

BENTHOS OF THE NORTH SEA: ABLE TO RECOVER OR DESPERATELY LOST?

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1. Introduction

The living creatures of the sediments (*i.e.* benthos) in the North Sea have not been a large public concern in the past. It was thought that the sea was one big reservoir where all material could be dumped without too much damage because most substances are dispersed and quickly disappear from view (most likely into the bottom). However, it has been shown, e.g. in the Quality Status Report of the North Sea (North Sea Task Force, 1993), that life in the sea bottom is especially influenced by human activities in the coastal zone, and that this in turn influences all levels of the ecosystem. Indeed the benthos, the plankton and the nekton (e.g. fish) are in continuous interaction with each other and with the abiotic environment.

The flux of energy and organic matter through ecosystems is the most important driving force of these systems. Benthic organisms, especially in coastal waters, play a crucial role in the functioning of the ecosystem, for example in the control of phytoplankton and macroalgal blooms, and in the exchange of materials between the sediments and the water column. Within the plankton, primary production needs sufficient nutrients (nitrogen, phosphorus), which are formed within the sediments through mineralisation of the sedimented organic material. The benthos has no primary production of its own (except in intertidal areas and in coral reefs) and completely depends for its organic matter on sedimentation from the water column.

The structural characteristics of the benthic communities have been relatively well documented in the last 20 years. The state of the art is summarized in the Quality Status Report of the North Sea, Subregion 4 (North Sea Task Force, 1993).

The coastal zone is the most vulnerable since environmental impacts of human activities (e.g. fishing, industrial operations, dredging etc.) and reductions in benthic biodiversity are most likely to occur there.

However, our knowledge of patterns of secondary production of the benthos is limited because of the tedious species-by-species methods of estimating production (in contrast with photosynthesis for primary production). Effects of e.g. eutrophication on primary production are well documented whereas the impact on production of higher trophic levels are far less understood.

2. Belgian coastal subtidal zone

The Belgian coastal zone used to be subdivided in the early eighties in a polluted eastern zone with muddy sediments near the mouth of the Westerschelde and a less polluted western zone near the French border (Vincx and Herman, 1989). The mud content in the eastern zone shows significant seasonal fluctuations; this fluctuation has no effect on the structure of the meiobenthic communities. Despite the strong relationship between the characteristics of the meiobenthic communities and the sediment structure, the influence of the Westerschelde is reflected in a clear decrease in trophic, family and species diversity of meiobenthic communities.

Benthic communities are very well suited for monitoring purposes because they do not migrate very much, are abundant throughout the year and show an integrated picture of long-term pollution. In Figure 1a, a typical North Sea benthic community is illustrated and the arrows indicate the important trophic interactions. In Figure 1b, the impoverished situation of parts of the Belgian coastal zone is characterized by benthic communities which consist mainly of only a few species of deposit feeders. The richer situation is found in the sandier sediments where the redox potential becomes negative

only at a sediment depth of a few centimetres. Here the zoobenthic community consists of a high number of individuals, species, and trophic levels from the different size classes of the faunal communities within the sediments. The poorer situation is typical of the muddy substrates off the Belgian coast where dissolved oxygen is depleted within the top few millimetres (high turbidity of the water column, low diversity and no complex higher trophic levels).

