The sandy littoral zoobenthos of the Polish Baltic coast

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Baltic littoral
Benthos

Ashraful Mohammed Haque
Institute of Oceanology,
Polish Academy of Sciences,
Sopot

Maria Szymelfenig
Institute of Oceanography,
Gdańsk University,
Gdynia

Jan Marcin Węsławski
Institute of Oceanology,
Polish Academy of Sciences,
Sopot

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Abstract

Macrobenthos and meiobenthos were quantitatively sampled in the sandy littoral along the Polish Baltic Sea coast in August 1994. Macrofaunal abundance (0–987 indiv. m^{-2}), biomass (0–3.19 g m^{-2} wet wt.) and the number of species (3) were very low. Eight meiofaunal animal groups were found. Meiofaunal abundance (38–760 indiv. 10^{-1} cm^{-2}) was dominated by Nematoda and Turbellaria, the biomass (0.86–34.9 mg 10^{-1} cm^{-2} wet wt.) by Oligochaeta. In terms of biomass, the macrobenthos:meiobenthos ratio ranged from 0.02 to 5.17. Macrofaunal abundance and biomass were more variable than those of the meiofauna.

1. Introduction

The Polish coastal zone of the Baltic Sea is of great economic importance and has been the subject of numerous investigations over a long period of time. As regards environmental factors, the most comprehensive data concern temperature, salinity, and oxygen content in water (Majewski, 1972; Cyberska and Lauer, 1990; Cyberska, 1994). Biological studies of many groups of organisms have been carried out (Ciszewski, 1985; Okołotowicz, 1985; Pliński, 1987; Żmudziński, 1987; Trzosińska *et al.*, 1989; Skóra, 1992a,b). The Gulf of Gdańsk, the Pomeranian Bay and the Szczecin Lagoon in particular have been very thoroughly investigated (Herra and

Wiktor, 1985; Pliński and Picińska, 1985; Radziejewska and Drzycimski, 1988; Majewski, 1990; Wiktor, 1990). A large number of studies have focused on the inflow of various types of pollutants from the land into coastal waters (Teleżyński, 1985; Andrulewicz, 1992b; Rybiński *et al.*, 1992; Sobol and Szumilas, 1992). Despite the increasing interest in the coastal zone, little information on the southern Baltic littoral zones and beaches is available (Żmudziński and Ostrowski, 1982). Our knowledge of the productivity, energy budget, food chains, and tolerance to pollution remains sparse since ecological research of Polish beaches has hitherto been almost non-existent.

The aim of this work is to describe the abundance, biomass and distribution of the littoral zoobenthos with special regard to the sediment type and organic matter content in the surf-zone along the western and central sections of the Polish coast.

2. The study area

Some 524 km of the southern shoreline of the Baltic Sea belong to Poland. By comparison with the rocky, western and northern shores of the Baltic Sea, the Polish coastline is relatively smooth. Furthermore, it is accumulative-abrasive, these two shore types occurring alternately (Bołdyriew *et al.*, 1982). The coast consists mainly of sandy beaches and dunes (Krzymińska, 1991). There are also a few cliffs. The sandy sea floor extends into the coastal zone to a depth of 40–50 m. Sand is easily moved by wave action, so the sea floor here is continually changing its form. To a large extent, the bottom sediments consist of sand, and sometimes of gravel and pebbles (Uścinowicz, 1991).

The coastal zone is influenced by conditions in the open sea. The water temperature off the Polish coast fluctuates considerably, most frequently ranging between 18°C to 20°C in August and from 1°C to 2°C in February. Ice cover usually appears in January and February but is limited to the shallowest areas (Majewski, 1975). Short-lived changes in water temperature off the shoreline are ascribed to upwelling. Slow but significant long-term variations in the salinity have been recorded, the trend being a rising one (Cyberska, 1994).

As the shallow seawater is generally well aerated from the surface to the bottom, areas of oxygen depletion are absent. Oxygen deficiency may, however, appear during periods of prolonged ice cover. In shallow coastal waters the oxygen saturation varies seasonally, oscillating around 100% during the year (Trzosińska *et al.*, 1989).

In the entire coastal area nutrient concentrations fluctuate strongly from season to season, which is indicative of a high intensity of primary production. Phosphate and silicate concentrations fall to a minimum in spring, whereas the lowest nitrate concentrations are typical of the summer period (Trzosińska *et al.*, 1989).

The whole coast is strongly affected by land-based factors acting mainly through the rivers and the atmosphere. The impact of these factors results in a wide range of phenomena occurring in the environment of the coastal biocenoses (Andrulewicz and Trzosińska, 1984a,b). The system of offshore currents plays a significant role in the distribution of contaminants. The velocity of shallow water currents rarely exceeds 10 m s^{-1}; this increases only around the Hel Peninsula when, under stormy conditions, it can rise to as much as 50–100 m s^{-1} (Majewski, 1975). Pollutants entering the coastal zone are most probably transported by the prevailing surface currents (Andrulewicz, 1992a).

3. Material and method

Samples were collected from the littoral zone (after Odum, 1982) at 17 different locations on the Polish coast of the Baltic Sea in August (Fig. 1).

