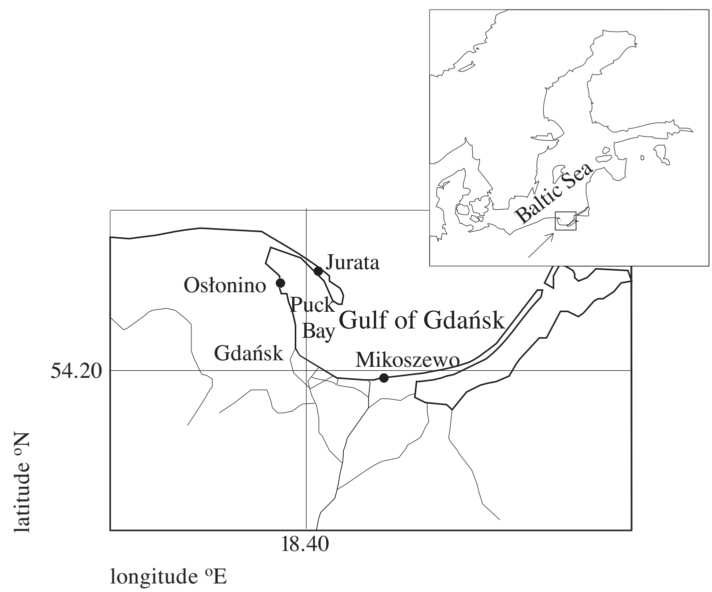


Fig. 1. The study area

in diameter and 18.5 cm in length). The macrofauna were collected from the sediment core samples by slicing this into 4 layers (0–1 cm, 1.1–3 cm, 3.1–5 cm, 5.1–10 cm). A separate sediment core for meiobenthos samples was sliced into 7 horizontal sections (0–0.5 cm, 0.6–1 cm, 1.1–2 cm, 2.1–3 cm, 3.1–5 cm, 5.1–7 cm, 7.1–10 cm). Triplicate samples were collected each time and preserved in 10% formalin. All together, 1134 samples were analysed for meiofauna (162 cores, each of 7 layers) and 648 samples for macrofauna (162 cores, 4 layers each). The macrofauna biomass was measured after 3 months (wet formalin weight) and subsequently recalculated to dry weight according to Rumohr *et al.* (1987). The meiofauna was processed according to the procedure by Elmgren and Radziejewska (1989). The volumetric method and conversion factors were used for dry weight determinations of meiofauna (Feller and Warwick, 1988). The sand at the stations was fine-grained, except at Osłonino, where some coarse material was admixed (Haque *et al.*, 1997). The organic matter content in the sand was low at Jurata and Mikoszewo ($< 0.5\%$), but higher and more variable at Osłonino (up to 3%, Haque *et al.*, 1997).

3. Results

Annual mean zoobenthos biomass

The annual mean total macrobenthos biomass at particular intervals displayed no clear vertical distribution pattern. With respect to the thickness of the sediment layers, the biomass increased with depth at Jurata, but decreased at Osłonino (Tab. 1). At Jurata the macrofauna biomass in the upper 5 cm interval almost equalled that in the lower 5 cm interval.

Table 1. Annual mean macrobenthos abundance and biomass in sediment intervals at stations

Station	Sediment interval [cm]	Mean	Minimum	Maximum	SD
		Abundance [indiv. m^{-2}]			
Jurata	0.0–1.0	907.2	0	4713.4	1356.5
	1.1–3.0	756.6	0	2505.3	774.8
	3.1–5.0	440.1	0	1061.5	387.9
	5.1–10.0	552.0	0	1443.7	457.7
Osłonino	0.0–1.0	2641.2	0	7813.2	2752.6
	1.1–3.0	1893.8	254.8	6794.1	2070.1
	3.1–5.0	495.4	127.4	1783.4	506.9
	5.1–10.0	352.4	0	1358.8	428.8
Mikoszewo	0.0–1.0	0	0	0	
	1.1–3.0	30.9	0	169.9	54.0
	3.1–5.0	3.9	0	42.5	12.8
	5.1–10.0	0	0	0	

