Eco-morphodynamics of the North Sea seafloor and macrobenthos zonation.

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Abstract

In order to assess the responses of marine benthic foodwebs to disturbances of the seafloor, we must understand the relation between the fauna and the morphology and dynamics of the sediment. At present we are yet still lacking dependable and detailed measurements to evaluate this interaction. In our paper we interlink the knowledge on seabed morphology, morphodynamics, sedimentology and ecology. During two cruises we collected data on seabed morphology (multibeam echo sounder, side-scan sonar) and benthos and sediment (boxcore). Small, distinct differences that can't simply be attributed to sediment characteristics were found, for example, in the fauna composition on the top of sand ridges as compared to the troughs. Thus, we show a relationship between benthic life and seabed morphology.

1. Introduction

Ecologically justified management and use of the North Sea has become more and more important during the past years. To improve management opportunities a proper integration of field management and knowledge regarding the ecomorphodynamics of the North Sea is required. Currently, relatively few suitable measurements have been made (Degrear, 2000, Komarova and Hulscher, 2000) on the actual morphodynamics of the seafloor, resulting in a lack of reliable high-quality data. The interaction of morphodynamic processes with benthic fauna of the seafloor has been subject to little research (McLachlan, 1996; Kenny et al., 2000; Brown et al., 2000). However, morphodynamic processes are an essential factor influencing the suitability of the habitat for colonization by benthic fauna (McLachlan, 1996; Newell et al., 1998; Ólafsson et al., 1994; Trush et al., 1992). Moreover, no consensus among scientists has been reached on routine application of scientific methods (Brown et al., 2000).

The lack of accurate measurements and a lack of clarity about the relative importance of different natural processes in affecting benthic macrofauna hamper evaluation of existing knowledge. Although it is generally accepted that a relationship between physical parameters including sediment composition, and biological parameters, including the organisms living on or in the sediment (e.g. Gray, 1974; Rhoads, 1974; Snelgrove and Butman, 1994), most studies have focused on the integration of bathymetry and sediment structure measurements with biological communities in order to create a habitat map of larger areas (e.g. Eckman et al., 1981; Todd et al, 2000; Gordon et al, 2000). Only few investigations have addressed the effect of small-scale morphological features on benthos zonation (Baptist et al., submitted). In an attempt to extent our knowledge the Delft Cluster Programme "Coast and River" of which the presented work is a part, was established with a section about 'Ecomorphodynamics of the North Seafloor' (Baptist et al., 2000, 2002). The programme aims at a process-based approach of short and long term dynamics of small- and large-scale phenomena on the seafloor. In the present study we focus on 'small-scale' (scale of meters) morphological structures in order to find out whether there are structural differences in macrozoobenthos composition between the troughs and the on average only 1.5m more elevated crests of these features.