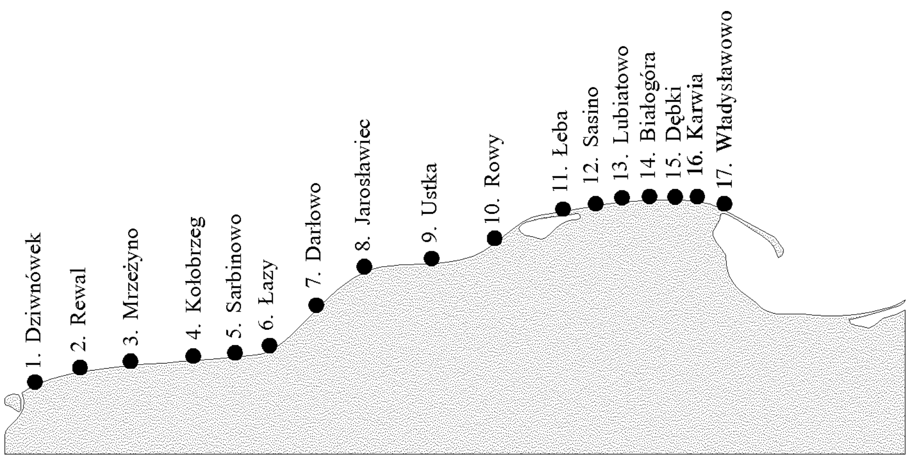


Fig. 1. The study area (stations)

There were two sampling profiles (the first one 10 m distant from the second) at each station, each profile consisting of two sampling points, A and B. Points A were located where the depth of water was around 0.5 m, about 10 m away from the actual waterline; points B were set more or less on the waterline (Fig. 2). Water temperature and salinity were measured with an autonomous STD Sonde (Bergen Sensor Data). A hand-operated sampler was used for the collection of zoobenthos and sediments. For collecting macrobenthos a sample core of sediment 10 cm long and 10 cm

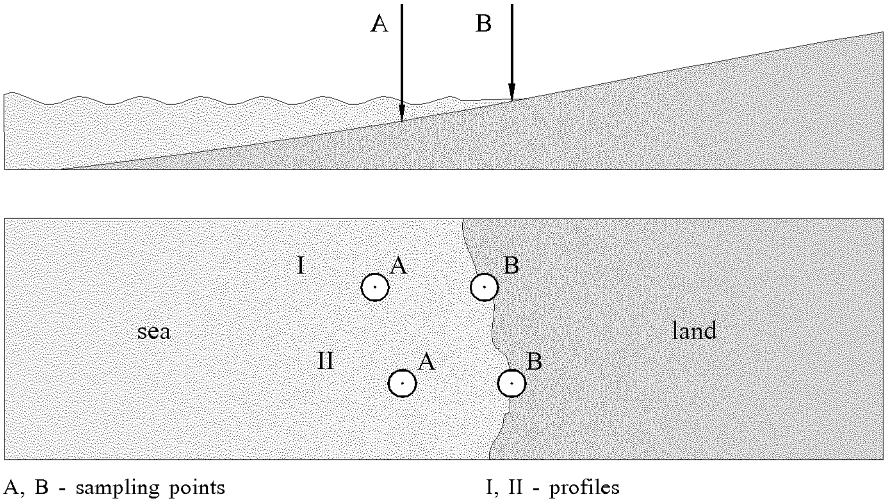


Fig. 2. Sampling strategy

in diameter was taken. A second core provided a subsample for meiobenthos analysis (a core 10 cm in length and 1 cm in diameter) and subsamples for determining the type and content of organic matter in the bottom sediments. The cores for macrobenthos and sediment determinations were divided horizontally into two 5 cm sections, an upper and a lower one. The meiobenthos cores were sliced horizontally into 6 segments: at 0–1 cm, 1–2 cm, 2–3 cm, 3–5 cm, 6–7 cm and 8–10 cm. The biological material was preserved in 10% formalin, and the sediment for the remaining analyses was frozen. In effect, four sediment cores for the macrofauna analyses were collected at each sampling station – two from points A and two from points B. The mean value from a station is the value calculated from all four cores; the mean values from points A and B were calculated from the respective pairs of samples. Macrofauna samples were strained through a 1 mm mesh metal sieve. The organisms identified under a low-power stereoscopic microscope were counted. After 3 months the organisms were dried on filter papers and weighed; the formalin wet-weight of the macrobenthos could thus be found. The macrobenthos abundance and biomass were calculated per 1 m^2. The meiobenthos analysis was carried out in accordance with the procedure described by Elmgren and Radziejewska (1989). Using the results obtained by Radziejewska *et al.* (1994) and a method proposed by Feller and Warwick (1988), the meiobenthos biomass (the formalin wet-weight) was computed. The abundance and biomass of the meiobenthos were calculated per 10 cm^2. The organic matter content in sediment was measured by drying, combusting and calculating differences in weights. Grain-size analyses of the sediment fractions were done by sieving methods, and the sediment type was determined using the standard Wentworth grain-size grade scale for sediments (Davis, 1972).

4. Results

Physicochemical parameters

In the regions investigated the average summer temperature of the water was 20.1°C and the salinity 7.25 PSU. There were three different sediment types: fine, medium and coarse sand (Fig. 3), medium sand being the most common. The sediment was found to be homogenous at both points (A and B) and layers (0–5 cm and 6–10 cm) at Mrzeżyno, Łeba, Lubiatowo, Dębki (fine sand), Kołobrzeg, Łazy, Jarosławiec, Ustka, Sasino, Władysławowo (medium sand) and Darłowo (coarse sand).

