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EVALUATION OF THE ECOLOGICAL VALUE OF THE FORESHORE HABITAT-MODEL AND MACROBENTHIC SIDE-SCAN SONAR INTERPRETATION: EXTENSION ALONG THE BELGIAN COASTAL ZONE

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INTRODUCTION

Notwithstanding the high ecological importance of the Belgian coastal zone (e.g. international importance for waterfowl), the area is largely subjected to anthropogenic impacts (e.g. harbours and coastal defence works). Hence, a (knowledge-based) sustainable management of the coastal zone is indispensable to reconcile the ecological value with the numerous human activities.

A scientifically validated evaluation of the environmental impacts of planned operations (i.e. Environmental Impact Study, EIS) is necessary, but can only be done when enough knowledge on the ecosystem is available. Unfortunately, the ecology of the Belgian coastal zone is only fragmentally known. Because of the important structural and functional role of macrobenthos within the marine ecosystem, the main emphasis was put on this ecosystem component.

Since early '90 the macrobenthos habitat of the Western Coastal Banks, mainly Potje, Trapegeer, Broersbank and Den Oever, received intensive and interdisciplinary (biology and geology) scientific attention (Van Assche & Lowagie, 1991; Degraer & Vincx, 1995, 1997, 1998; Degraer *et al.*, 1999; Degraer *et al.*, 2002): (1) spatial and temporal variation of the macrobenthos, (2) population dynamics of the bivalve *Spisula subtruncata*, and (3) characterization of the macrobenthos habitat through (a) modelling of the link between the macrobenthos and the physico-chemical environment (HABITAT model) and (b) standardized macrobenthic interpretation of side-scan sonar recordings (Macrobenthic Side-Scan Sonar Interpretation, MSSSI). Nowadays, a detailed knowledge of the macrobenthos habitat of the Western Coastal Banks is available. This knowledge already allowed to adjust a plan for coastal defence works and provided valuable information for the preparation of the management plan for the area. In contrary, the macrobenthos habitat outside the Western Coastal Banks (Koksijde towards the Belgian-Dutch border) is largely unstudied. Ecosystem information, necessary for EIS of planned activities or the set-up of a sustainable management plan, is thus largely lacking.

This study presents a first step towards filling the gap within the knowledge of the macrobenthos habitat of the full Belgian coastal zone. This knowledge will further be used to validate and adapt the time- and cost-efficient evaluation tools of the macrobenthos habitat (HABITAT model and MSSSI) along the full Belgian coast. This validation and adaptation is necessary for a scientifically-sound usage of the models within an ecological evaluation of future operations along the Belgian coast (e.g. EIS). Therefore this study aims at (1) the description of the spatial distribution of the macrobenthos along the full Belgian coast, (2) the characterization of the macrobenthos habitat along the full Belgian coast, (3) the validation of the applicability of the HABITAT model along the full Belgian coast and (4) the validation of the applicability of MSSSI along the full Belgian coast.

METHODOLOGY AND STANDARD MATERIALS

Survey strategy

For the evaluation of the capability to predict macrobenthic community occurrences from either the HABITAT model or the macrobenthic side-scan sonar interpretation, a stratified random sampling strategy was adopted based on remote sensing. As such, the areas were geo-acoustically surveyed prior to the sampling campaigns. Two transects were sailed per area. The spacing was chosen according to the swath width as to obtain a full-coverage view of the seafloor. The imagery was processed and for the major differentiations in the strata, sampling locations were proposed along the central part of the entire ensonified area. Due to shiptime constraints, only one sample per stratum could be retained. Ideally, a higher number of samples would be required to obtain a representative view of the interpretation of the sonar imagery versus the occurrence of macrobenthic communities.

Shiptime, navigation and positioning

Shiptime was granted by Coastal Waterways, Ministry of the Flemish Community. All of the surveys were carried out with M/V Oostende XI. Table I gives an overview of all the relevant campaigns. M/V Oostende XI is equipped with differential global positioning systems (DGPS) of which the Sercel NR 103 was used. The final processing of all the data was performed in UTM 31N - ED50 coordinates (Hayford 1924 reference plane), as this is the standard for survey work on the Belgian continental shelf.

Table I. Overview of the side-scan sonar recording (SSS) and the sampling campaigns.

Areas	Side-scan sonar	Surficial sampling	Time lapse (days)
Baland Bank	14/10/2000	15/11/2000	32
Wenduine	15/10/2000	23/11/2000	39
Blankenberge	15/10/2000	23/11/2000	39
Paardenmarkt	04/10/2000	23/11/2000	50

The hydro-meteo conditions in between the sonar and sampling campaigns were dominated by SSW to SW winds with peaks of more than 6 Bf. From October, 28th 2000, the wind blew consistently from a SSW direction. Before the sonar campaigns, on October 14 and 15, a wind force of more than 6 Bf occurred, mainly from the south. A normal wind distribution pattern characterized the month preceeding the first side-scan sonar survey on October, 4th, however, with some storm depressions mainly from the WNW (Data source: Ministry of the Flemish Community, Waterways Coast Division).

Sampling and laboratory treatment

To obtain full coverage data on the macrobenthos and its physico-chemical environment, approximately 10 samples per area were taken, according to a stratified random sampling strategy based on remote sensing. At each station, samples for macrobenthos and sedimentology were collected. Water depth at the time of sampling was measured.

Table II gives a methodological overview of the measurements and samplings performed during the campaigns.

Table II. Methodology

macrobenthos	Van Veen grab, bulk sample
sediment texture	Van Veen grab, bulk sample and short sediment cores
depth measurement	Multibeam bathymetry
nature of the seafloor	Very-high resolution digital side-scan sonar

The macrobenthos was sampled using a Van Veen grab (sampling surface 0.1026 m^2). The samples were sieved using a 1 mm mesh-sized sieve and fixated in an 8% formaldehyde-seawater solution. After staining with Bengal rose, all organisms were sorted out and identified to species level, if possible. Densities were expressed as the number of individuals per square meter (ind./m^2).

From each Van Veen grab sample, a subsample for sedimentology was taken using a core (diameter: 3.6 cm). The subsample was dried immediately at 60°C. After sieving the sediments on a 1 mm mesh-sized sieve, the grain-size distribution of the remaining sediment was analyzed by means of a LS Coulter counter with a measuring range from 2 to 850 µm. Sediment fractions 2-850 µm are expressed as volume percentages, while sediment fractions coarser than 1 mm are expressed as mass percentages. Median grain-size was calculated only using the sediment fraction 2-850 µm.

At each location, an extra sample was taken for standard grain-size analysis. The whole Van Veen grab was subsampled to obtain a sample representative for the upper 10 cm of the seafloor. In the laboratory, each sample was photographed. After drying, the bulk sample was first split up to +/- 500 g and sieved on a 710 µm mesh. Subsequently, a subsample of about 25 g was obtained through splitting. The sample was wet sieved. After drying, the coarse fraction was treated on a sieve rack with a mesh interval of 0.25 phi. If the fraction less than 53 µm was more than 5 %, the fine fraction was analysed with a Sedigraph (X-ray instrument). The final results were statistically treated to obtain the most relevant sedimentological parameters. Sediment grain-size fractions were classified according to the Wentworth scale.

Mathematical analyses of the macrobenthos data

Macrobenthic diversity was expressed as the number of species per sample (N_0). Community structure was analyzed by means of Two-Way Indicator Species Analysis (TWINSPAN; using the quantitative and qualitative dataset), Detrended Correspondence Analysis (DCA; using the quantitative dataset after a fourth root transformation) and group-averaging Cluster Analysis (using the Bray-Curtis similarity index, based on the quantitative dataset after a fourth root transformation). Indicator Species Analysis (IndVal) was used to determine the species indicative for the observed community structure (Dufrêne & Legendre, 1997). Indicative species are defined as dominant species (ten most abundant species) with an indicator value > 30 and significantly (Monte Carlo permutation test: $p < 0.05$) indicative for a certain sample group.

Bathymetrical registrations

The M/V Oostende XI enabled the acquisition of multibeam bathymetry (Atlas Fansweep). A tidal correction was performed on the basis of the procedures described in Van Cauwenberghe *et al.* (1992). The data was gridded (1*1 m and 5*5 m) using the Kriging algorithm. Due to the full-coverage data acquisition, the choice of the interpolation method is less crucial regarding accuracy. Contour maps were generated from the gridded data and could be exported to a variety of software programmes.

Side-scan sonar

Side-scan sonar imagery was collected to obtain very-high resolution imagery of the seafloor. The application of this technology is nowadays widely used for seabed habitat mapping as it produces an almost photorealistic picture of the seabed (Kenny *et al.* 2000). Its use is especially favourable in shallow water as the transducers can produce a wide swath regardless of the water depth. Reference is made to Blondel & Murton (1997) for operational procedures and technical constraints.

Side-scan sonar imagery is a reflection of the acoustic energy that is backscattered from the seafloor and as such an image is composed of different grey scales. The differences in backscattering are in decreasing order determined by (1) the geometry of the sensor-target system; (2) the angle of incidence of each beam, local slope, etc.; (3) the physical characteristics of the surface such as the micro-scale roughness and (4) the intrinsic nature of the surface (composition, density, relative importance of volume versus surface diffusion/scattering for the selected frequency) (Blondel & Murton, 1997). Regarding the acoustic response of the marine sediments themselves, the most important parameters, ranked in order of importance, are (1) porosity; (2) density; (3) overburden stress; (4) the degree and type of lithification and (5) the grain-size and distribution (Stoll 1989).

For the present project, a GeoAcoustics dual frequency side-scan sonar was deployed of which the 410 kHz frequency was preferred during the acquisition. During the surveying, an optimal ship speed of 4 knots was maintained. All the data were recorded digitally using ISIS acquisition software (Triton-ELICS). The processing (at 10 cm resolution) was performed with ISIS and Delphmap. Corrections for the height of the fish above the seabed (the slant range), lay-back/offset and the vessel speed were taken into account. The imagery recorded along the two transects was merged into 1 mosaic. For the overlapping zone, the highest quality imagery was retained. For the shown examples of the side-scan sonar images, the already geometrically corrected imagery was reprocessed to obtain a maximum resolution. Finally, the images were exported as Geotiffs and eventually as ECW (a wavelet format, highly compressed) and as such could be imported in other software programmes.