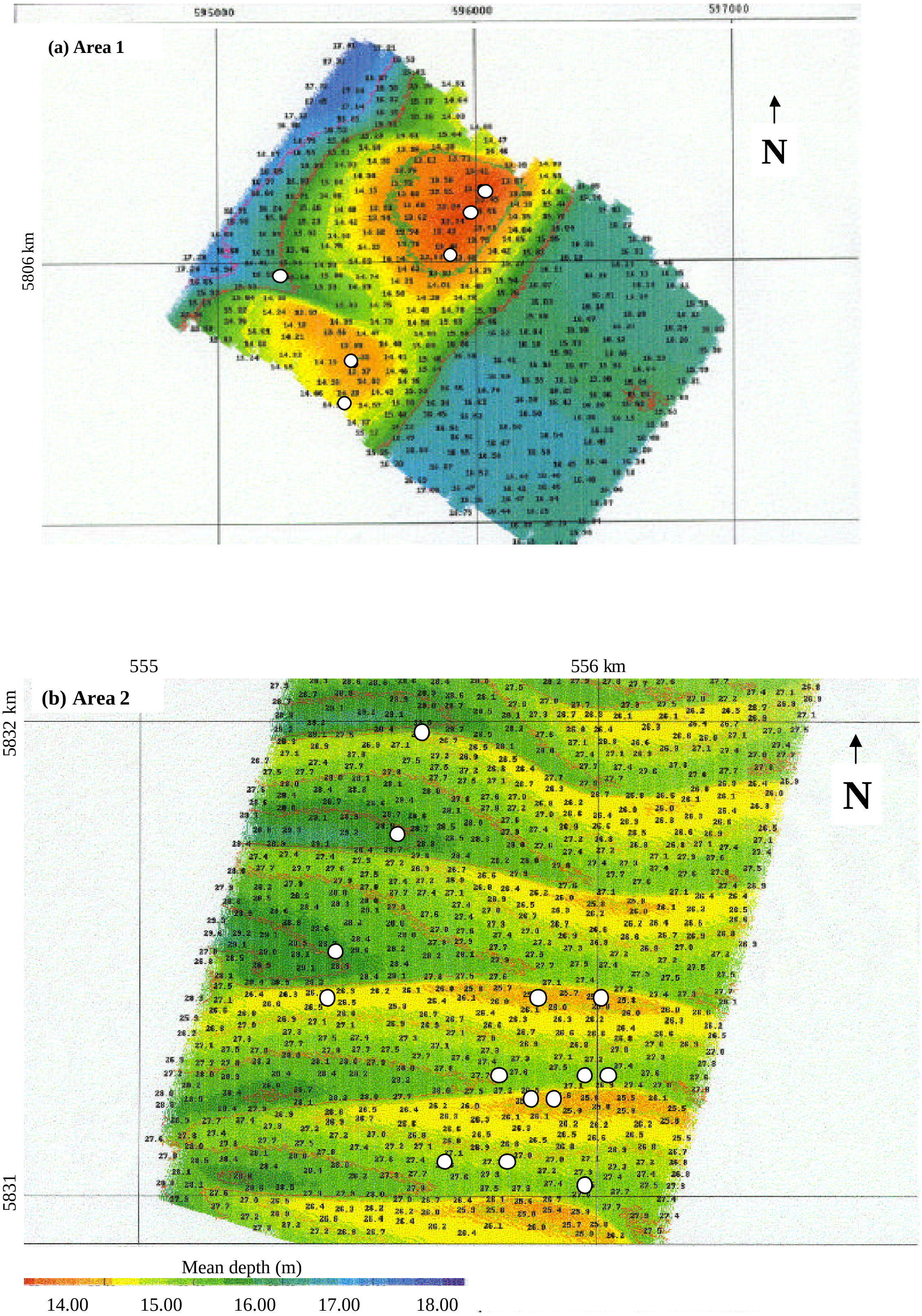

Figure 1: Simrad EM 3000 chart of the sampling areas (uncorrected for depth). Colours illustrate the relief of the sea floor. Black circles represent sampling stations. (a) In area 1 sand-waves are seen; (b) Area 2 consists of a shoreface-connected ridge and swail.

2. Method

2.1 Sampling area and sampling

Two research areas, which are characteristic of the Southern Bight of the North Sea, are investigated in this study. One area represents a coastal environment, the second area represents a large portion of the inner shelf (Alphen and Damoiseaux, 1987; fig. 1). Seafloor morphology and morphodynamics of the research areas are characterized by time series of measurements by multibeam echosounder, which are collected every six months. Sedimentary structures and composition of fixed sample locations are monitored simultaneously in 10-cm diameter core samples from boxcores. Grain-size measurements are collected from untreated samples in a Malvern 2000 laser particle-sizer after sieving off the fraction > 2mm, which consists almost entirely of shell material. Each station was classified either as a crest- or a trough station depending on its position in the morphodynamical structure. Boxcore samples were analysed for macrofauna.

The first area (1 x 2.5 km, Fig. 1a) comprises a shoreface-connected ridge and swail, 15 km West of Zandvoort. The waterdepth in this area ranges from 15 to 18 m. Ridge morphology is characterized by a steep seaward flank and a moderate slope of the landward flank. Bedforms on the shoreface-connected ridge consist of asymmetric sandwave-like features (wavelength 700-800 m) with superimposed megaripples (wavelength 4-6 m). The second research area (1 x 5 km, Fig. 1b) is situated ca. 50 km West of IJmuiden at a waterdepth of 26 to 30 m. The seafloor morphology is dominated by East-West oriented asymmetric sandwaves with an amplitude of 1-3 m, and a wavelength of approximately 200 m. The sandwaves are covered with megaripples with a wavelength of 10-15 m and an amplitude of < 0.5 m.