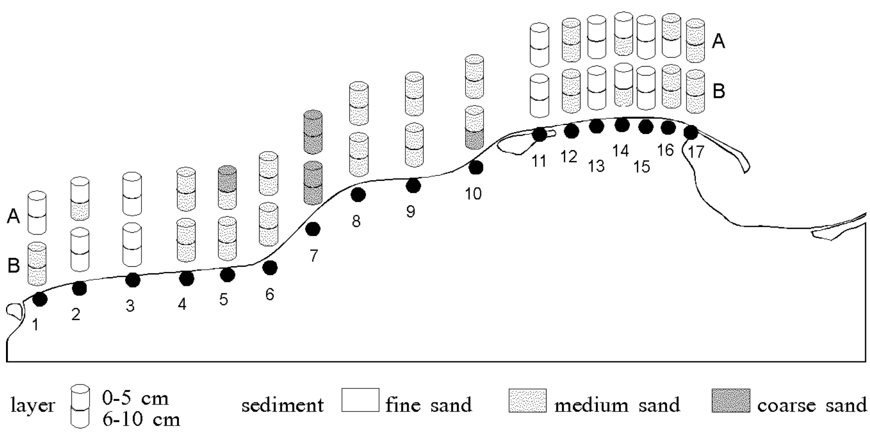


Fig. 3. Sediments along the Polish coast

The organic matter content in the upper and lower layers differed slightly at the two sampling points of particular stations (Fig. 4), except for the lower layer (6–10 cm) at point B at Mrzeżyno, where the maximum value (1.18%) was noted. The minimum value (%0) was recorded mainly in the upper layers at both points from Lubiatowo to Dębki. The average organic matter content was low (0.1–0.35%).

Macrozoobenthos

The most striking result was that there was no macrobenthos at the first seven stations on the western coast from Dziwnówek to Darłowo (Fig. 5).