Representation of the geo-environmental data

From the multibeam gridded data, xyz data was extracted along a line including the positions of the sampling points; hence the samples are positioned correctly onto the bathymetrical profile. This line was superposed on the map with the acoustic facies delimitations and the intersections were separately retained. As such, the level of transition from one acoustic facies into another is also correctly transferred onto the bathymetrical profile. For the visualisation figures where also side-scan sonar imagery is included, data of only one transect could be used. As such, the best side-scan sonar trackline was chosen and was reprocessed individually to obtain a maximum resolution. As the original acoustic facies delineations on the side-scan sonar imagery were performed on the mosaics (composed of 2 transects), there might be a slight variation in distance regarding the transition between the acoustic facies on the side-scan sonar imagery. Moreover, it needs mentioning that the interpretation is best interactively done and taking into account the whole imagery.

The morpho-sedimentological characterisation is mainly based on the side-scan sonar imagery in combination with the multibeam bathymetry. The description of the true sedimentological nature of the seafloor is here based on the individual sampling points. No interpolation of these data into contour maps was possible as only about 10 samples were taken per area that were chosen to explain differences in acoustic facies.

GENERAL DESCRIPTION OF THE AREA OF INVESTIGATION

Introduction

The applicability of the HABITAT model and the Macrobenthic Side-Scan sonar Interpretation (Degraer *et al.* 2002) was evaluated along the foreshore of the full Belgian coast based on six well-spread transects, perpendicular to the coastline. For their exact location, areas were chosen of higher environmental interest and/or availability of other data (Figure 1). For the present project, only the 4 transects outside the Habitat area are investigated in detail. The test zones in the Habitat area (both westernmost transects), were already discussed in Degraer *et al.* (2002).

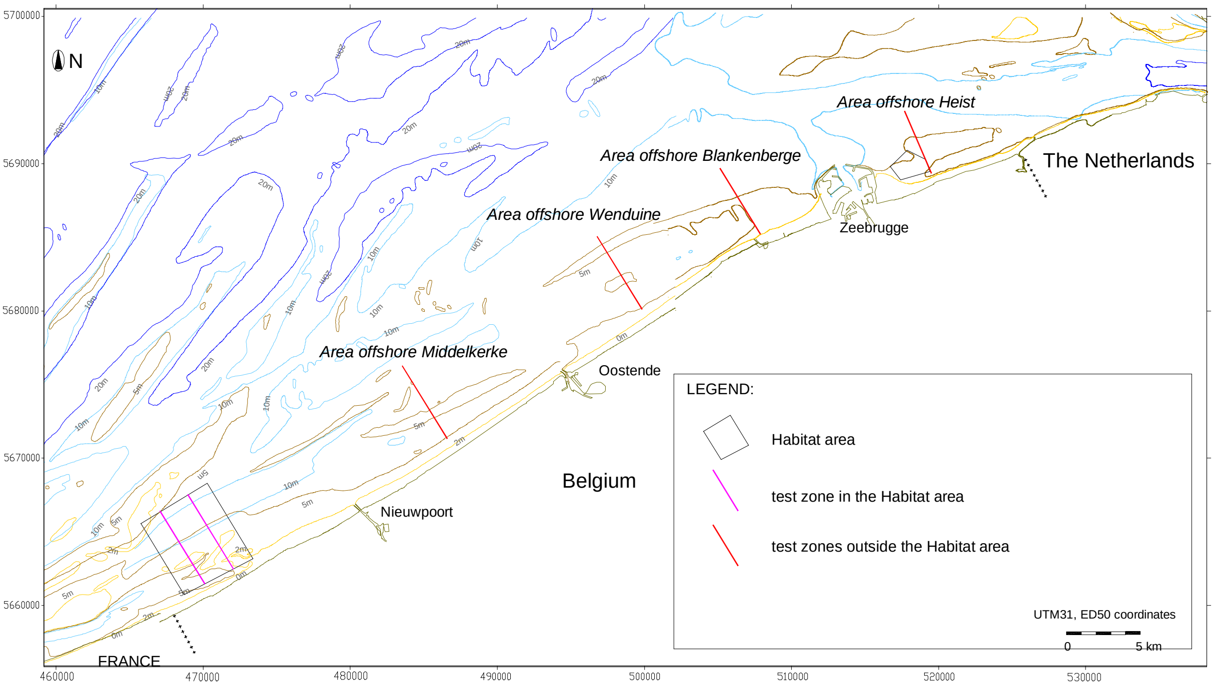

Figure 1. The Belgian coastal zone with an indication of the present areas of investigation; respectively located offshore the coastal cities Middelkerke, Wenduine, Blankenberge and Heist.

Contrary to the approach followed in Degraer *et al.* (2002), the geo-acoustic measurements were performed prior to the sampling as to optimise the sample locations according to the differences in acoustic facies (*stratified random sampling approach*). All of the data was investigated in terms of their acoustic facies, sediment nature and macrobenthic community structure. Details on the modelling into acoustic facies is described in the section on the evaluation of the macrobenthic side-scan sonar interpretation and its meaning is synthesised in Table VIII. The side-scan sonar imagery corresponding with the descriptions is shown in the Figure 28 to 38.

To provide a first insight into the physical nature of the foreshore, each of the transects is firstly described in terms of their morpho-sedimentological characteristics. Subsequently, the macrobenthic community structures along the Belgian foreshore are discussed.

Results

MORPHO-SEDIMENTOLOGICAL CHARACTERISATION OF THE AREAS OF INVESTIGATION

Area offshore Middelkerke

A profile was chosen offshore Middelkerke, along the central part of the Belgian coastal zone, comprising a complex sandbank-swale system. From north to south, the section cuts the Grote Rede swale, the Baland Bank, the southern branch of the Grote Rede, the coast parallel Stroombank, the Kleine Rede swale and the shoreface.

The depths vary from – 8 m in the swales up to –3.2 m MLLWS along the top of the Stroombank.

Figure 2 gives an overview of the 6 km long bathymetric profile chosen along the sampling points. The profile clearly typifies the sandbank-swale morphology (beware of the serious vertical exageration). The Baland Bank is superimposed with large to very-large dune structures, especially along its southern slope. The Stroombank has a two-fold upbuilding, characterised by a break around –6 m MLLWS. No large to very-large dunes are commonly observed. The Kleine Rede is generally devoid of bedforms, except for some undulations. The shoreface has a plateau-like appearance.

The alternation in acoustic facies from the side-scan sonar imagery confirms the complexity of this section. The sandbank areas generally show a medium reflectivity with a slightly grainy to grainy texture with sediments having a median grain-size around 200 µm without a significant silt-clay enrichment. The north flank of the Baland Bank is dominated by ebb-dominated large dunes. Along the topzone, the crestline of a very-large dune can be remarked which is clearly flood-dominated (Figure 28). Its sediments merely fall within the range of medium sands (> 250 µm) and show higher percentages of shelly material. The stoss slope of this very-large dune is superimposed with ripples; as such it is a typical compound dune. Remark the homogeneous nature along the steep slope of this dune due to the turbulent nature of the current passing these large structures. Towards the southern branch of the Grote Rede, the dunes decrease in height and tend to be ebb-dominated. The dunes become more vague along the transition towards the Stroombank. Fine sandy sediments generally characterise this sandbank. Remarkable is the break around –6 m MLLWS. On the sonar images, a slightly darker reflectivity and featureless pattern can be recognised. Sampling showed fine sandy sediments, albeit with 31 % of shelly material. Higher up the Stroombank, again dune structures appear having their smallest wavelength along the top. These are likely due to wave interference. Interestingly, the wavelength largely increases along the upper steep flank of the sandbank (Figure 3). Subsequently, sand ribbons appear, characteristic for high current velocities. At the foot of the steep flank a typical patchy, low reflectivity acoustic facies shows up, but clearly subdued to current scouring. The median grain-size is only 24 µm due to a 61 % silt-clay composition (Figure 3).