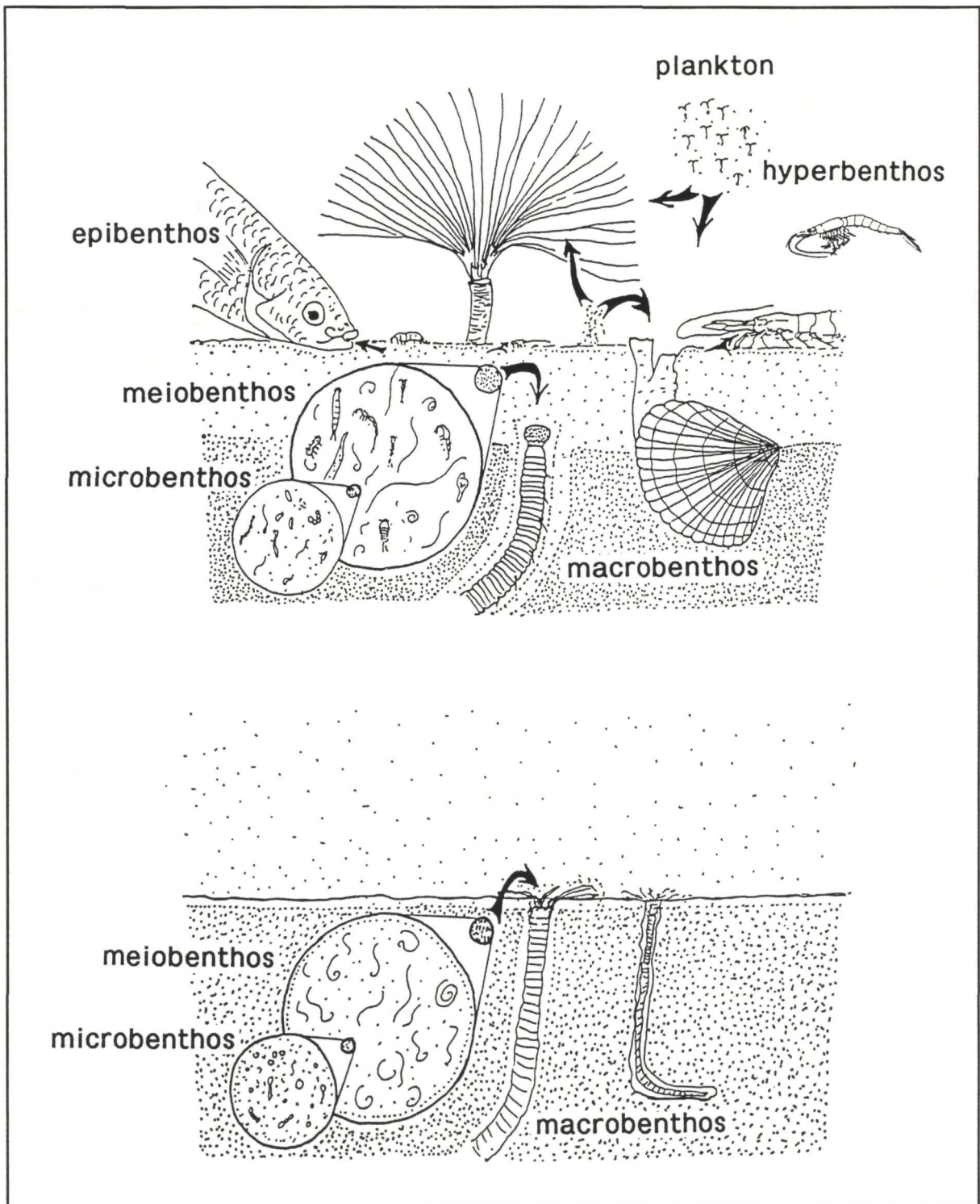


Fig. 1a - (top) *Typical benthic foodweb for sandy sediments in the coastal subtidal zone of the North Sea (adapted after Platt et al., 1983).*

Fig. 1b - (bottom) *Impoverished benthic community for silty (polluted) sediments in the coastal subtidal zone of the North Sea.*

In recent years this typical division between east and west coast has become less obvious since impoverished communities are found along the whole coast, depending on the siltation of the sediments. However, comparison of data on interstitial fauna of 1977-1985 with data from 1993 indicates that its recovery is possible as long as non-polluted areas for recruitment are sufficiently close. Nevertheless, the huge amount of nutrients in the coastal waters cause severe stress on the benthic communities since dissolved oxygen is quickly removed from the sediments.