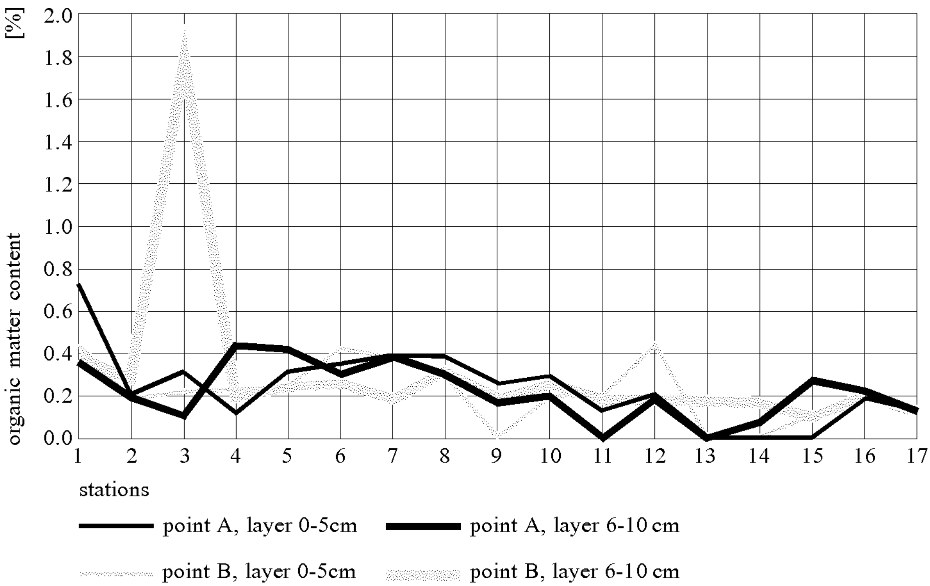


Fig. 4. Organic matter content in the sediment of the supralittoral

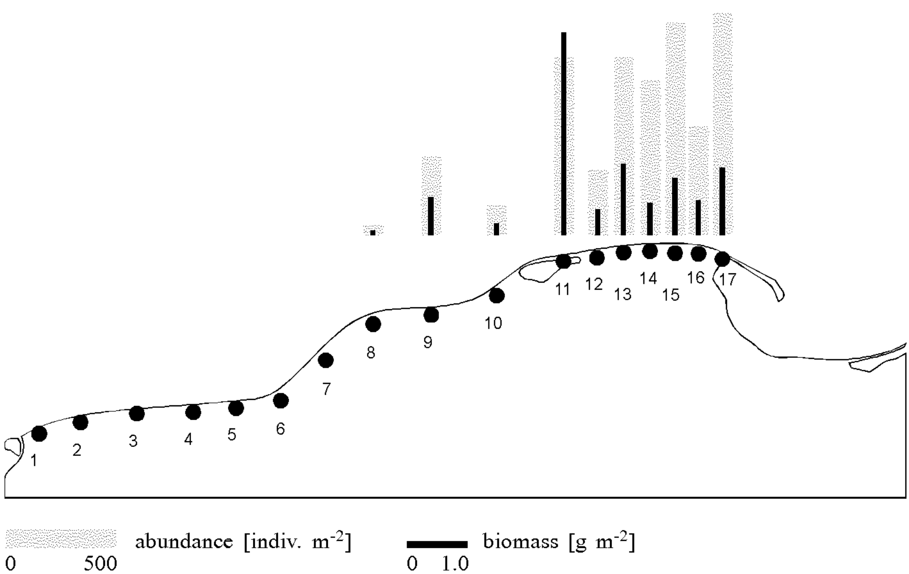


Fig. 5. Macrozoobenthos abundance and biomass

At the other stations three species of macrobenthos were found – *Bathyporeia pilosa*, *Eurydice pulchra* and *Sphaeroma hookeri* – which ranged in abundance from 31 to 987 indiv. m^{-2} and in biomass from 0.02 to 3.19 g m^{-2}. The most common species was *Bathyporeia pilosa*, which was found at all stations from 8 to 17 and made up to 60% of the total benthos biomass. *Sphaeroma hookeri* was found only at Łeba, where the maximum total biomass was recorded (3.19 g m^{-2}). *Eurydice pulchra* was found at four stations (9, 11, 12, 15). The highest mean macrobenthos abundance (876 indiv. m^{-2}) was recorded at Władysławowo, and the lowest (31 indiv. m^{-2}) at Jarosławiec, where the biomass was also very low (0.02 g m^{-2}).

At the stations where macrozoobenthos was recorded at both points A and B, the differences in abundance and biomass between the points were unremarkable except at Władysławowo. Noticeable and regular differences in the abundance and biomass of macrobenthos (Fig. 6) were recorded between the upper (0–5 cm) and lower (6–10 cm) layers at point A (depth of 0.5 m): the upper layer was always richer in animals. At point B (0 m depth) no clear trend was discernible.

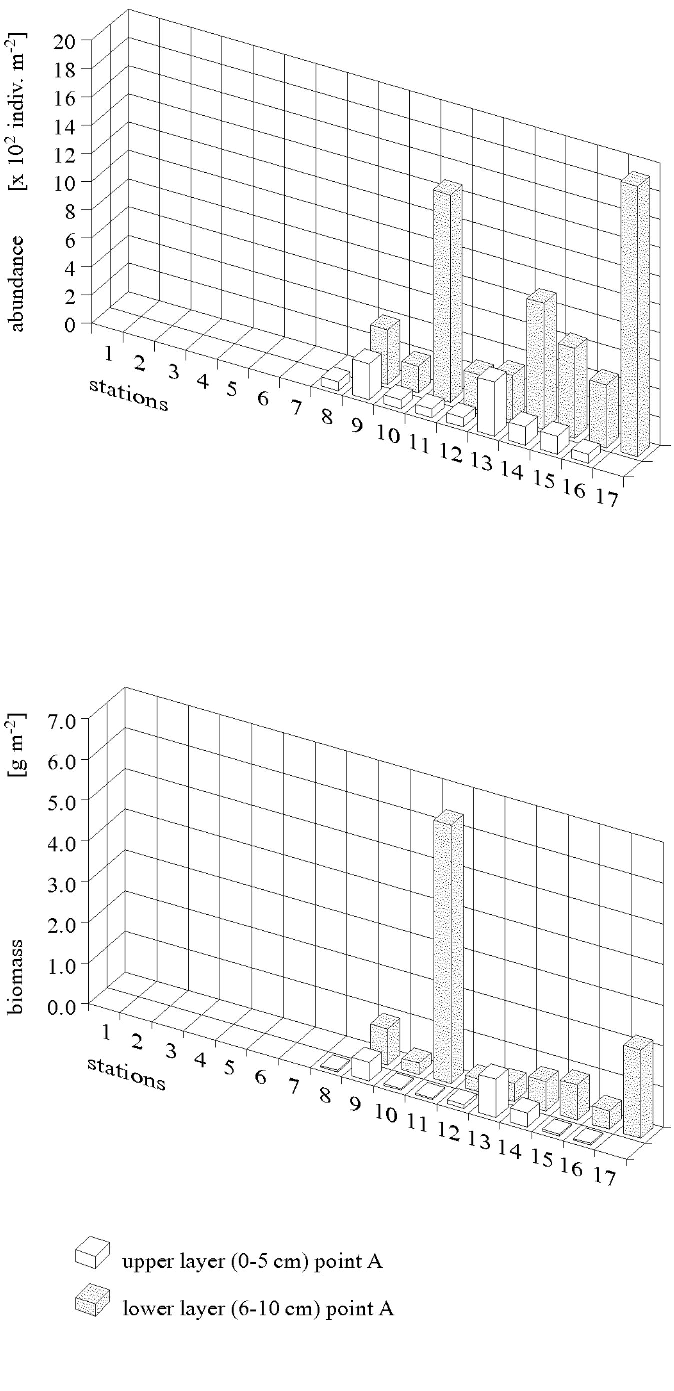
Meiobenthos

Eight meiofaunal taxa of higher rank were found (Fig. 7). Nematoda and Turbellaria were dominant as far as abundance is concerned. Harpacticoida and Gastrotricha also affected the abundance; the biomass, however, was strongly dominated by Oligochaeta. Halacaridae, Bivalvia, Amphipoda and Copepoda nauplii (all nauplii were assumed to belong to the Copepoda taxon) were recorded at very irregular intervals. Meiobenthos was present at all points (Fig. 8).