Table 1. (continued)

Station	Sediment interval [cm]	Mean	Minimum	Maximum	SD
		Biomass [g m^{-2}]			
Jurata	0.0–1.0	0.527	0	2.507	0.741
	1.1–3.0	2.349	0	8.527	2.922
	3.1–5.0	2.602	0	11.612	3.272
	5.1–10.0	5.571	0	12.081	4.381
Osłonino	0.0–1.0	5.158	0	21.426	6.802
	1.1–3.0	5.434	0.519	24.265	7.152
	3.1–5.0	6.654	0.100	22.729	8.398
	5.1–10.0	2.804	0	9.709	3.084
Mikoszewo	0.0–1.0	0	0	0	
	1.1–3.0	0.128	0	1.357	0.407
	3.1–5.0	0.009	0	0.009	0.002
	5.1–10.0	0	0	0	

At Osłonino, the biomass in the upper interval exceeded that in the lower interval by a factor of almost 6. At Mikoszewo macrofauna was found only between 1 and 5 cm. The annual mean meiobenthos biomass decreases with increasing sediment depth at both Jurata and Osłonino. At Mikoszewo, the meiobenthos biomass decreased slightly with depth. At all three localities the meiobenthos biomass ranged from 0.007 to 0.52 g d.w. m^{-2} (in 1 cm – thick sediment layers, Tab. 2).

Table 2. Annual mean meiobenthos abundance and biomass in sediment intervals at stations

Station	Sediment interval [cm]	Mean	Minimum	Maximum	SD
		Abundance [indiv. m^{-2}]			
Jurata	0.0–0.5	323.7	10.9	871.5	325.2
	0.6–1.0	381.5	7.5	953.7	325.5
	1.1–2.0	394.5	23.4	1134.0	379.1
	2.1–3.0	176.1	15.1	526.8	156.8
	3.1–5.0	187.0	16.8	664.3	184.6
	5.1–7.0	109.7	5.9	319.6	91.1
	7.1–10.0	125.5	6.7	733.9	218.1

Table 2. (continued)

Station	Sediment interval [cm]	Mean	Minimum	Maximum	SD
		Abundance [indiv. m^{-2}]			
Osłonino	0.0–0.5	177.9	40.3	442.0	127.5
	0.6–1.0	186.5	46.1	403.5	111.9
	1.1–2.0	139.6	52.0	404.3	103.1
	2.1–3.0	58.6	20.9	125.0	30.5
	3.1–5.0	37.0	3.4	103.2	32.8
	5.1–7.0	15.3	4.2	31.04	10.2
	7.1–10.0	56.9	0	265.06	95.9
Mikoszewo	0.0–0.5	79.8	0	730.6	216.3
	0.6–1.0	73.2	0	507.5	147.5
	1.1–2.0	139.3	0.8	561.1	170.0
	2.1–3.0	101.0	14.3	436.2	123.8
	3.1–5.0	142.1	19.3	339.7	122.6
	5.1–7.0	125.0	3.4	441.2	134.4
	7.1–10.0	104.0	0	545.2	158.3
		Biomass [g m^{-2}]			
Jurata	0.0–0.5	0.211	0.008	0.723	0.206
	0.6–1.0	0.305	0.005	0.826	0.253
	1.1–2.0	0.287	0.042	0.774	0.238
	2.1–3.0	0.152	0.044	0.457	0.130
	3.1–5.0	0.179	0.025	0.363	0.110
	5.1–7.0	0.109	0.003	0.234	0.065
	7.1–10.0	0.171	0.004	0.996	0.291
Osłonino	0.0–0.5	0.237	0.025	0.882	0.260
	0.6–1.0	0.199	0.031	0.406	0.140
	1.1–2.0	0.131	0.052	0.254	0.061
	2.1–3.0	0.074	0.024	0.145	0.038
	3.1–5.0	0.050	0.011	0.117	0.036
	5.1–7.0	0.021	0.002	0.056	0.018
	7.1–10.0	0.146	0	1.112	0.345
Mikoszewo	0.0–0.5	0.028	0	0.226	0.066
	0.6–1.0	0.028	0	0.173	0.052
	1.1–2.0	0.054	0	0.206	0.063
	2.1–3.0	0.038	0.005	0.158	0.046
	3.1–5.0	0.051	0.005	0.138	0.043
	5.1–7.0	0.073	0.002	0.236	0.083
	7.1–10.0	0.059	0	0.309	0.087