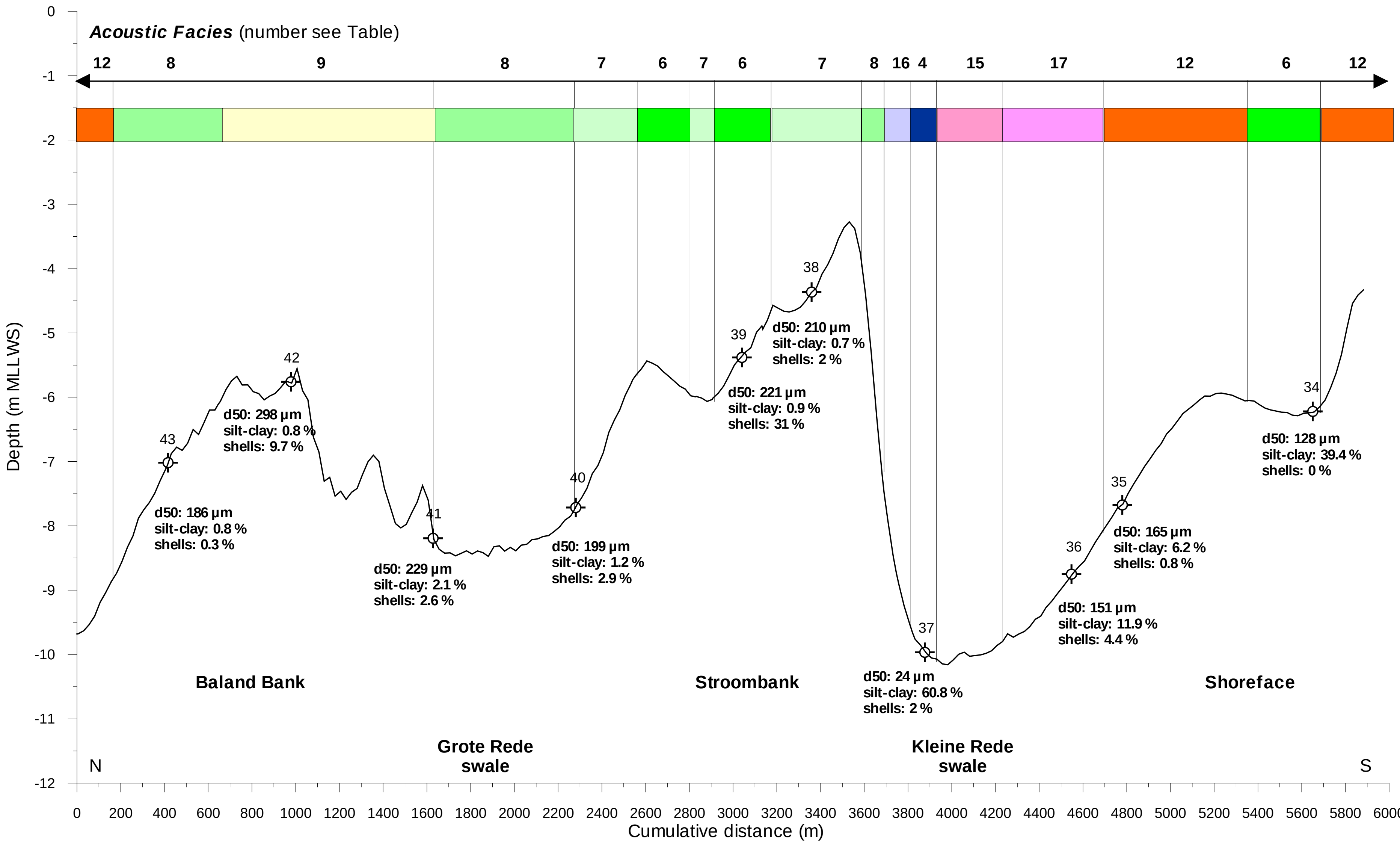

Figure 2. Area offshore Middelkerke. From north to south, the section cuts the Grote Rede swale, the Baland bank, the southern branch of the Grote Rede, the coast parallel Stroombank, the Kleine Rede swale and the shoreface. The associated side-scan imagery is shown in the Figures 28 to 31.

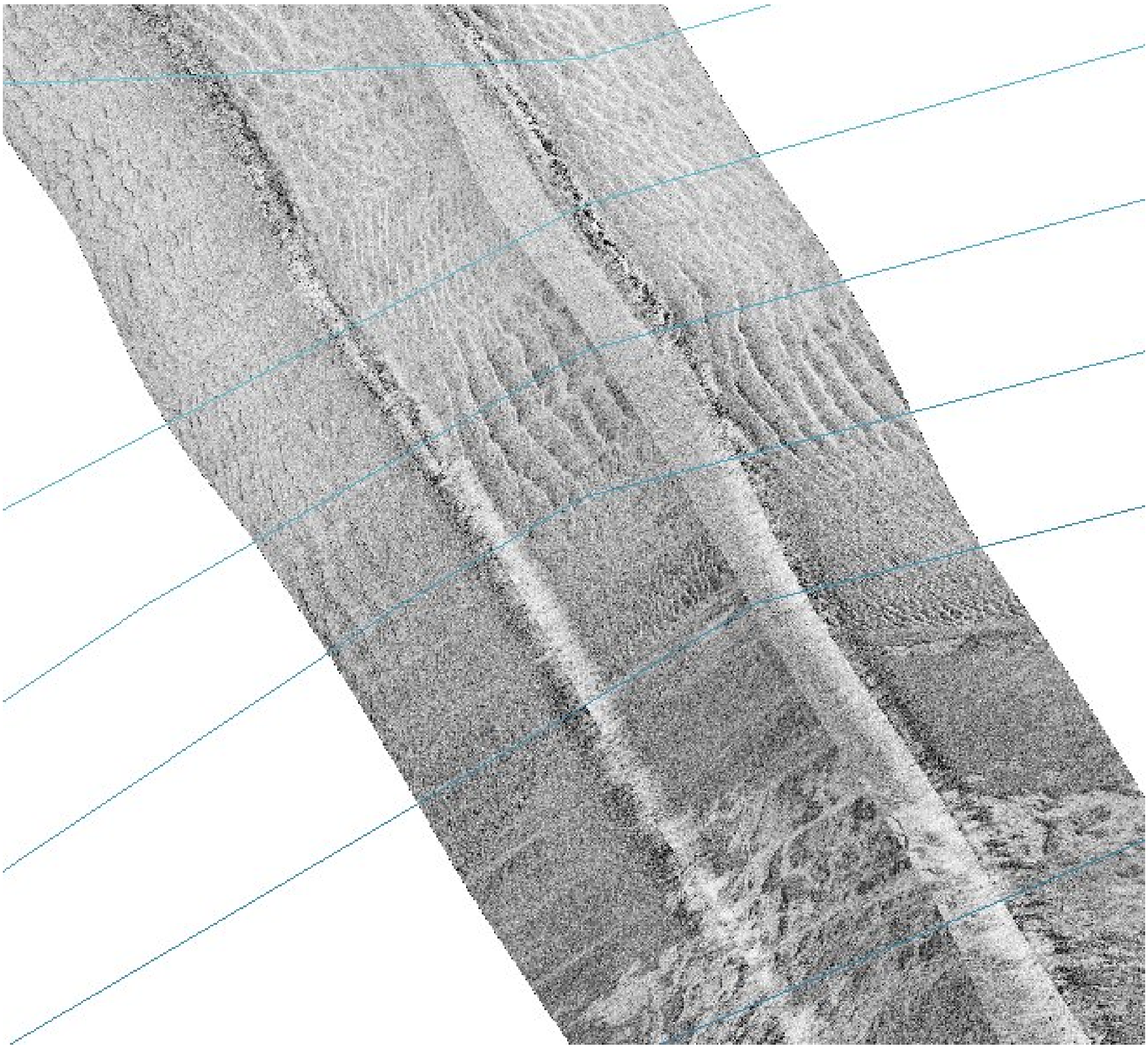

Figure 3. Side-scan sonar mosaic along the steep slope of the Stroombank. The blue lines represent depth contours in MLLWS (here in N-S direction from –4 to –9 m MLLWS).

Still, in the deeper part of the Kleine Rede, a high reflectivity, grainy and mottled acoustic facies occurs (Figure 3). Generally, a medium reflectivity, grainy textured with a mottled pattern dominate the shoreface, except for a plateau-like feature around – 6 m MLLWS which is merely featureless. Fine sandy sediments are typical with a silt/clay enrichment up to 39 %. Note the presence of acoustic facies 17 at the foot of the shoreface, characteristic for high current environments (Table VIII).

Area offshore Wenduine

A profile was chosen offshore Wenduine, east of Oostende, essentially comprising the Wenduine Bank, the Kleine Rede swale and the shoreface. Interestingly, the profile crosses the dumping place B/9 located in the Kleine Rede where mainly dredged material from Oostende Harbour is dumped.

The depths vary from – 8 m in the northern branch of the Kleine Rede swale up to –3.5 m MLLWS along the top of the Wenduine Bank.

Figure 4 gives an overview of the 6 km long bathymetric profile chosen along the sampling points. The profile clearly typifies the sandbank-swale morphology (beware of the serious vertical exageration). The Wenduine Bank is clearly devoid of bedforms and has no pronounced morphology. Remarkably, is the extent of the dumping place B/9 which has the appearance of a sandbank, albeit not highly hydrodynamically streamlined. The shoreface has a step-like morphology.

A diversity of acoustic facies typifies this section. A medium reflectivity, mottled acoustic facies generally occurs at the foot of the slopes. The Wenduine Bank is indeed devoid of bedforms as exemplified by the featureless sonar imagery. The sediments have a median grain-size around 175 µm. However, along its steep slope flood-dominated dune structures appear and at its foot sediments in the range of medium sands occur with an enrichment of shells. The deepest part of the northern branch of the Kleine Rede is strongly patchy in nature; still its reflectivity is merely low and its texture smooth to slightly grainy. The muddy seafloor is clearly altered by the current. Also, along the northern slope of the dumped sediment mass, current lineations occur and hence also witness an intense flow–topography interaction. It needs emphasis that the sediments involved have a median grain-size in the range of fine sands with a high silt-clay composition. Somewhat higher up (-6.5 to -5.5 m MLLWS), small wavelength wave ripples occur. The topzone is more sandy and the finer fractions are completely washed out. The shell percentage varies around 3.5 %. Flood-dominated dune structures appear. Interestingly, zones can be distinguished where material is likely recently dumped (Figure 5, red encircled areas). The wavelength of the dune structures gradually diminish to fade out just over the top of this peculiar sediment mass.

After a small area, where the seafloor is more or less homogeneous, striations tend to occur towards the foot of the southern slope. The sediments clearly get finer: from medium sands at the upper slope to fine sands with a silt-clay composition of 13.5 % at the foot. Lineations can clearly be seen along the deeper part of the southern branch of the Kleine Rede (see Figure 33). The seafloor is composed of clayey sediments with a median grain-size of 1 µm due to a silt-clay composition of 94 %. The shoreface is more sandy and again a mottled medium reflectivity acoustic facies predominates. Higher up the shoreface, the seafloor is featureless.