The greatest meiobenthos abundance was found at Łazy (the mean from four cores – 760 indiv. 10^{-1} cm^{-2}) and the lowest at Mrzeżyno (38 indiv. 10^{-1} cm^{-2}). The highest biomass (34.9 mg 10^{-1} cm^{-2}) was noted at Dziwnówek (because of the presence of Oligochaeta), the lowest (0.86 mg 10^{-1} cm^{-2}) at Ustka. At particular stations the abundance displayed clear differences between the five principal taxa (Fig. 9). In biomass Oligochaeta were dominant (up to 39 mg 10^{-1} cm^{-2}); the biomass (0.5–1 mg 10^{-1} cm^{-2}) and variability of other taxa were low.

Insignificant and irregular differences in the meiobenthos abundance and biomass were observed between the deeper (A, 0.5 m) and shallower (B, 0 m) points (Fig. 10). The meiobenthos was exceptionally abundant at station 6 (Łazy) owing to the presence of Harpacticoida, and the biomass was unusually high at station 1 (Dziwnówek) because of the Oligochaeta present there.

a


abundance [x 10² indiv. m⁻²]
0
2
4
6
8
10
12
14
16
18
20
stations
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
biomass [g m⁻²]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
stations
1
2
3
4
5
6
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16
17
upper layer (0-5 cm) point A
lower layer (6-10 cm) point A

b

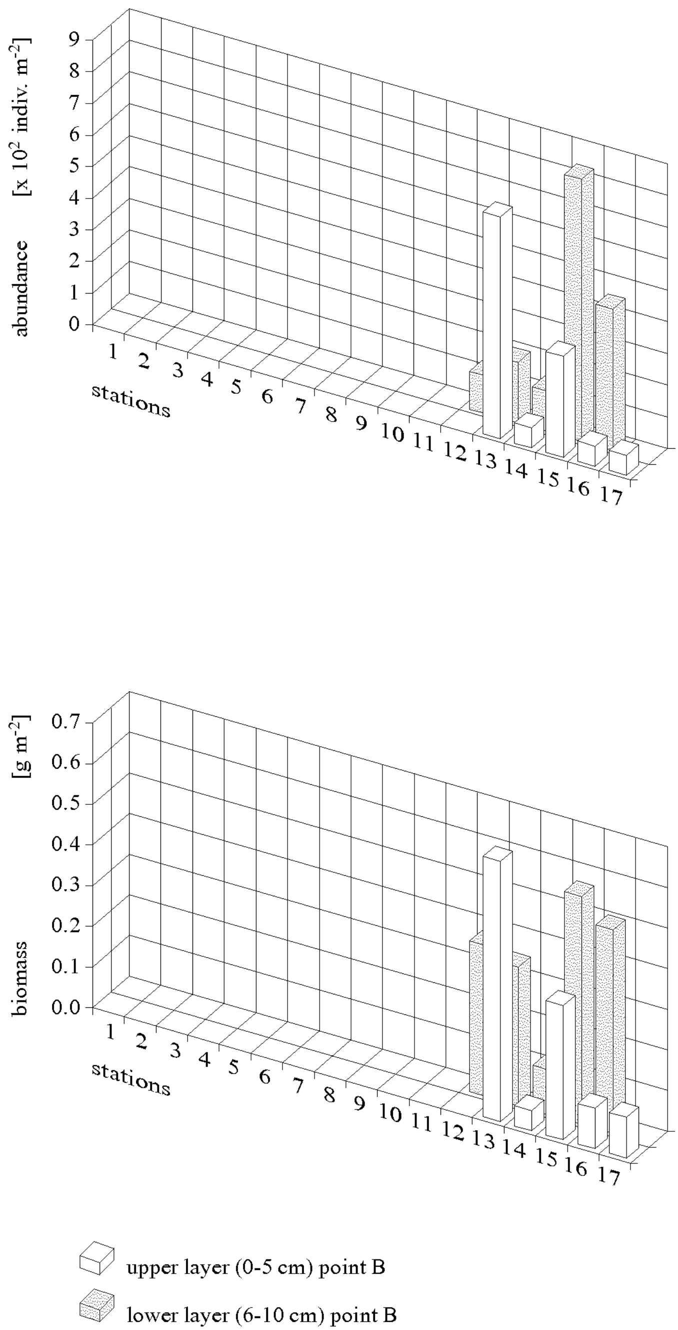


Fig. 6. Macrozoobenthos abundance and biomass – the differences between sediment layers: (a) at point A (0.5 m), (b) at point B (0 m)