Seasonal changes in the vertical distribution of the zoobenthos biomass

The macrofauna biomass at Jurata was equally distributed in the upper 5 cm and lower 5–10 cm layers in the summer months, this distribution being subject to slight changes in the course of the year (Fig. 2). While the meiofauna biomass increased in the surface sediments from April to October, it was significantly larger in deeper layers in the autumn and winter months (Fig. 2). The seasonal pattern of the meiobenthos at Osłonino is similar to that at Jurata, the domination of the biomass being more pronounced in the upper layer (Fig. 2). The macrobenthos at Osłonino was seasonally variable (the opposite of the situation at Jurata), with the biomass in the upper sediment layer increasing in spring and autumn (Fig. 2). In spring and autumn the meiobenthos dominated the upper sediment layer at Mikoszewo, whereas summer and winter data show the major part of the biomass to be located in the lower sediment layer. Macrobenthos was present all the year round in the 1–3 cm sediment layer only.

Vertical distribution of zoobenthos size groups in the sediment

The relative size of the average zoobenthos specimen was obtained on dividing the biomass per number of specimens in the various sediment layers. The mean size of a macrobenthos specimen increased markedly from surface to deep sediment layers, except at Mikoszewo, where an insufficient number of animals had been collected (Fig. 3). A similar, though less pronounced pattern was found to govern the meiobenthos distribution: the greater the depth of sediment, the larger the individual specimens (Fig. 3).

Vertical distribution of particular taxa in the sediment

In terms of biomass the macrofauna was dominated almost exclusively by Polychaeta in lower sediment layers (< 5 cm). Large Oligochaeta, Bivalvia and Gastropoda were abundant in the surface stratum (0–1 cm, Fig. 4). Mikoszewo was exceptional in that only large Oligochaeta were present in the 3–5 cm sediment layer and mainly Amphipoda in the 1–3 cm stratum. At Jurata and Osłonino the meiofauna biomass was divided almost equally among 6 higher taxa in upper 1 cm. Deeper down, Oligochaeta and Nematoda were prevalent (Fig. 5). At Mikoszewo the position was different – abundant Oligochaeta occurred below the 5 cm stratum, while the upper layers were totally dominated by Nematoda. Other taxa contributed to the biomass only in the 2–5 cm layer (Fig. 5).