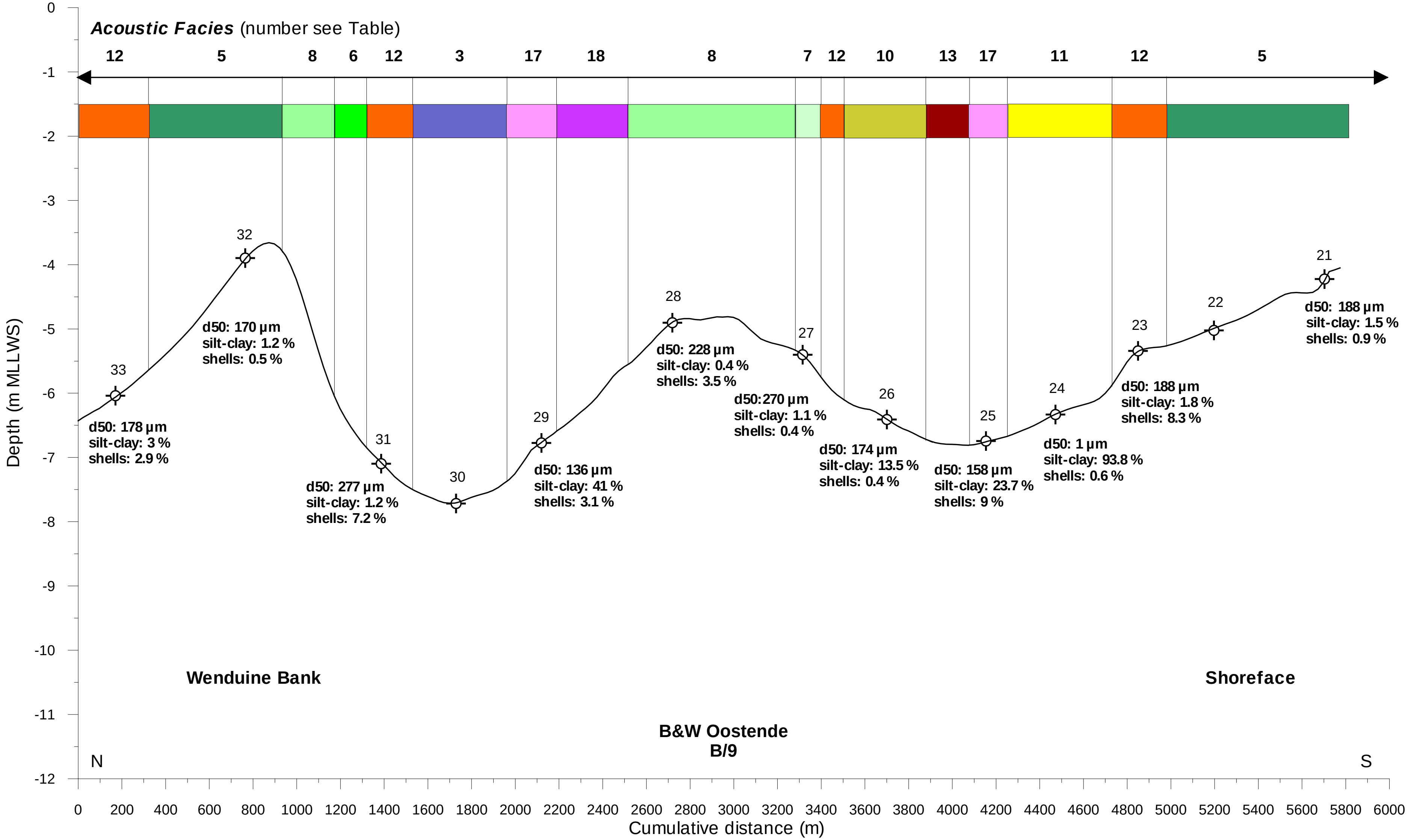

Figure 4. Area offshore Wenduine essentially comprising the Wenduine Bank, the Kleine Rede swale and the shoreface. The profile crosses the dumping place B/9 located in the Kleine Rede where mainly dredged material from Oostende Harbour is dumped. The associated side-scan imagery is shown in the Figures 32 to 35.

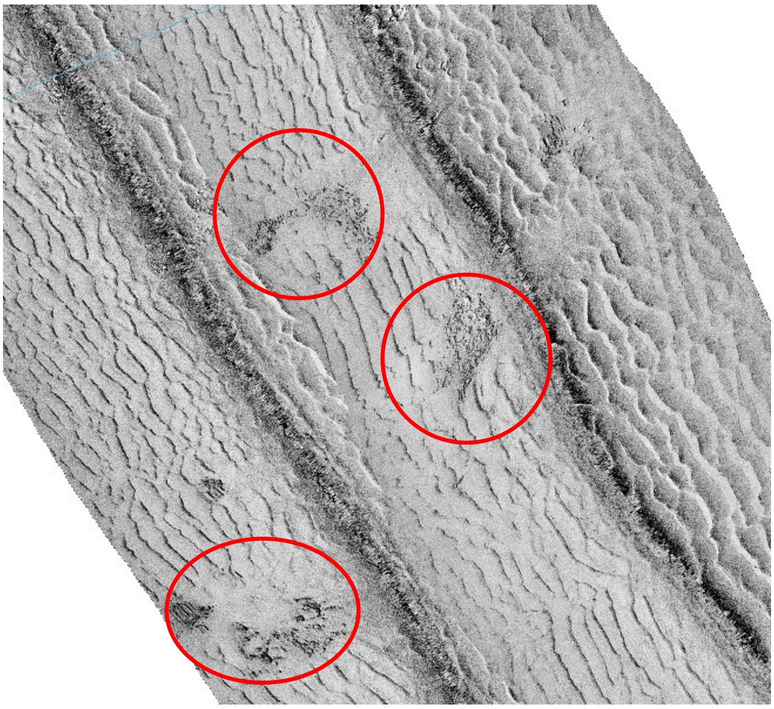

Figure 5. Detail of the topzone of the B/9 dumping place. Red encircled are likely areas of recently deposited dumped material.

Area offshore Blankenberge

A profile was chosen offshore Blankenberge, west of Zeebrugge Harbour comprising the eastern broad extent of the Wenduine Bank, the end of the flood parabola of the Kleine Rede swale and the shoreface.

The depths vary from – 9 m at the offshore extremity up to – 4 m MLLWS along the shoreface. The Kleine Rede swale has a rather flat relief with depths varying around – 6 m MLLWS.

Figure 6 gives an overview of the 6 km long bathymetric profile chosen along the sampling points. The profile has a very flat appearance (regardless of the serious vertical exageration) and is clearly devoid of bedforms. The transiition to the shoreface is sharp.

Along the whole profile, hardly any differentiation in acoustic facies can be observed. Clayey to silty sediments characterise the whole northern slope of the Wenduine Bank; the silt-clay compostion varies around 65-80 %. The highest part does show sediments with a median grain-size of 177 µm and the silt-clay fraction seems to be completely washed out. Further to the south, the sediments remain fine sandy with a silt-clay composition around 30 % and hardly any shells. The acoustic facies remains undifferentiated.

Area offshore Heist

A profile was chosen offshore Heist, east of Zeebrugge Harbour and comprising the Paardenmarkt shoal, the western broad extent of the Appelzak swale, being an ebb parabola, and the shoreface.

The depths vary from – 9.5 m at the offshore extremity (Wielingen) up to – 3 m MLLWS along the shoreface. The Paardenmarkt shoal reaches here –4.5 m MLLWS.

Figure 7 gives an overview of the 6 km long bathymetric profile chosen along the sampling points. Apart from the northern slope and the shoreface, the profile has a flat appearance (regardless of the serious vertical exageration) and is devoid of larger bedforms. The transition to the shoreface is again sharp.

Although, the shape of the profile resembles that of the profile offshore Blankenberge, much more differentiation is seen in the acoustic facies. At the foot of the northern slope, sediments in the range of medium sands are observed; the seafloor is composed of large dune structures. Higher up the slope, the surficial sediments tend to become finer and even mid-way, a median grain-size of 27 µm is measured. Still, a medium reflectivity, grainy textured and a patchy pattern characterises the upper slope area; the sediments are composed of fine sands. Small wavelength wave ripples characterise the topzone, albeit overlain with loose mud. Subsequently, areas with more or less mud alternate and the silt-clay composition of the sediments remains high.