The following example shows that recovery of the benthic communities is possible as long as the oxygen concentrations are enhanced and when the sediment conditions become less 'toxic'.

Example 1: MEIOBENTHOS

Meiobenthos consists of microscopic animals which live in the bottom of the sea and which are shown to be good indicators of pollution studies (Vincx and Heip, 1987). Within the meiobenthos, nematodes are always dominant (>90%).

In general, the composition, distribution and biomass of the North Sea meiobenthos is well known (*cf.* Heip *et al.*, 1990; Huys *et al.*, 1992) but the role of the meiobenthos within the food web is not well documented. The numerical abundance of the meiofauna indicates that this size category of organisms (< 1 mm) is important in the total energy flow of marine benthic ecosystems. However, their contribution as a food source is poorly understood. There is a general agreement that their main importance lies in an enhancement of decomposition processes by stimulating microbial activity as a result of grazing, excretion and bioturbation. The bacterivores and deposit feeders especially may alter the abundance, metabolic activities and composition of the microbial community, which in turn affects sediment biogeochemistry.

It is known that grain size, oxygen and chemical substances determined by the redox reactions, pH, salinity, temperature and pollution have a strong structuring impact on the meiobenthos. The abiotic environment is built up by the interaction of these factors. The synergistic impact of some factors stresses the complex character of the system. The reaction of the meiofauna with each of the components of the abiotic environment is difficult to estimate and can only be tested by experiments. Nevertheless, as the meiofaunal assemblage lives in, and is adapted to, the abiotic, interstitial environment, a detailed knowledge of the interaction of the meiofauna with its abiotic environment as a whole is needed.

This study is part of the project the Belgian Impulse Programme *Marine sciences* of the Federal Office for Scientific, Technical and Cultural Affairs.

Two stations along the Belgian Coast were selected in order to test extreme habitat conditions (Figure 2). Station 702 is situated near the mouth of the Westerschelde and station 115 is located on the western part of the Belgian coast, near the French border. Original data from both stations will be presented from June 1993 (Steyaert *et al.*, unpublished) and compared with data from the period 1977-1985 (Vincx and Herman, 1989).

Samples are taken by subsampling a box-corer on board the R.V. *Belgica*. Subsequently, the cores are vertically subdivided into 1 cm slices and used for the determination of meiofauna density, bacterial density, sediment composition, redox potential, organic carbon, pigment and nutrient concentrations (Steyaert *et al.*, unpublished).

Station 115 has extremely high numbers of meiobenthos (2898 individuals/10 cm²) in comparison with station 702 (791 individuals/10 cm²) (Figure 2). This difference in density is the result of the complex interaction of biological, physical and chemical factors. Grain size has a direct impact on structural and spatial conditions and an indirect influence on the chemical and the physical environment (Heip *et al.*, 1985). Sandy sediments (median 200 µm) are in general believed to be the most attractive habitats. In these sediments the interstitial spaces - the habitat for most meiobenthos - are most conspicuous in comparison with finer or coarser sediments (Marcotte, 1986).