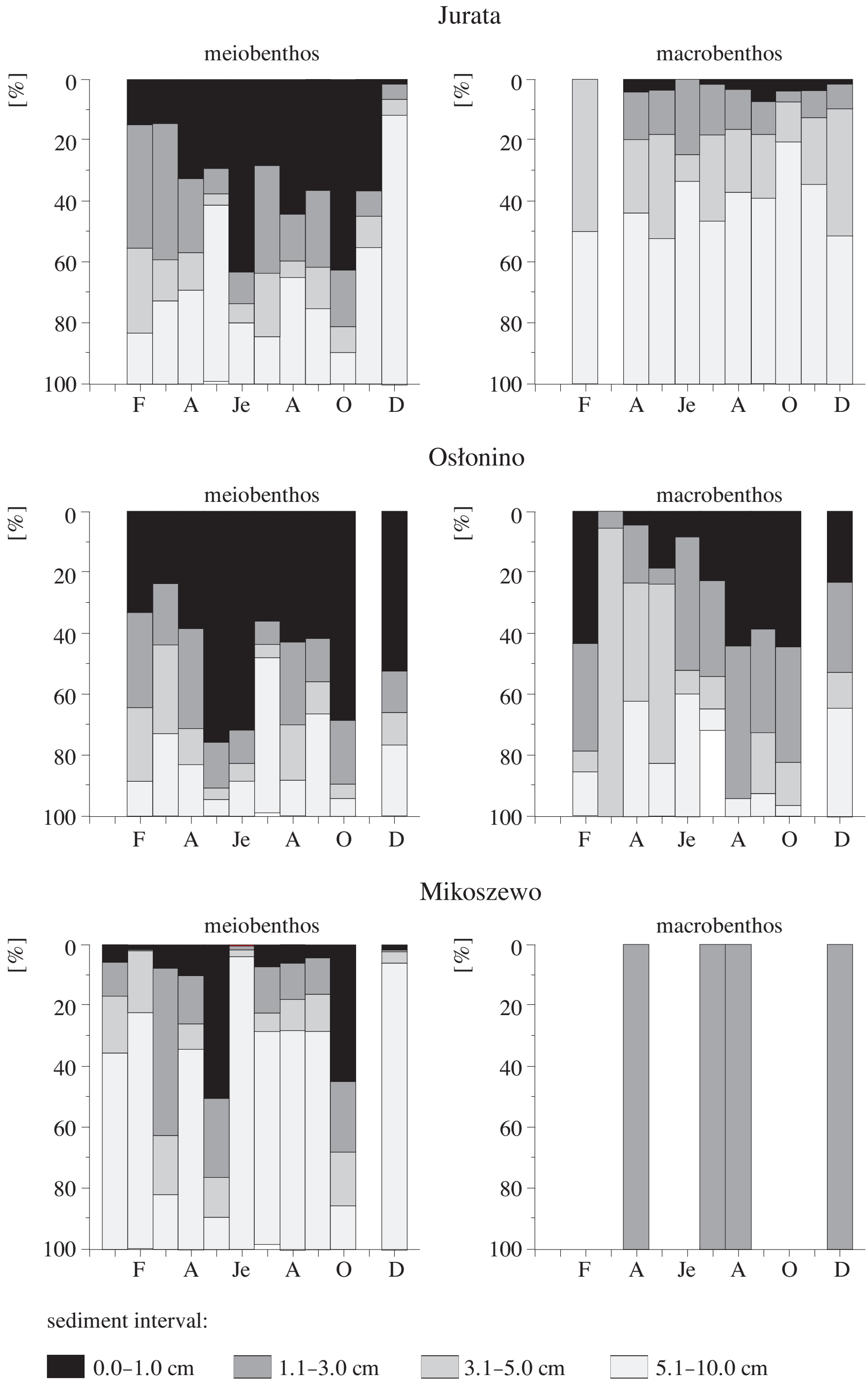
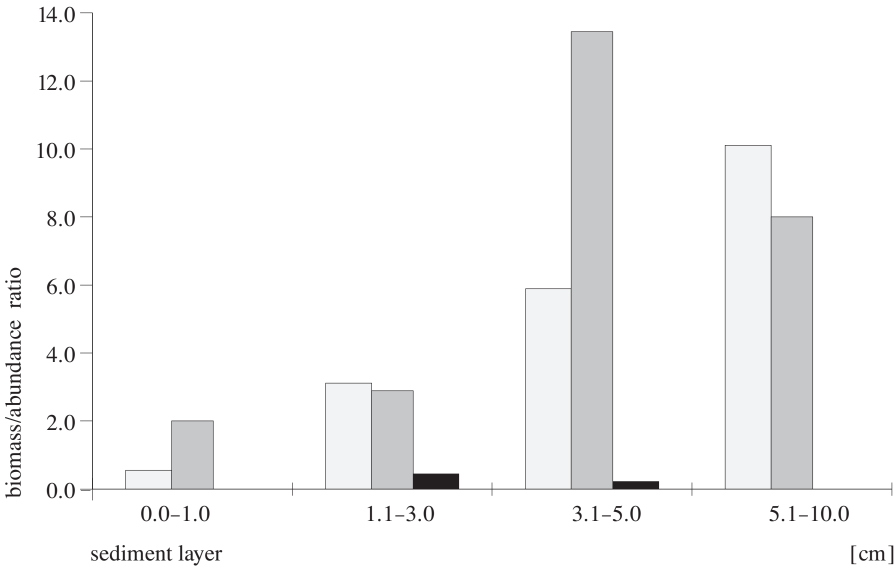