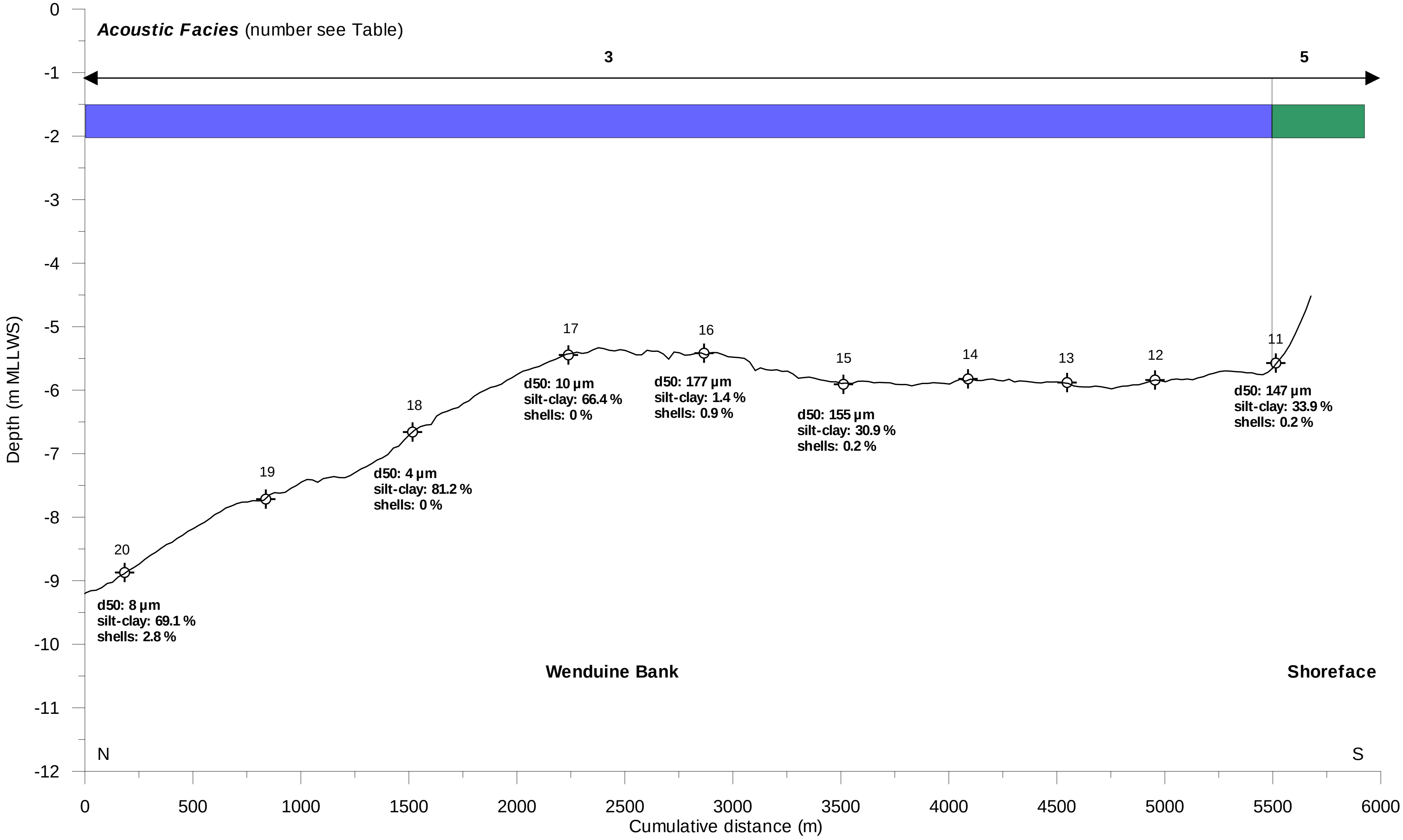

Figure 6. Area offshore Blankenberge, west of Zeebrugge Harbour comprising the eastern broad extent of the Wenduine Bank, the end of the flood parabola of the Kleine Rede swale and the shoreface. The associated side-scan imagery is shown in Figure 36.

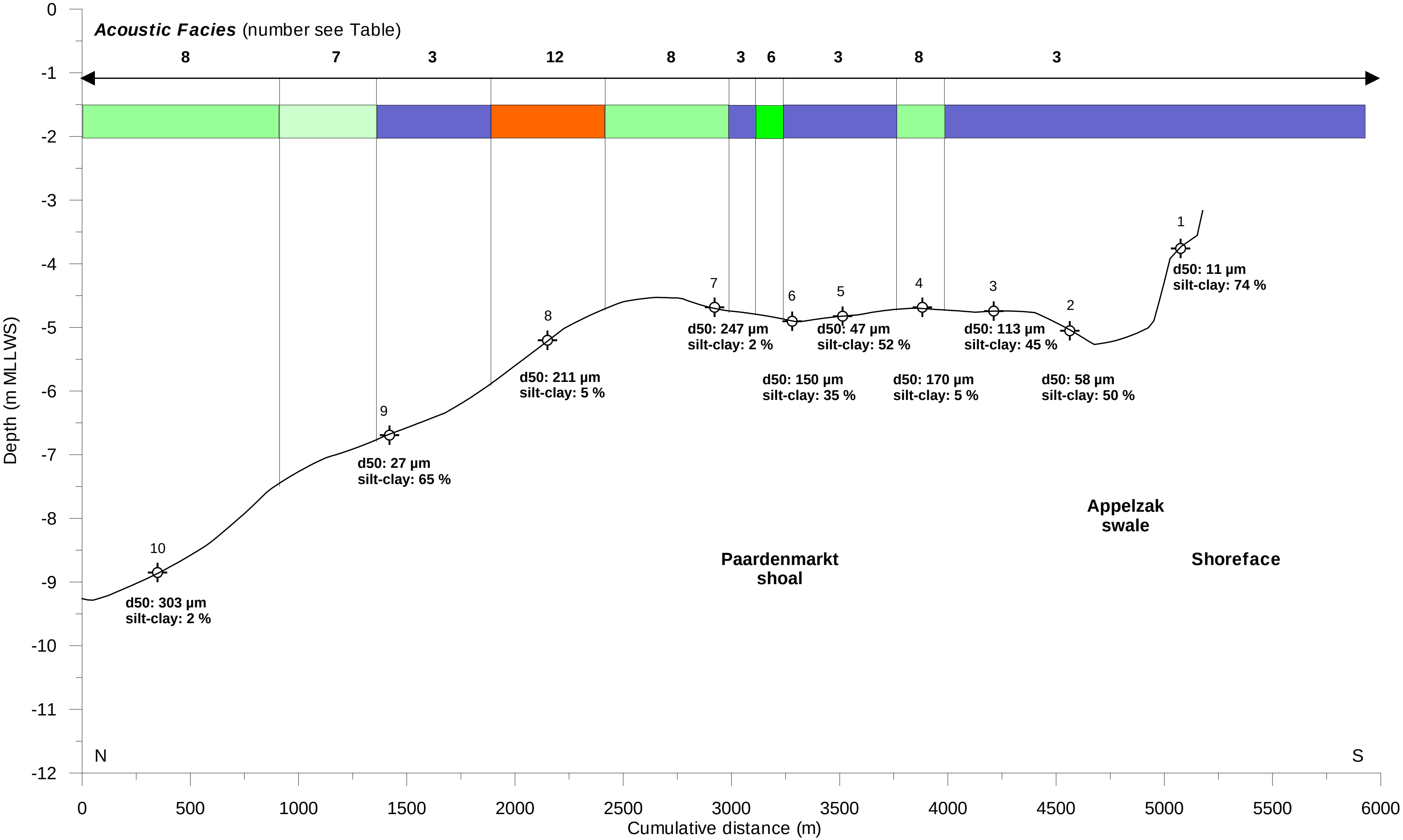

Figure 7. Area offshore Heist, east of Zeebrugge Harbour and comprising the Paardenmarkt shoal, the western broad extent of the Appelzak swale, being an ebb parabola, and the shoreface. The associated side-scan imagery is shown in the Figures 37 and 38.

MACROBENTHIC COMMUNITY STRUCTURE ALONG THE BELGIAN COAST

To evaluate the applicability of the HABITAT model along the foreshore of the full Belgian coast, it is necessary to test the model both inside and outside the area of the Western Coastal Banks. Because the prediction accuracy is highly dependent on the knowlegde, used to set up the model, new insights changing the former knowledge will drastically lower the accuracy. New insights might be of physical (e.g. sedimentology and bottom texture) as well as biological nature. It is thus of utmost importance to have a straightforward view on the benthic community structure of the test transects.

Because of new knowledge on the taxonomy of the genus *Magelona*, a new species, *M. johnstoni*, is discerned. *Magelona mirabilis* tends to be found in estuarine conditions, while *M. johnstoni* is typically found in the marine environment. Re-identifications of individuals of *Magelona* found in this study and within the study of Degraer *et al.* (2002) showed that *M. johnstoni*, and not *M. mirabilis*, is found along the Belgian foreshore. Therefore, within this study the transitional species association between the *A. alba* – *M. bidentata* and *N. cirrosa* community, formerly defined as the *M. mirabilis* species association (Degraer *et al.*, 2002), is renamed as the *M. johnstoni* species association.

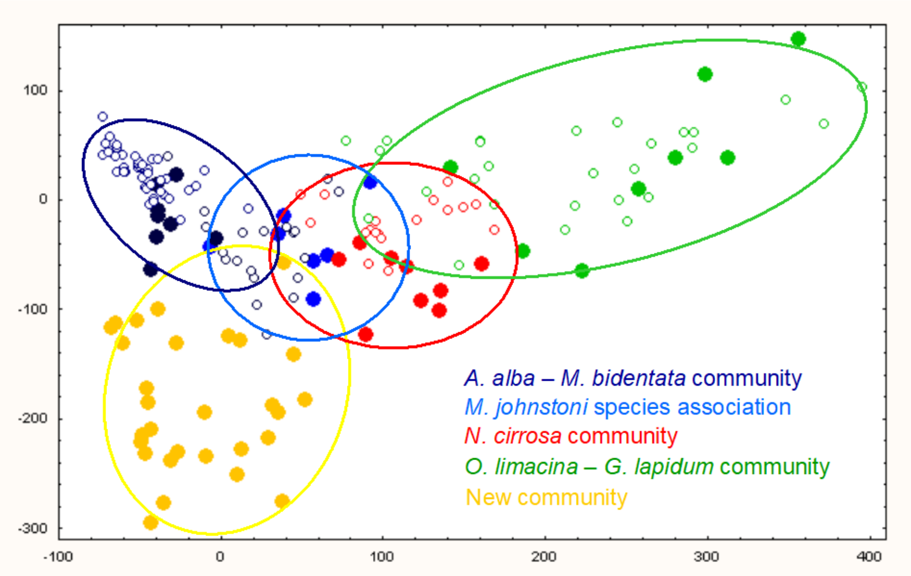

Figure 8. Correspondence Analysis plot (axis 1 and axis 2) of the samples collected in this study (large closed circles) in relation to those collected in the Habitat area in October 1999 (Degraer *et al.* 2002) (small open circles), with indication of the stationgroups representing four communities and one transitional species association.

By means of multivariate analysis techniques (TWINSPAN, correspondence analysis and cluster analysis) using 61 samples were assigned to five sample groups (Figure 8). Four of these groups (52 % of the samples) matched with one of the three communities or transitional species association, discriminated on the Western Coastal Banks (see Degraer *et al.*, 2002). Yet, 29 samples (48 %) could not be linked to a known macrobenthic community or species association and should thus be regarded as a new community or species association.
When comparing the habitat preferences of the formerly known communities (*A. alba* – *M. bidentata*, *N. cirrosa*, and *O. limacina* – *G. lapidum* community) and the *M. johnstoni* species association along the full Belgian coast with the Western Coastal Banks a high similarity is found (Table III). On average the *A. alba* – *M. bidentata* community occurs in fine sandy sediments (median grain-size: 211 – 220 µm) with a relatively high mud content (clay: 1 – 2 %; silt: 5 – 7 %) in relatively deep waters (water depth: 9 –11 m). The *N. cirrosa* community prefers medium sandy sediments (median grain-size: 266 - 271 µm) with low mud content (< 1 %) at shallower depths

(water depth: 5 m). The transitional *M. mirabilis* species association is found in an intermediate habitat between the *A. alba – M. bidentata* and the *N. cirrosa* community. A coarser sediment (meadian grain-size: 345 – 356 µm) with relatively low mud content (< 3 %) at shallow depth (water depth: 5 m) is characteristic for the *O. limacina – G. lapidum* community.
The habitat preferences of the new community are mainly characterized by the sediment's high mud content (clay: 13 %; silt: 36 %) and low median grain-size (95 µm).