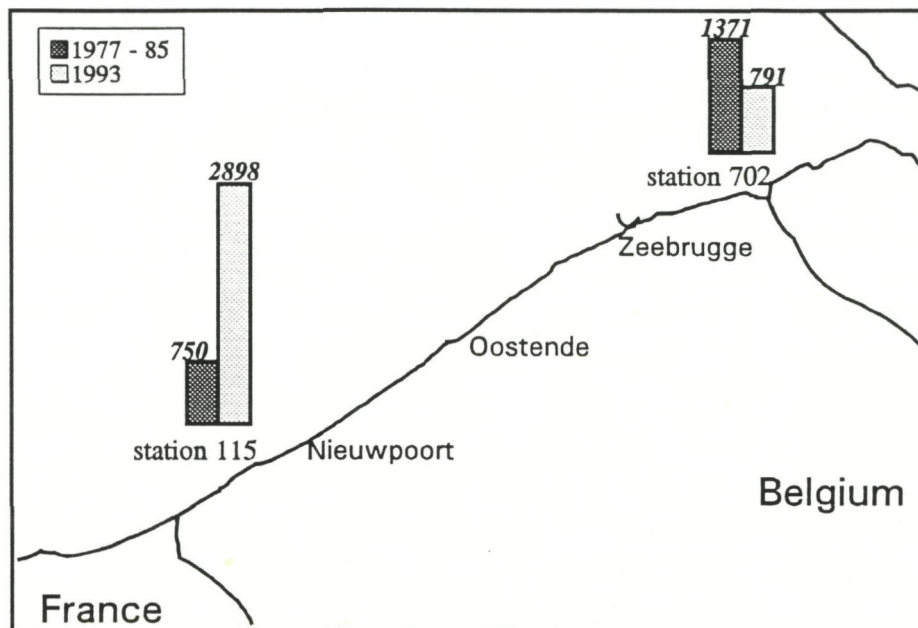


Fig. 2 - *Densities (individuals/10 cm²) of meiobenthos in two coastal stations along the Belgian coast.*

The sediment in station 702 consisted in 1993 mainly of fine sand with a median diameter of the total sediment fraction of 188 μm ; the silt and clay fraction is less than 10%. In contrast station 115, with a fivefold higher meiobenthic density, has a rather silty fine sandy sediment (median of the total sediment fraction is 47 μm ; silt and clay fraction is 97%).

A second strong structuring parameter is the oxygen supply, as most meiobenthic animals have very high oxygen demands. As a consequence they are restricted to the uppermost oxic layers of the sediment where free oxygen is available. Apart from these oxygen reducers, there exist organisms which can generate energy from the reduction of other chemical species. This will result in a typical species assemblage around the oxic, the oxidized, the RPD (Redox Potential Discontinuity) transition zone and the reduced layer. The overall reducing and oxidizing capacity of the sediment is given by the redox potential.

Nematode density, bacterial density, redox potential, pigment concentration - as a quantitative indicator for algae -, nutrients and organic carbon are measured in a vertical profile at both stations (Figures 3 and 4).

In station 702, the RPD layer is situated at a depth of approximately 3 cm. The oxygenated layer has higher numbers of individuals in the nematode, bacteria and algae communities. The organic carbon concentration, which gives an indication of the overall present energy, shows maximum values at 3 cm depth. The downward and upward gradients of nitrate, nitrite, ammonia, phosphate and silicate are directly coupled to, and the result of, the geochemical cycles. At station 115 the redox potential is negative over the whole sediment depth, which does not seem to have a negative influence on the numbers of nematodes and bacteria. The question of whether the species present are especially adapted to these anoxic conditions is still under investigation.

Comparison of recent data with earlier studies

Figure 5 demonstrates positive evolution to an enriched meiobenthic community (station 702) around the mouth of the Westerschelde, as evidenced by both enhanced diversities and abundances. On the other hand the meiofauna of the western part of the Belgian coast (station 115) shows a clear decreasing trend, probably related to the finer sediments. Lower densities as well as a lower diversity have been demonstrated.