2.2 Statistical analysis

The similarity of the species composition and abundance was compared among and within the two areas and the two sampling seasons. Only species of which more than 2 individuals were found were used. The statistical program PRIMER 5 was used for analysis of the data set. Data were square root-transformed. A triangular similarity/distance matrix was calculated using the Bray Curtis similarity index.

3. Results

3.1 Sediment

Area 1: The median grain-size range of the seafloor sediments in this area was 300 to 366 µm for March 2001 and sediments were fining seaward. Boxcore samples showed a homogeneous sediment structure and bedforms indicate wave influence. No difference in sediment structure was observed between cores taken in March and September 2001.

Area 2: The median grain-size range is 274-304 µm for March 2001 with no systematic variation between sand wave crests and sandwave troughs. In March 2001 sediments generally lack sedimentary structures, however, cross-bedding was observed at some sandwave crests and burrows as well as living *Echinocardium cordatum* (sea urchin) in some sand wave troughs. Bioturbation is more prominent in September 2001. In contrast to March 2001, burrows and specimens of *Echinocardium cordatum* were observed at sandwave crests, and semi-vertical mollusc burrows, probably caused by *Donax vittatus* (banded wedge shell), in sandwave troughs.

3.2 Macrobenthos

The analysis shows four main clusters (Figure 1). Interestingly, the two sampling areas can be clearly distinguished, as can the two sampling periods. The leftmost cluster (cluster 1) combines crest-stations from area 2 where no macrobenthos was present in the samples. Cluster 2 combines trough stations from area 2. Cluster 3 comprises all March-samples from area 2 and cluster 4 spans all results from area 1 and one trough station from area 2. This illustrates that a difference in species composition was found between sampling area 1 and 2. Small but distinct differences were found in the benthic fauna composition between the

crests and troughs. Three of the species found regularly at the trough stations were absent at crest stations (Table 1). For sampling area 2 a differences in species composition and abundance was found between sampling seasons (). In contrast to area 1, where all samples contained benthic animals, in 54% of the crests samples of area 2 no benthic individuals were found. The species composition was very homogeneous in area 2 for both crests and troughs (similarity index crests: 100%; troughs: < 66%) in the September samples. During March, however, similarity of all samples is high (similarity index: 60%) with no clear clustering of crests or trough samples. In area 1 the clustering is less clear as compared to area 2.