The macrobenthic community structure of the four formerly known groups along the full Belgian coast is also very similar to that of the Western Coastal Banks (Table III). The *A. alba – M. bidentata* community clearly has the highest macrobenthic species richness (N_0: 23 – 37 spp.) and density (3403 – 7589 ind. m^{-2}) and no less than seven of the community's ten most abundant species were shared between the full Belgian coast and the Western Coastal Banks. A comparable species richness (N_0: 10 – 11 spp.), density (363 – 350 ind. m^{-2}) and list of the ten most abundant species (5 spp. in common) was detected for the *N. cirrosa* community between both areas. The lowest species richness (N_0: 6 – 9 spp.) and density (169 – 365 ind. m^{-2}) was found for the *O. limacina – G. lapidum* community in both the full Belgian coast and the Western Coastal Banks. Within the community, both areas had six of the ten most abundant species in common. Even the *M. johnstoni* transitional species association could be biologically detected along the full Belgian coast.

The new community is characterized by a low species richness (N_0: 7 spp.), but rather high density (967 ind. m^{-2}). The bivalve *Macoma balthica* is the major indicator species for this new community. Three of its four most dominant species are abundantly present in the *A. alba – M. bidentata* community and two of its ten most dominant with both the *N. cirrosa* and community and the *M. johnstoni* species association.

The different communities show a clear difference in relative abundance along the full Belgian coast compared to the Western Coastal Banks (Table III). Whereas the *A. alba – M. bidentata* community (relative dominance: 40 %) predominated the Western Coastal Banks, the new community is most abundant when considering the full Belgian coast.

A difference in community composition of the eastern and the western Belgian coast, with a high dominance (87 %) of the new community along the eastern coast, is observed (Figure 9). The new community is almost absent along the western coast (7 %), where the *A. alba – M. bidentata*, *N. cirrosa* and *O. limacina – G. lapidum* community and the *M. johnstoni* species association were predominantly found (27 %, 23 %, 23 %, and 20 %, respectively). In general, a decreasing community diversity is found from the Western Coastal Banks towards the Belgian-Dutch border.

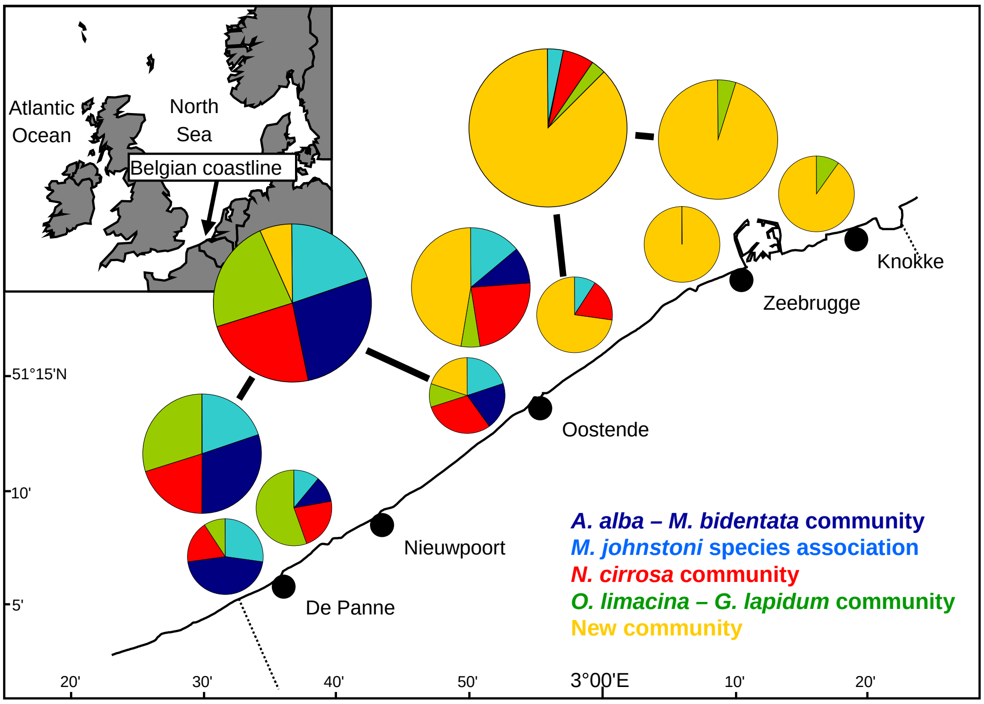

Figure 9. Relative spatial distribution of all five species associations along the Belgian coast. Small pies: at transect level; medium sized pies: western, central and eastern Belgian coast; large pies: western and eastern Belgian coast.

Discussion and conclusions

From the morpho-sedimentological characterisation, it is clear that the sediments are clearly differentiated along the coastal zone. This is most exemplified through the differences in relative frequency of occurrence of the acoustic facies along the different areas represented from west to east and compared to the Habitat area (Figure 10). From Figure 10, it can be said that the profile offshore Middelkerke and offshore Wenduine relatively match with the profiles in the Habitat area; hence the medium reflectivity acoustic facies predominate. The profiles offshore Blankenberge and Heist are clearly different in nature and are dominated by the low reflectivity acoustic facies. The latter profiles do not have high reflectivity acoustic facies.

Generally, it can be said that the surficial sediments along the Belgian coastal zone fine in a NE direction, still it is clearly demonstrated that this is largely dependent on the interaction between the morphological features that may cause an enhanced flow-topography interaction. This is explicitely shown for the profile offshore Wenduine where the extension of the dumping site gives rise to a clear morphological and sedimentological differentiation. Hence a variety of acoustic facies is found including those representative of high current velocities and even scouring is observed. Striking is however the difference in occurrence of acoustic facies between the profile offshore Blankenberge (hardly any differentiation) and the profile offshore Heist, although they practically witness the same large-scale morphology. Their orientation in respect to the tidal currents including local hydrodynamic effects are apparantly causing more complex seafloor patterns.

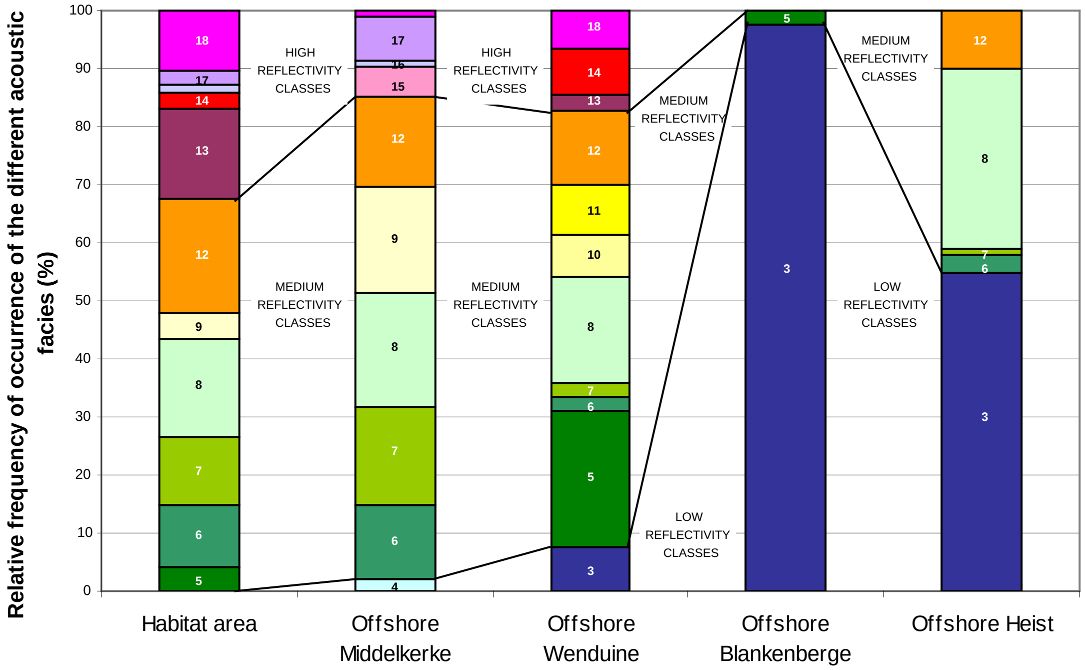

Figure 10. Comparison of the relative frequency of occurrence of the different acoustic facies along the Belgian coastal zone.

The relation of the acoustic facies with the occurrence of macrobenthic communities will be discussed in the section on the macrobenthic side-scan sonar interpretation, still it can already be remarked that acoustic facies 12, representative of the occurrence of the biologically rich *A. alba - M. bidentata* community, is important for each of the areas, except for the zone offshore Blankenberge.

Although for the characterisation of the macrobenthic communities along the Belgian coastal zone small differences within the habitat preferences and the community structure of the *A. alba – M. bidentata, N. cirrosa*, and *O. limacina – G. lapidum* community and the transitional *M. johnstoni* species association, described from the Western Coastal Banks (Degraer *et al.*, 2002) and detected in this study, can be found, it is clear that the same communities can be distinguished along the full Belgian Coast.

Only one new community was detected in this study. From a macrobenthic perspective, the new community is most related to the *A. alba – M. bidentata* community: both communities have three of their ten most dominant species in common, but the new community has a much lower diversity and density. Because the community is mainly characterized by the bivalve *M. balthica*, the community is defined as the *M. balthica* community.

Combined with its community structure, the habitat preferences of the new community (very-fine sand and high mud content) point towards a “new step” along the sedimentological gradient. From medium sands, with low mud content, towards fine sands, with relatively high mud content, a gradual shift from the macrobenthos-poor *N. cirrosa* community, over the transitional *M. johnstoni* species association, to the macrobenthos-rich *A. alba – M. bidentata* community exists (Van Hoey *et al.*, in prep.). A next step within this gradual shift might well be represented by the *M. balthica* community within a very-fine sandy, muddy sediment. Because the ecological importance of the *M. balthica* community seems to be rather low (e.g. low diversity and density), the highest ecological importance along the sedimentological gradient is found at the *A. alba – M. bidentata* community.