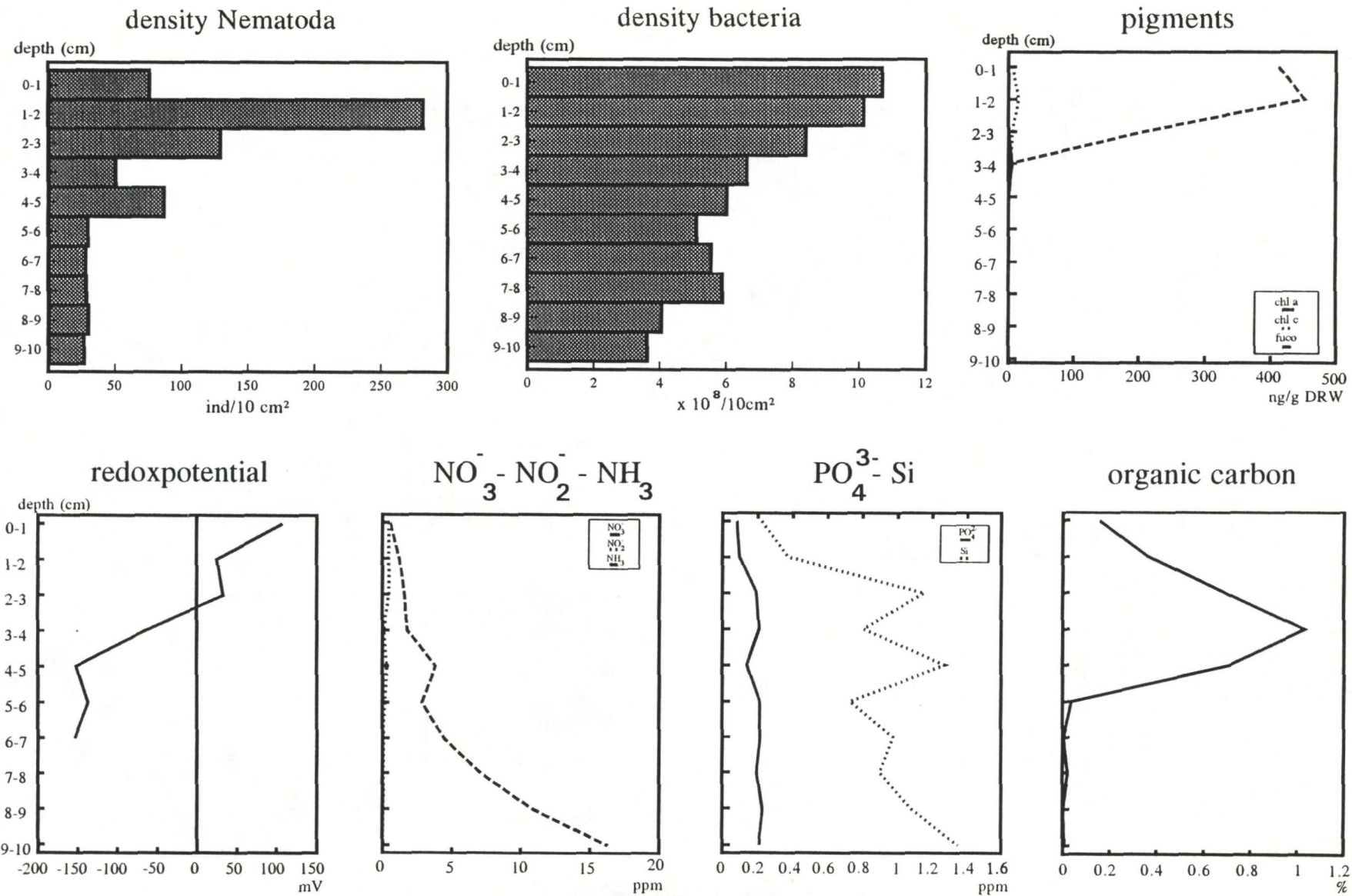


Fig. 3 - Vertical profiles within the sediment of densities of nematodes and bacteria versus environmental factors (pigments, redox potential, N-nutrients, phosphates, silicates and organic carbon) at station 702 (June, 1993) (Steyaert et al., unpublished).