Fig. 2. Seasonal changes in percentage of meio- and macrobenthos biomass in sediment intervals at stations

a



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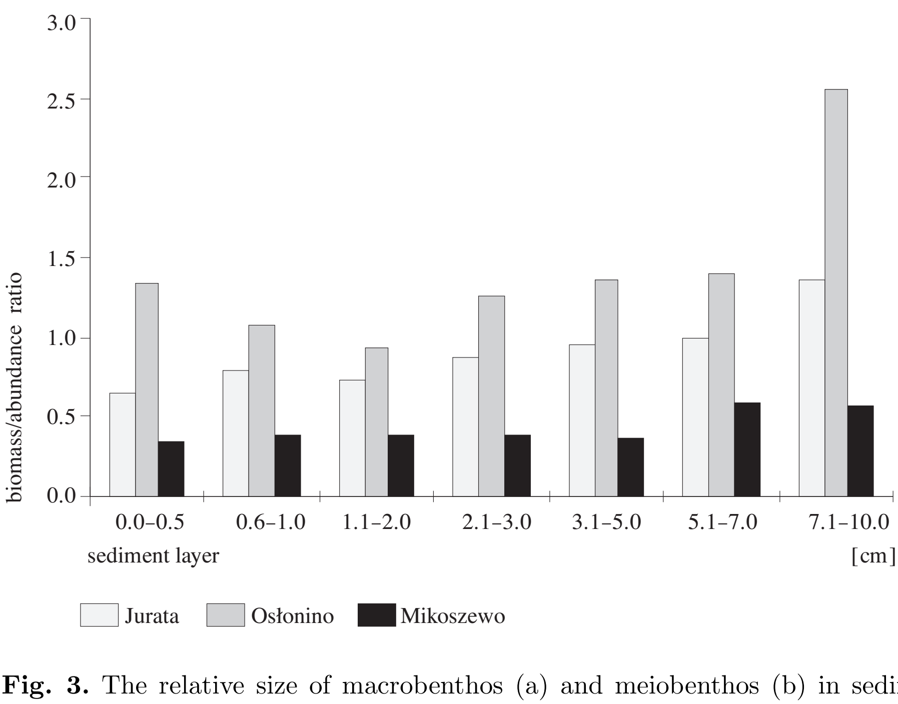

Fig. 3. The relative size of macrobenthos (a) and meiobenthos (b) in sediment layers (annual mean)