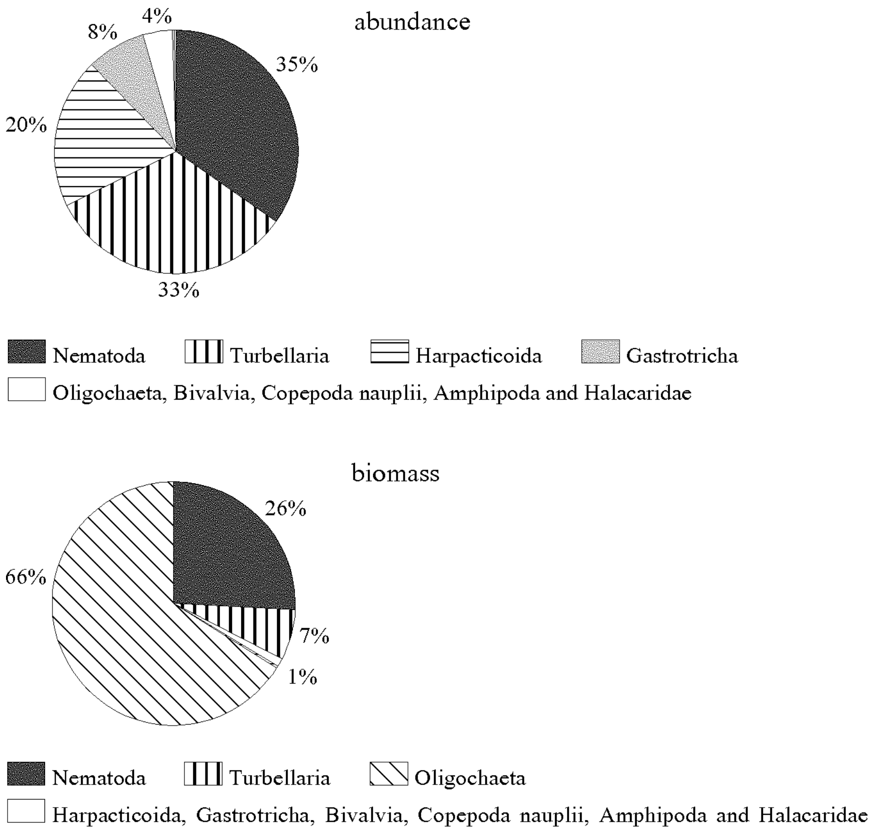


Fig. 7. Percentage of meiobenthic taxa

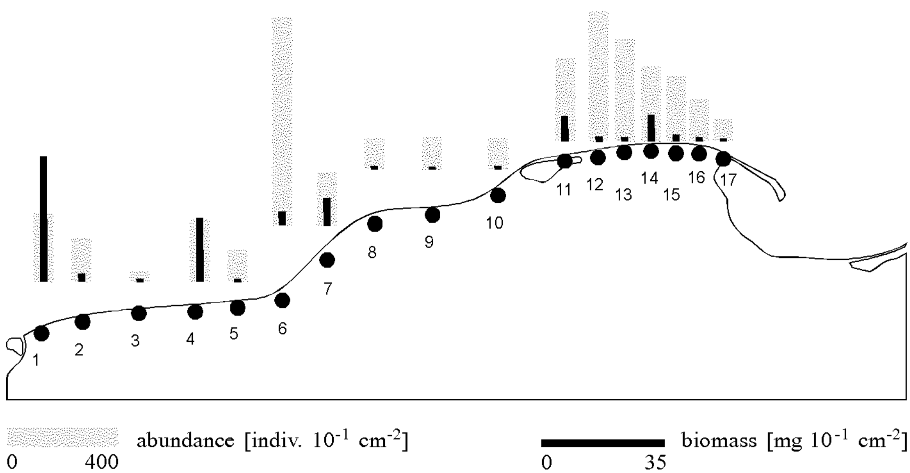


Fig. 8. Meiobenthos abundance and biomass

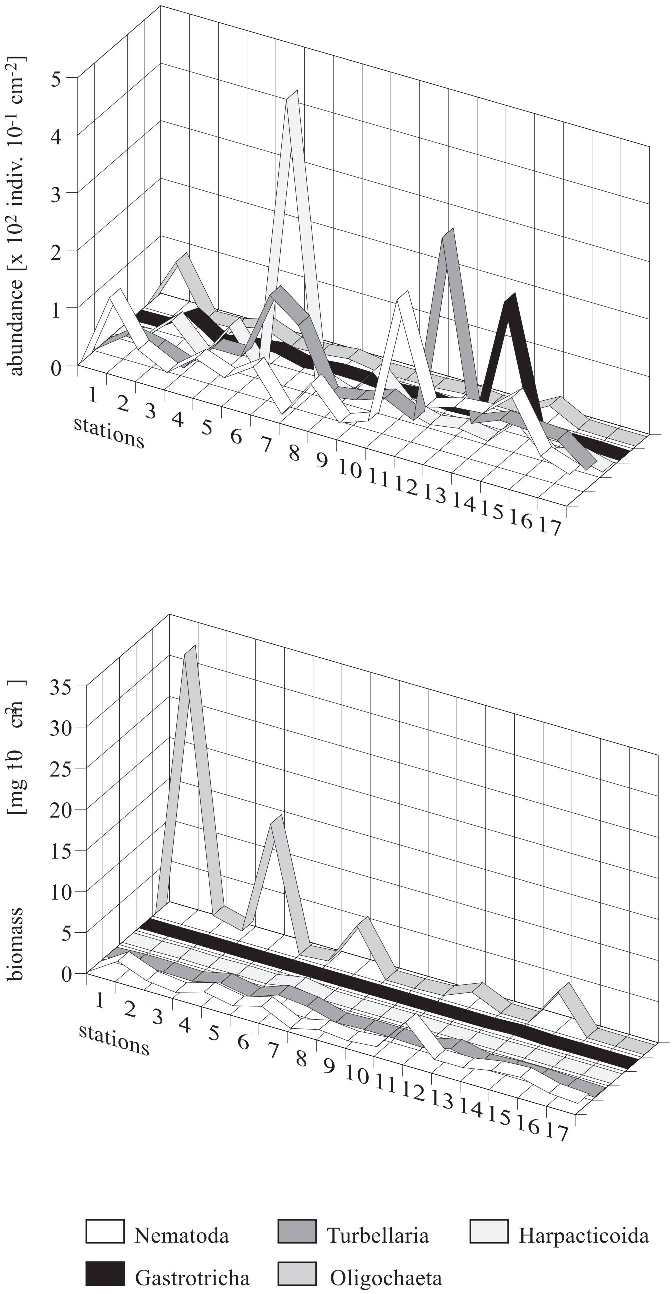
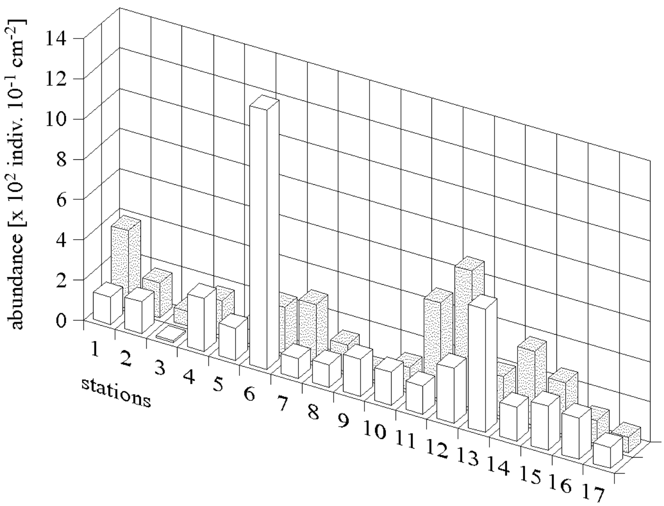