Most probably, the fine sandy and muddy sediments of the *M. balthica* community can be linked to the estuarine effect of the mouth of the Westerschelde with its high input of fine particles. This would explain the restricted geographical distribution of the community: generally, its relative abundance is negatively correlated to the distance to the mouth of the Westerschelde. Because of the predominant presence of the *M. balthica* community, all other communities are only found scarcely along the eastern Belgian coast. Combined with the community's generally low species diversity, the eastern Belgian coast is far less diverse than the western Belgian coast.

Table III. Relative spatial distribution, habitat characteristics and macrobenthic community structure of all four communities and the transitional species association distinguished in October 1999 ('Habitat' area) and November 2000 (Belgian coast).
1, relative occurrence; 2, depth; 3, median grain-size; 4, clay content; 5, silt content; 6, *very*-fine sand content; 7, fine sand content; 8, medium sand content; 9, coarse sand content; 10, gravel content; 11, ten most abundant species, with indication of indicator species (bold); 12, species richness (N_0); 13, macrobenthic density.

	A. alba – M. bidentata community		*M. johnstoni* species association		*N. cirrosa* community		*O. limacina – G. lapidum* community		New community
	'Habitat' area	Belgian coast	'Habitat' area	Belgian coast	'Habitat' area	Belgian coast	'Habitat' area	Belgian coast	Belgian coast
1	40%	13 %	19 %	11 %	16 %	15 %	25 %	15 %	47 %
2	11 m	9 m	7 m	7 m	5 m	5 m	5 m	5 m	6 m
3	220 µm	211 µm	218 µm	255 µm	266 µm	271 µm	345 µm	356 µm	95 µm
4	1.3 %	1.5 %	0.7 %	0.2 %	0.2 %	< 0.1 %	< 0.1 %	0.5 %	12.7 %
5	5.4 %	6.5 %	3.8 %	1.1 %	0.8 %	0.2 %	0.2 %	1.8 %	36.4 %
6	5.0 %	3.5 %	4.3 %	0.7 %	1.7 %	0.4 %	0.6 %	0.7 %	9.0 %
7	55.1 %	22.5 %	59.1 %	21.4 %	43.1 %	20.9 %	20.7 %	4.3 %	26.9 %
8	30.2 %	42.7 %	30.7 %	46.7 %	50.4 %	55.2 %	61.7 %	30.2 %	13.0 %
9	3.1 %	20.0 %	1.4 %	28.1 %	3.9 %	22.0 %	16.7 %	48.6 %	1.8 %
10	6.1 %	3.2 %	2.0 %	1.8 %	0.9 %	2.1 %	7.6 %	10.0 %	< 0.1 %
11	*Abra alba* *Mysella bidentata* ***Scoloplos armiger*** *Pariambus typicus* ***Siophanes bombyx*** *Eumida sanguinea* *Lanice conchilega* Cirratulidae **Magelona johnstoni** ***Fabulina fabula***	**Abra alba** ***Spiophanes bombyx*** **Cirratulidae** Magelona johnstoni ***Mysella bidentata*** ***Notomastus latericeus*** ***Lanice conchilega*** ***Anaitides maculata/mucosa*** ***Nephtys hombergii*** ***Fabulina fabula***	Magelona johnstoni *Spiophanes bombyx* **Nephtys cirrosa** **Urothoe poseidonis** *Fabulina fabula* **Spio martinensis** **Nephtys hombergii** *Scoloplos armiger* *Capitella capitata* Donax vittatus	Spiophanes bombyx Magelona johnstoni *Nephtys cirrosa* *Anaitides maculata/mucosa* *Urothoe poseidonis* *Fabulina fabula* *Scoloplos armiger* *Donax vittatus* *Nephtys hombergii* *Bathyporeia* sp.	**Nephtys cirrosa** *Spiophanes bombyx* ***Echinocardium cordatum*** *Montacuta ferruginosa* *Bathyporeia pelagica* *Scoloplos armiger* *Urothoe poseidonis* *Bathyporeia guilliamsoniana* *Magelona johnstoni* *Fabulina fabula*	Nephtys cirrosa *Donax vittatus* *Spiophanes bombyx* ***Bathyporeia* sp.** Magelona johnstoni *Scolelepis squamata* *Scoloplos armiger* *Nephtys hombergii* *Pontocrates altamarinus* *Urothoe poseidonis*	***Nephtys cirrosa*** ***Urothoe brevicornis*** *Ophelia limacina* *Scoloplos armiger* *Mytilus edulis* spat Actiniaria Spiophanes bombyx ***Gastrosaccus spinifer*** *Urothoe pulchra* *Bathyporeia elegans*	Nephtys cirrosa *Scoloplos armiger* ***Urothoe brevicornis*** ***Ophelia limacina*** *Spisula subtruncata* *Microphthalmus similis* *Spiophanes bombyx* *Glycera lapidum* *Gastrosaccus spinifer* *Bathyporeia* sp.	Cirratulidae Nephtys hombergii ***Macoma balthica*** *Abra alba* *Petricola pholadiformes* *Heteromastus filiformis* *Polydora* sp. Pectinaria koreni *Nephtys* juv. Nephtys cirrosa
12	37 spp.	23 spp.	17 spp.	14 spp.	11 spp.	10 spp.	9 spp.	6 spp.	7 spp.
13	7589 ind. m^{-2}	3403 ind. m^{-2}	1269 ind. m^{-2}	901 ind. m^{-2}	350 ind. m^{-2}	363 ind. m^{-2}	365 ind. m^{-2}	169 ind. m^{-2}	967 ind. m^{-2}

EVALUATION OF THE HABITAT MODEL ALONG THE BELGIAN COASTAL ZONE

Introduction

Degraer *et al.* (2002) demonstrated that, when (1) the different macrobenthic communities and their seasonal variability and (2) their habitat preferences are known, information on the biologically relevant, physico-chemical parameters of biologically unexplored sites allows to predict the 'macrobenthic potential' of these new sites. Herewithin, the 'macrobenthic potential' is defined as the dynamics of the macrobenthic community structure (e.g. species composition, diversity, and densities) within a certain habitat. The HABITAT model, allowing to objectively predict the macrobenthic 'potentials' within the area of the Western Coastal Banks with an overall *a priori* accuracy of up to 90%, was put forward. Still, it was suggested that further testing, refinement and spatial extension of the model are necessary.
For detailed information on the logics behind the HABITAT model one is referred to Degraer *et al.* (2002).

Within this section the applicability of the HABITAT model, orginally set up for use in the area of the Western Coastal Banks, is tested along the whole Belgian coast.

Because of new knowledge on the taxonomy of the genus *Magelona*, a new species, *M. johnstoni*, is discerned. *Magelona mirabilis* tends to be found in estuarine conditions, while *M. johnstoni* is typically found in the marine environment. Re-identifications of individuals of *Magelona* found in this study and within the study of Degraer *et al.* (2002) showed that *M. johnstoni*, and not *M. mirabilis*, is found along the Belgian foreshore. Therefore, within this study the transitional species association between the *A. alba – M. bidentata* and *N. cirrosa* community, formerly defined as the *M. mirabilis* species association (Degraer *et al.*, 2002), is renamed as the *M. johnstoni* species association.

Results

HABITAT MODEL AS DEFINED FOR THE BELGIAN WESTERN COASTAL BANKS

Next to its capability to determine which environmental variables are the best predictors of the communities' habitat preferences, discriminant analysis further computes classification functions, which can be used to determine to which community or species association a sample most likely belongs based solely on habitat characteristics. The mathematics behind discriminant analysis are provided by Degraer *et al.* (2002).

The HABITAT model is defined as a set of classification functions that can be used to objectively predict the occurrence of a macrobenthic community based on discriminating habitat characteristics. Based on a selection of habitat characteristics to be used and the communities to be discerned, different classification function sets can be set up. Depending on the environmental data available and the level of detail of community discrimination, a selection of the set of classification functions can be made.

Based on the data collected during the HABITAT project, eight sets of classification functions were derived: four sets of discriminating habitat characteristics at two different levels of community detail (Degraer *et al.*, 2002). Two sets of discriminating habitat characteristics take into account chemical environmental variables, such as nutrients, while both other sets only use physical variables, such as bathymetry and sedimentology. Since no chemical variables were measured within the framework of this project, only the classification functions, derived from the latter sets, can be tested along the whole Belgian coast.

To extend the HABITAT model to a larger geographical area, a new set of classification functions was set up. Therefore, all data on the macrobenthos and its habitat, collected at the Belgian Continental Shelf (BCS) between 1994 and 2000 (> 1000 samples), were used to set up a classification function set to discriminate between the *A. alba – M. bidentata*, the *N. cirrosa* and the *O. limacina – G. lapidum* community using only the sediment's mud content (0 – 63 µm) and median grain-size.

HABITAT MODEL (DEGRAER *ET AL.*, 2002): APPLICABILITY ALONG THE FULL BELGIAN COAST

At first the applicability of the Habitat model, set-up for use in the Western Coastal Banks (Degraer *et al.* 2002), was tested along the full Belgian coast. Generally, low overall accuracies (max. 71 %) were found (Table IV). A strong community / species association dependent accuracy was found for each of the models: highest accuracies were found for the *O. limacina – G. lapidum* community (min. 75 %), while the *A. alba – M. bidentata* community and the *M. mirabilis* species association had the lowest accuracies (max. 43 %).
Samples from the new community were generally assigned to the *A. alba – M. bidentata* community (71 – 92 %).

Table IV. Overview of the *a priori* accuracy (%) of the four classification function sets. M3a to M4b: Classification function set 3a to Classification function set 4b, according to Degraer *et al.* (2002).