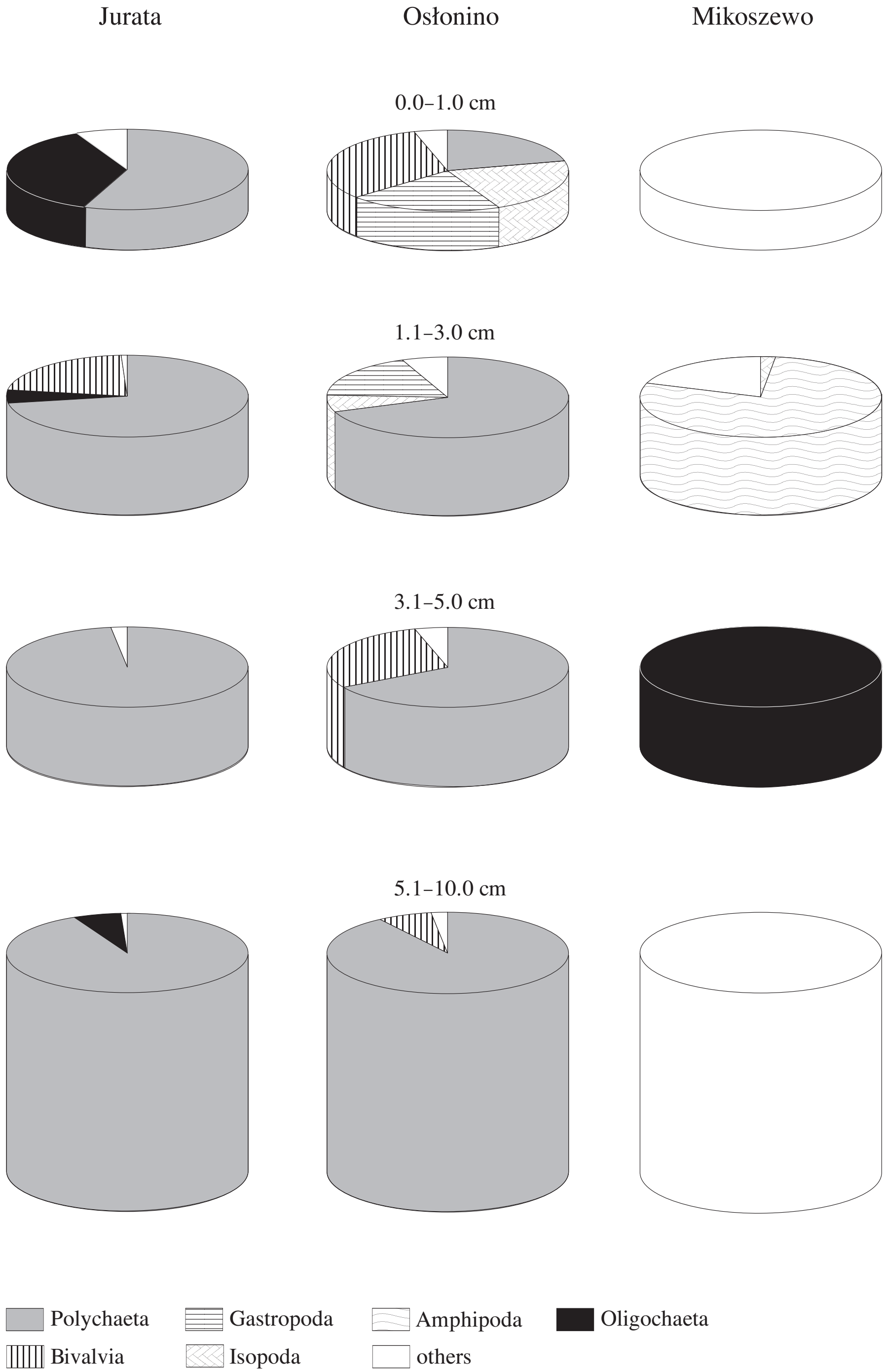

Fig. 4. Percentage of major taxa in macrobenthos biomass in sediment layers at stations (annual mean)