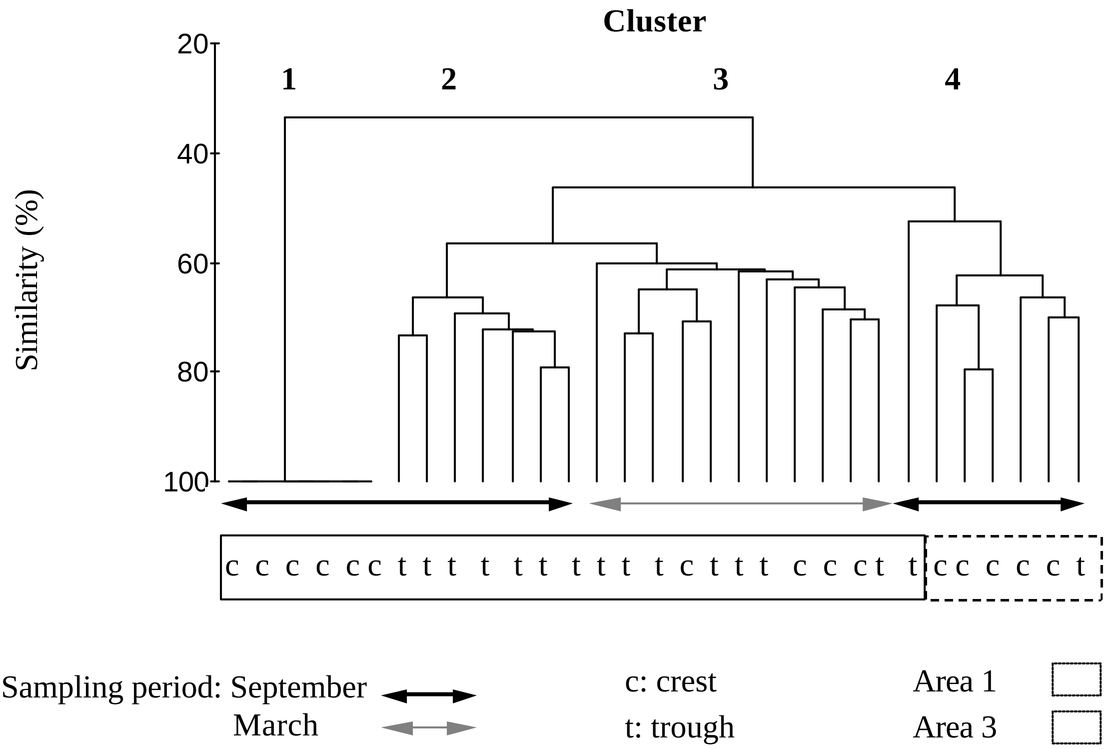

Figure 2: Results of the cluster analysis. The shaded areas indicate the sampling area (1 or 2). The coloured lines point out the sampling period in which the samples were taken (March or September 2001). For each sample the morphodynamic characteristic is indicated along the x-axis. The leftmost cluster represents the stations where no macrobenthos individuals were found in the boxcore samples.

4. Conclusion

Our results of the benthic surveys indicate distinct differences between the macrobenthos composition of sand-wave crests and troughs, being independent of sampling period, sampling area or sediment composition. Species abundance is higher in the troughs as compared to crests, where in 54% of the samples no animals where found at all. We therefore conclude that morphological features as sand waves may result in differences in macrobenthic communities. Although the concept of habitat maps combining several marine parameters (for example substrate type, benthic assemblage, habitat complexity, relative current strength and depth, Todd et al., 2000) is not new, earlier studies have focused on large-scale relationships rather than on small-scale diversity. The current study emphasizes that also in relatively 'uniform' areas with bedforms on the scale of only a few meters offer potential for zonation of benthic fauna and therefore promote species diversity which is generally viewed as a positive indicator for habitat quality. Further investigation into the relationship between the benthic community and the morphodynamic processes on the seafloor are likely to yield interesting information about the role of morphodynamic processes in shaping benthic assemblages.

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Table 1: List of macrofauna species found in the boxcore samples. All species were used for cluster analysis except the mobile fauna indicated with *. Taxa names are printed in bold letters. Underlined names indicate species absent in the crest samples.

Nemertinae:	Diastylis bradyi	Nephtys hombergii
Nemertinae species	Liocarcinus holsatus juv.	Nephtys longosetosa
	Megaluropus agilis	Nephtys spp. juveniel
Mollusca:	Cumacea	Nereis longissima
Abra prismatica	Pinnotheres pisum	Ophelina limacina
Donax vittatus	Synchelidium haplocheles	Owenia fusiformis
Ensis americanus cf directus	Thia scutellata	Paraonis fulgens
Euspira pulchella	Urothoe elegans	Phyllodoce mucosa
Tellimya ferruginosa	Urothoe poseidonis	Scolelepis bonnieri
Tellina fabula	Copepoda sp.	Scoloplos armiger
	Aricidea jeffreysii	Spio filicornis
Crustaceaea:	Capitella capitata	Spio martinensis*
Bathyporeia guilliamsoniana	Chaetozone setosa	Spiophanes bombyx
Bathyporeia elegans	Eteone longa	Travisia forbesii
Bathyporeia pelagica	Goniada maculata	
Bathyporeia nana	Lanice conchilega	**Echinodermata:**
Bathyporeia tenuipes	Magelona papillicornis	Echinocardium cordatum
Callianassa subterranea	Nephtys caeca	Ophiura spec.juv.
Crangon crangon*	Nepthys cirrosa	