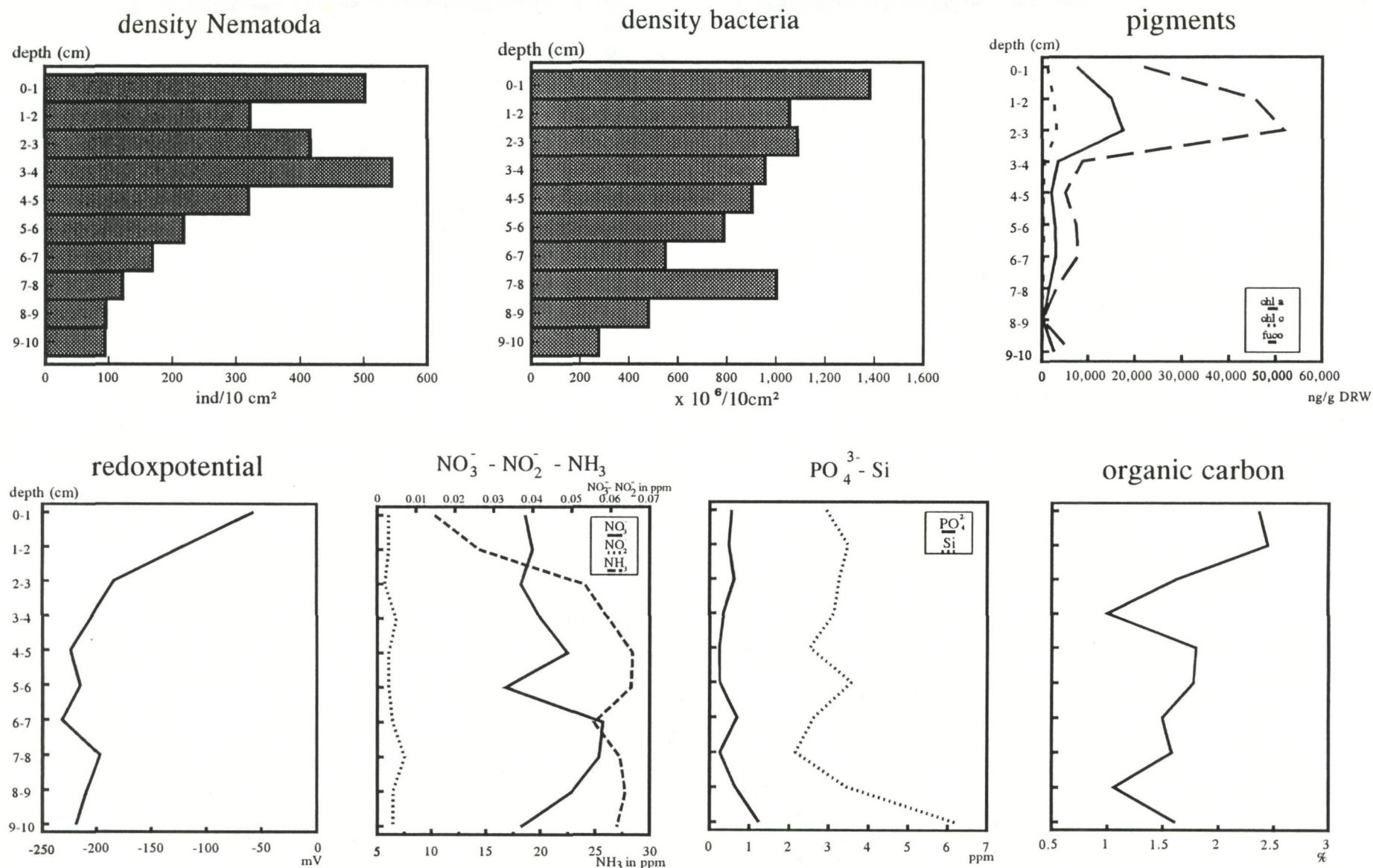


Fig. 4 - Vertical profiles within the sediment of densities of nematodes and bacteria versus environmental factors (pigments, redox potential, N-nutrients, phosphates, silicates and organic carbon) at station 115 (June, 1993) (Steyaert et al., unpublished).