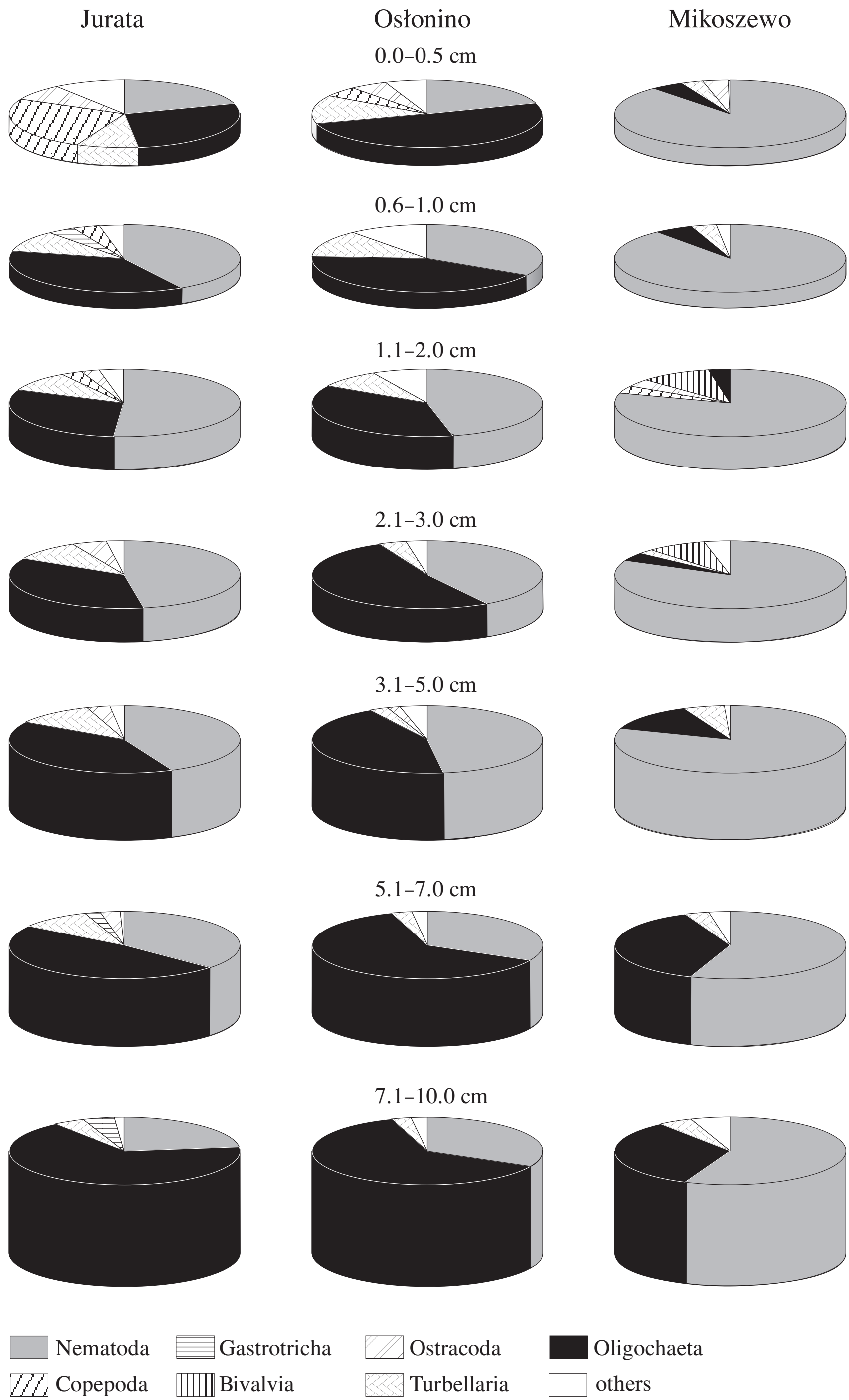

Fig. 5. Percentage of major taxa in meiobenthos biomass in sediment layers at stations (annual mean)

4. Discussion

Differences were observed in the vertical zoobenthos distribution patterns at the stations. Especially clear was the dominance of the meiofauna in the lower parts of the Mikoszewo core and the very limited occurrence of macrofauna there, unlike the situation at Jurata and Osłonino. This might be explained by the unstable sediment and salinity fluctuations due to the proximity of the river Vistula (Haque *et al.*, 1997). Mikoszewo was faunistically different from the other stations, since Nematoda dominated the biomass in all the sediment layers there, unlike the other localities, where Oligochaeta were prevalent. Such a strong dominance of Nematoda could be attributed to the considerable pollution of the water (Heip, 1980). Macrofauna was more abundant in the lower sediment strata at Jurata compared to Osłonino, which is the main difference between the two sites. The conditions at Jurata are more stable, with less organic matter compared to the turbid, organic-rich sand at Osłonino (Haque *et al.*, 1997).