Fig. 9. Principal meiobenthic taxa



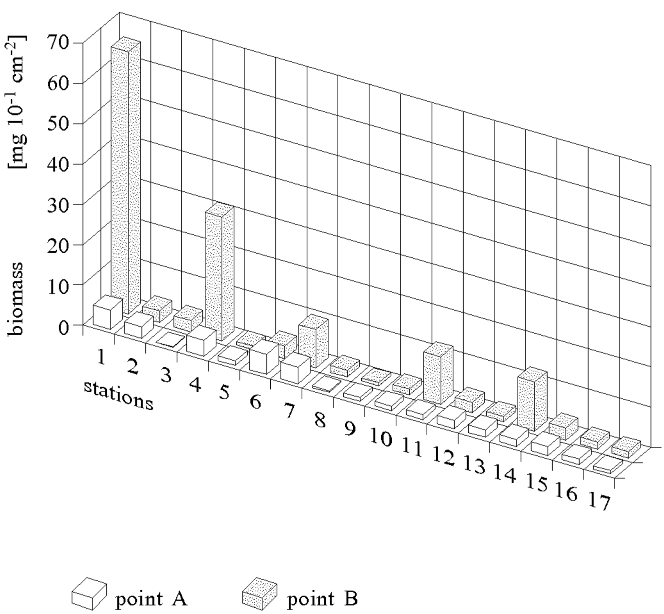


Fig. 10. Meiobenthos abundance and biomass at points A (0.5 m) and B (0 m)

The vertical distribution of meiobenthos was rather obscure: no clear pattern in its total distribution in the particular layers in the total core with regards to abundance and biomass was observed.

Macrobenthos:meiobenthos ratio

Meiobenthos occurred at both points (A and B) at each station (Tab. 1). Macrobenthos was not present at the first seven stations at point A or at the first eleven stations at point B, which made it impossible to compute the macro:meiobenthos biomass ratio. Generally the macro:meio biomass ratio was very small. At point B of every station it was less than 1. In three cases at point A the ratio was greater than 1 (Ustka 1.41, Łeba 5.17, Władysławowo 2.38).

Table 1. Comparison of macro- and meiobenthos biomass

Number of stations and name of place	Biomass (wet wt.) [g m^{-2}]				Ratio	
	Macrobenthos		Meiobenthos		Macrobenthos:Meiobenthos	
	A	B	A	B	A	B
1. Dziwnówek			4.76	65.07	*	*
2. Rewal			2.91	2.92	*	*
3. Mrzeżyno			0.08	2.72	*	*
4. Kołobrzeg			3.98	30.75	*	*
5. Sarbinowo			1.13	0.88	*	*
6. Łazy			5.06	3.16	*	*
7. Darłowo			4.02	9.51	*	*
8. Jarosławiec	0.04		0.43	1.62	0.09	*
9. Ustka	1.35		0.96	0.76	1.41	*
10. Rowy	0.31		1.09	1.4	0.28	*
11. Łeba	6.41		1.24	11.71	5.17	*
12. Sasino	0.41	0.37	2.01	2.61	0.2	0.14
13. Lubiatowo	0.99	0.88	1.98	1.39	0.5	0.63
14. Białogóra	0.78	0.22	1.81	12.19	0.43	0.02
15. Dębki	0.9	0.89	2.24	2.98	0.4	0.3
16. Karwia	0.49	0.59	1.37	1.7	0.36	0.35
17. Władysławowo	2.15	0.1	0.76	1.6	2.83	0.06

* since the macrobenthos biomass is 0, the macrobenthos:meiobenthos ratio cannot be computed.