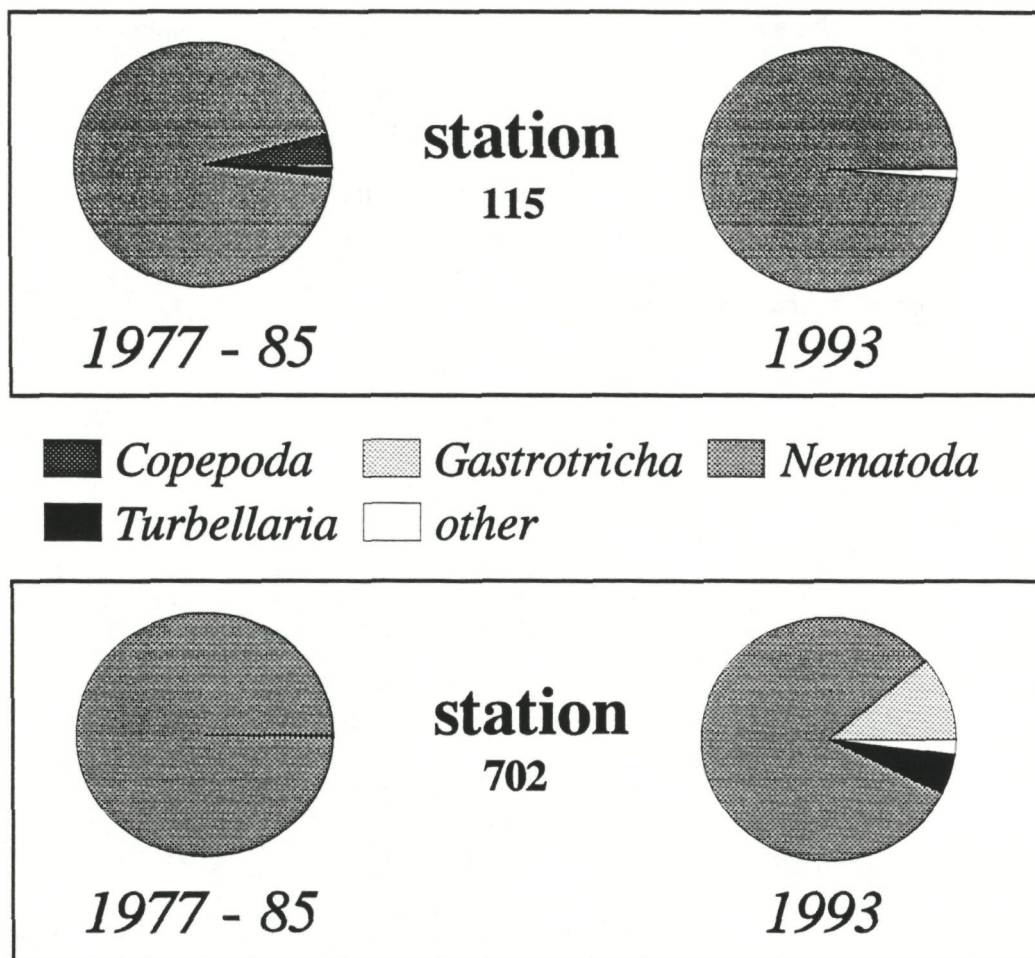


Fig. 5 - Comparison of meiobenthic composition in station 115 and station 702 of the periods 1977-1985 and 1993 (Steyaert et al., unpublished).

The extreme changes along the Belgian coastal zone are probably the result of the high sediment transports (Anonymous, 1993). This stresses the fact that recovery of the interstitial fauna is possible as long as non-polluted areas for recruitment are sufficiently close and water quality becomes better.

Example 2: HYPERBENTHOS

The hyperbenthos is the association of animals living in the water layer close to the seabed. It includes all bottom-dependent species and life history stages (mainly crustaceans and fish) which perform, with varying amplitude, intensity and regularity, seasonal or daily vertical migrations above the sea floor. Since it is not possible to sample hyperbenthic animals quantitatively with conventional techniques used in zooplankton or macrobenthos research, the study of the hyperbenthos is often neglected even in comprehensive ecological studies. Still, mobile hyperbenthic animals are an important component of the biomass of coastal regions. They contribute substantially to the diet of fish. They can be significant predators, structuring zooplankton populations, and can have an important role as grazers of organic matter and in the coupling of benthic and pelagic food webs (cf. Figure 1a).