The small-scale vertical distribution of meiofauna in sediments has been studied very little in the Baltic; some data are presented in Tab. 3. Some authors found diverse meiofauna down to 1 m below the sand surface (Sywula, 1966). In the Gulf of Gdańsk sublittoral, the most numerous and diverse (5 to 11 taxa, on average) meiobenthic populations were restricted to the top 1 cm layer, while 80–90% of the total meiobenthos abundance inhabited the upper 3 cm layer (Szymelfenig, 1992). In the Wadden Sea tidal flat, peak meiofauna abundance was reported in the top 10 cm of sediment (Witte and Zijlstra, 1984). In the mangrove sediments of South Africa highest densities were encountered within the top 10 cm (Dye, 1983). On the west coast littoral of India, approximately 70% of the total meiofauna occurred in the upper 2 cm of sediments (Ansari, 1978). Hence, the present sampling depth can be regarded as representative for the 'ecological' sampling of the sandy sediment biocenosis. Some taxa inhabiting deep layers of sediment are probably missing from our collection, but most of the functional groups and the bulk of the biomass were sampled.

In the littoral zones the meiofauna usually undertake vertical migrations correlated with the alternate drying and wetting of the sand during the tidal cycle. Vertical fluctuations of meiofauna, inhabiting different depth zones in the top 20 cm of sediment, were often very distinct (Dye, 1978; McLachlan, 1978). Such movements may be also modified by temperature differences between summer and winter, and day and night (McLachlan *et al.*, 1977). The can also be affected by rain (Ansari *et al.*, 1984; Boaden, 1968; Bush, 1966; McLachlan *et al.*, 1979). Other authors take the view that vertical migrations are caused by chemical changes, especially in the oxygen content

Table 3. The vertical distribution of the meiobenthos in the Baltic Sea and other regions

Location	Layer	Percentage	References
Gulf of Gdańsk	top 1 cm	most numerous and diverse (5 to 11 taxa, on average)	Szymelfenig (1992)
	3 cm upper layer	80–90% of meiofauna	
Puck Bay	upper 1–2 cm	most of the meiofauna	Miłosek (1989)
Wadden Sea tidal flat of Holland	top 10 cm	peak meiofauna	Witte and Zijlstra (1984)
Mangrove sediments of South Africa	within the top 10 cm	highest densities were encountered	Dye (1983)
South African beaches	top 20 cm	often inhabited by bulk of fauna	Dye (1978), McLachlan (1978)
littoral Indian west coast	upper 2 cm	approximately 70% of the total fauna	Ansari (1978)
open Baltic	upper 10 cm	no pattern	Haque *et al.* (1996)
littoral sediments of the Gulf of Gdańsk	top 3 cm	64–95% abundance	present study

of the sediment (McLachlan, 1978; Brown and McLachlan, 1990; Quijón and Jaramillo, 1996).

The study area is more stable than similar biota in tidal waters. One sign of this is the observed segregation of the zoobenthos in particular sediment layers, a phenomenon absent from the turbid sands of the open Baltic coast (Haque *et al.*, 1996). Water level variations in the Gulf of Gdańsk are infrequent, and are due to storm surges or seiches (Nowacki, 1993). No oxygen deficiency has been reported in the upper sediment in the Gulf of Gdańsk littoral (Geringer d'Oedenberg and Wołowicz, 1996), so the main factors giving rise to vertical migration of fauna in the sediment, *i.e.* sea level changes and oxygen deficiency, are non-existent in the Gulf of Gdańsk littoral. The relative size of the animals in both meio-and macrofauna increases from top to bottom of the sediment core; a similar phenomenon was related to the distribution of small r-strategists in less stable, surface habitats, unlike the larger K-strategists, which prefer deeper, more stable biota (Giere, 1993). The relative size of the benthos inhabiting the moving sands of the open Baltic coast was similar to the small size classes in our material (Haque *et al.*, 1996). In both temperate (Szymelfenig, 1992) and tropical (Ansari, 1978) habitats, no seasonal vertical migration of meiobenthos in sediment was observed. The present investigation confirms these observations: the top sediment layer was richest in meiofauna throughout the study year.

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