5. Discussion

The results presented here show considerable variability in abundance, biomass and diversity of macro- and meiobenthos at the stations investigated along the Polish Baltic coast. With the exception of the seven westernmost stations, where macrobenthos is absent, the respective ranges of macrobenthos abundance and biomass were 31–987 indiv. m^{-2} and 0.02–3.19

g m^{-2} (formalin wet-weight). Żmudziński and Ostrowski (1982) reported the lowest biomasses and a number of stations with no littoral macrofauna in the same westernmost region. These authors (1982) also reported very high densities of *Bathyporeia pilosa* – 17 000 indiv. m^{-2} – at the eastern end of the Polish coast. As far as abundance is concerned, our results correspond with those obtained from similar sites in different geographical regions. An abundance of 153 indiv. m^{-2} is reported along the Mediterranean beaches of Sinai and Israel (Dexter, 1986/87) and of Egypt 66–822 indiv. m^{-2} (Dexter, 1989), and 1347 indiv. m^{-2} from the Red Sea (Dexter, 1986/87). In South Africa Koop and Griffiths (1982) obtained 0–1894 indiv. m^{-2}. On Portuguese beaches (Dexter, 1990) the abundance varied seasonally between 243 and 7382 indiv. m^{-2}. Biomasses of 0–15.37 g m^{-2} (dry weight) are reported from South Africa (Koop and Griffiths, 1982). Biomass values of 3.59 g m^{-2} (2462 indiv. m^{-2}) are reported from Pacific beaches and of 1.12 g m^{-2} (190 indiv. m^{-2}) from Caribbean beaches (Dexter, 1979). A comparison (Dexter, 1974) shows that the density of individuals on Pacific beaches was on average 7 times as high as on the Atlantic. The macrobenthos species composition of the Polish coast was very poor (maximum 3 species only). By contrast, 51 species were collected on the Red Sea beaches of the Sinai Peninsula (Dexter, 1986/87), but the number of species found along the beaches of South Africa varied from 0 to no more than 11 (Koop and Griffiths, 1982).

Meiofaunal numbers typically average 10^6 m^{-2} in marine sediments, and sandy beaches are no exception. They can display numbers as low as 0.05 $\times$ 10^6 m^{-2} or as high as 3 $\times$ 10^6 m^{-2} (Brown and McLachlan, 1990). Meiofaunal abundance and biomass are a function of a number of factors, such as grain size, wave energy, season and chemical conditions. So the results from different geographical regions are many and varied. The abundance obtained for the Baltic beaches were 1500 indiv. 10^{-1} cm^{-2} (Jansson, 1968) and 32–2250 indiv. 10^{-1} cm^{-2} (Jończyk and Radziejewska, 1984), for Scotland 203–4262 indiv. 10^{-1} cm^{-2} (Munro *et al.*, 1978), for Northern Ireland 295 indiv. 10^{-1} cm^{-2} (Boaden and Elhag, 1984). Results reported from the southern hemisphere (South Africa) include 2740–7270 indiv. 10^{-1} cm^{-2} (Dye, 1979), 55–584 indiv. 10^{-1} cm^{-2} (McLachlan *et al.*, 1977) and 40–650 indiv. 10^{-1} cm^{-2} in Western Australia (McLachlan, 1985). In Alaska the abundance of meiofauna was put at 400–4790 indiv. 10^{-1} cm^{-2} (Feder and Paul, 1980) and in India at 2270–6116 indiv. 10^{-1} cm^{-2} (Ansari and Ingole, 1983). The results obtained in this work (38–780 indiv. 10^{-1} cm^{-2}) are in general of the same order of magnitude, though in its lower range.

Information about biomass is scarce. For exposed sandy beaches of South Africa the standing crop biomass given by Dye and Furstenberg (1978) was about 1 g m^{-2} d.w. and 3–4 g m^{-2} d.w. by Koop and Griffiths (1982). Munro *et al.* (1978) reported 0.2 g m^{-2} d.w. for Scottish beaches but only 0.02 g m^{-2} for tropical Indian beaches. On Australian beaches the meiofauna biomass varied between 0.15 and 0.52 g m^{-2} d.w. (McLachlan, 1985). The meiobenthos biomass in the Polish coastal zone of the Baltic Sea covers a wide range of values (0.02–18 g m^{-2} d.w.). Oligochaeta influenced the total biomass noticeably (66%). However, because of their low abundance the total biomass was as high as that at only a few stations, whereas the biomass of other taxa displayed rather a low biomass (0.1–0.2 g m^{-2} d.w.).

The basic meiofaunal taxa are recorded independently of geographical region. Nematoda are usually dominant where abundance is concerned (Harris, 1972; Dye, 1979; Koop and Griffiths, 1982; McLachlan, 1985). Harpacticoida, Turbellaria, Oligochaeta and Gastrotricha are found on most beaches but the numerical relationships between them vary (Jansson, 1968; Gray and Rieger, 1971; Feder and Paul, 1980; Orren *et al.*, 1981; Jończyk and Radziejewska, 1984).

In accordance with local enviromental factors, the macrobenthos:meiobenthos ratio changes very considerably. The values reported for intertidal sandy beaches (South Africa) are 1 (Koop and Griffiths, 1982) and 0.2, 3.3, 6.0 (McLachlan *et al.*, 1984) but can also be as high as 25.1 on sandbanks of the tidal flats on the south-west coast of France (Castel *et al.*, 1989). The results presented in this work show that in terms of biomass the macrofauna:meiofauna ratio varies over a wide range. Much of the variability is due to the macrobenthos. It seems likely that in the biota of sandy beaches the meiobenthos is more stable than the macrobenthos.

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