A hyperbenthic sledge which consists of a heavy metal frame carrying two pairs of nets (3 m in length, mesh sizes of 0.5 mm on the right side and 1 mm on the left side) samples the hyperbenthos from 0 to 50 cm and from 50 to 100 cm above the bottom, respectively. The sledge is equipped with an automatic opening-closing mechanism, current meters and an odometer.

Under the Impulse Programme *Marine Sciences* an intensive sampling campaign has been organised in the North Sea and the first results along the Belgian coast (Dewicke and Mees, unpublished) show that a typical east-west gradient along the coast is present, as was found for the meiobenthic communities. Along the west coast the numbers of hyperbenthos reach the very high numbers found in the maximum turbidity zone of estuaries (Mees *et al.*, 1993) (Figure 6). Their temporal fluctuations and possible recovery has been under investigation since the summer of 1994.

hyperbenthos - september 1993

average density per station

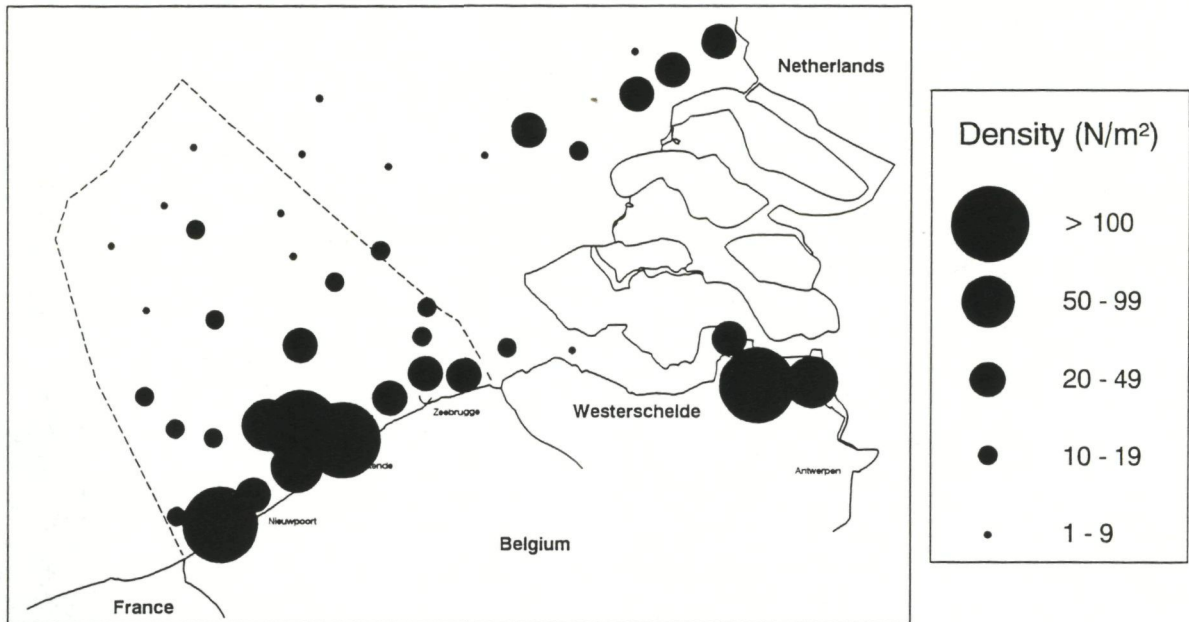


Fig. 6 - Average density of hyperbenthos in the Southern Bight of the North Sea and the Westerschelde (Dewicke and Mees, unpublished).

Acknowledgements

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