MODEL ACCURACY		Four groups		Three groups	
		M3a	M4a	M3b	M4b
a priori	*A. alba – M. bidentata* community	43	29	43	29
	N. cirrosa community	78	44	89	44
	O. limacina – G. lapidum community	75	88	75	75
	M. mirabilis species association	43	29	---	---
	Overall	61	48	71	50

HABITAT MODEL: SPATIAL EXTENSION

Based on the data on the macrobenthos and its habitat characteristics, collected from the full BCS during the period 1994 – 2000, a set of classification functions was derived (Table V). The *a posteriori* accuracies of the classification functions for each of the communities were: 75 % (*A. alba – M. bidentata* community), 85 % (*N. cirrosa* community), and 81 % (*O. limacina – G. lapidum* community).

Table V. The habitat characteristic environmental variables of the three known soft-sediment macrobenthic communities of the Belgian Continental Shelf (median grain-size (D_{50}), µm, and mud content, volume %), with indication of their community specific weight in the classification functions.
Parameter assessment based on all available macrobenthic data from the Belgian Continental Shelf.

	A. alba – M. bidentata community	*N. cirrosa* community	*O. limacina – G. lapidum* community
D_{50}	0. 0833	0.0958	0.1395
Mud content	0.8998	0.3523	0.4808
Constant	-12.9271	-14.3496	-291423

When applying the classification functions to the data collected during this study, a high to *very* high *a priori* accuracy was found for all three communities included in the model: *A. alba – M. bidentata* community, 86 %; *N. cirrosa* community, 89 %; *O. limacina – G. lapidum* community, 50 % (Table VI). Being a transition between the *A. alba – M. bidentata* and the *N. cirrosa* community, samples from the *M. johnstoni* transitional species association were assigned to both communities with an overall cumulative accuracy of 86 %. Samples from the newly discovered macrobenthic community were assigned to the *A. alba – M. bidentata* community for 100 %.

Table VI. Relative assignment (%) of the samples from this study to one of the three macrobenthic communities at the BCS, based on the classification functions. *A. alba – M. bidentata* community: n = 7; *M. johnstoni* species association: n = 7; *N. cirrosa* community: n = 9; *O. limacina – G. lapidum* community: n = 8; New community: n = 24.

	A. alba – M. bidentata community	*N. cirrosa* community	*O. limacina – G. lapidum* community
A. alba – M. bidentata comm.	86	0	14
M. johnstoni spec. ass.	14	72	14
N. cirrosa comm.	0	89	11
O. limacina – G. lapidum comm.	12	38	50
New community	100	0	0

Unlike samples belonging to a community included in the model, samples from the new community are characterized by a large Mahalanobis distance from the communities' centroids[1]. The *a posteriori* measured Mahalanobis distances from the samples of each community to their respective community centroid is small (averages: *A. alba – M. bidentata* community, 7 (SD, 8); *N. cirrosa* community, 5 (SD, 7); *O. limacina – G. lapidum* community, 9 (SD, 8)), compared to those of the new community (average distance from *A. alba – M. bidentata* community centroid: 122, SD: 209). Although the samples, biologically belonging to the new community, are assigned to the *A. alba – M. bidentata* community by the model, they can be discriminated from true samples from the *A. alba – M. bidentata* community by means of their large Mahalanobis distances. When assigning each sample with a Mahalanobis distance > 50 to the new community, a good classification (accuracy: 83 %) of the samples from the new community is achieved.

Taking into account the new community, a new predictive model was developed (Table VII). The *a posteriori* accuracies look very promising: *A. alba – M. bidentata* community, 83 %; *N. cirrosa* community, 70 %; *O. limacina – G. lapidum* community, 82 %; New community, 75 %. An overall *a posteriori* accuracy of 78 % was found. Because of the absence of new data, *a priori* accuracies were not determined yet.

[1] The habitat characteristic variables can be regarded as defining a multidimensional space in which each sample can be plotted. Within this multidimensional space, the community centroid represents the mean for all samples of each macrobenthic community. The Mahalanobis distance is defined as the distance of a sample from a community centroid. This measure thus provides an indication of whether or not a sample is an outlier within the multidimensional space.

Table VII. The habitat characteristic environmental variables of all four soft-sediment macrobenthic communities of the Belgian Continental Shelf (median grain-size (D_{50}), µm, and mud content, volume %), with indication of their community specific weight in the classification functions.

	A. alba – M. bidentata community	*N. cirrosa* community	*O. limacina – G. lapidum* community	New community
D_{50}	0.0841	0.0973	0.1404	0.0856
Mud content	0.3321	0.2968	O.4277	0.9135
Constant	-11.6570	-14.7982	-29.3235	-27.8975

Conclusions

Although being useful within the area of the Western Coastal Banks, the HABITAT model cannot be applied outside the area, as demonstrated by (1) the low accuracies for the communities taken into account in the HABITAT model and (2) the impossibility to predict the presence of communities not taken into account in the model.

The low accuracies can probably be explained by the area-specific set of environmental variables, determining the distribution of the communities: a spatial extension of the HABITAT model is thus indispensable. Therefore, a dataset, including samples from all over the BCS, was used to set up a new model. Using this new model, the distribution of the communities, present in the dataset, can accurately be predicted (*a priori* accuracy: 50 – 89 %). Unfortunately, the newly discovered community was not present in the dataset and could thus not be identified by the model. This problem was solved with the use of the Mahalanobis distances: unknown communities are inhabiting a different habitat, than included in the model, and will thus be spaced distant from any group centroids. Using this technique, an accuracy of 83 % for the new community was found.

A final model, taking into account all communities (incl. new community), with an overall *a posteriori* accuracy of 78 % was set up.

EVALUATION OF THE MACROBENTHIC SIDE-SCAN SONAR INTERPRETATION (MSSSI) ALONG THE BELGIAN COASTAL ZONE

Introduction

Starting from a geological expertise, two approaches were followed in the interpretation of side-scan sonar imagery in terms of the occurrence of macrobenthic communities (Degraer *et al.* 2002). The first approach was based on a direct correlation of high abundances of macrobenthos with a specific acoustic facies. A medium to high reflectivity patchy to mottled texture was correlated with the *A. alba – M. bidentata* community. One of the indicator species of this community is the tube-building polychaete *Lanice conchilega* and it was put forward that dense fields can create local sediment accumulations that side-scan sonar can detect . Secondly, an indirect link was sought based on the known correlations of the macrobenthos versus sedimentology on the one hand and sedimentology versus side-scan sonar imagery on the other hand. This means that if side-scan sonar imagery can be interpreted in terms of sediment nature, the occurrence of macrobenthic communities can be predicted. To facilitate this process, a standardised interpretation was put forward through the set-up of a table with different criteria and interpretation keys (Table VIII). Finally, the Table provided a discrimination of acoustic facies into a maximum of classes that could also be linked to a macrobenthic community preference. It needs emphasis that the set-up of the Table was a reflection of the experience that was gained within the Habitat area. The Table is three-fold:

1. The descriptive part is meant as a general guide to evaluate the imagery. The divisions made are such that anyone should be able to carry out this process. The discrimination into acoustic facies is based on differences in reflectivity, texture and a primary descriptor. The reflectivity is divided into low, medium and high and is related to the darkness of the imagery (signal amplitude). It should be evaluated relatively along the imagery as the backscattering is not standardized and is acquisition dependent (!). The texture can primarily be described as smooth, grainy, coarse to rough. A smooth texture means that almost all of the acoustic energy is lost, absorbed by loose to loosely packed sediments. These can easily be distinguished and are generally associated with fluid mud layers or strongly homogenised silt to fine sandy seafloors. A rough texture means that most of the energy is reflected, hence associated with hard substrates that can be localised shell accumulations or gravel. Patterns relate to the organisation of features on an image. An image can be featureless, or with irregularities or organised. The primary descriptors include the occurrence of lineations whereby bedform features are most common.

2. Geo-environmental interpretative keys are introduced in the Table to be able to maximally describe the variability of the area. This led to a maximum of 21 classes or acoustic facies that were defined. However, the number of classes can still increase depending on the ability of the Table to classify environments. Depending on the application, classes can also be merged. The validity of this part is crucial as it facilitates a further set-up of a diversity of correlations.

3. Depending on the application, the Table can be further translated to meet specific needs. In the framework of the Habitat related projects, the link towards the occurrence of macrobenthic communities is worked out.

Results

ACOUSTIC FACIES MODELLING AND ITS TEMPORAL VARIATION

To validate and upgrade the value of, especially, the interpretative part of the Table and to decrease its subjectiveness, it was felt necesarry to carry out a quantitative evaluation. However, before any test or evaluation of the Table could be performed, a general check-up of the Table was necessary. Therefore, it was chosen to treat data from all the campaigns carried out throughout the Habitat projects (period 1999-2000), and to structure it into a Geographical Information System (GIS, Arcview 3.2). This also included the georeferenced multibeam bathymetry and side-scan sonar imagery. As such, a broad comparative database was created and enabled to maximaly ground-truth and characterise the different acoustic facies. Moreover, a module 'Habitat Digitizer Extension' (NOAA, National Oceanic and Atmospheric Administration, US) was implemented allowing to structure the delineated acoustic facies into a hierarchical Habitat classification scheme. There are several advantages to using classification schemes with a hierarchical structure including: the detail of habitat categories that can be expanded or collapsed to suit user needs, the thematic accuracy of each category/hierarchical level can be determined, and additional categories can be easily added or deleted at any level of the scheme according to the needs. Spatial analysts (Arcview) tools allowed to test the classification scheme for the different environments and enabled to define quantitative relations between the acoustic facies and the geo-environmental variables. Most attention was paid to the validation of the sedimentological interpretation of the acoustic facies, as this variable is most often crucial in marine environmental studies.

In this report, emphasis is put on the results of the evaluation of the Table along the Belgian coastal zone. An extensive evaluation based on all observations within the Habitat related projects can be found in Vanstaen (2002). Moreover, the use of the Table has been additionally tested along the Trapegeer slope in May 2001 and has been described in Verfaillie (2002). The differences that were encountered were verified and if applicable integrated in the Table. As such, the Table is a sound basis for the multidisciplinary interpretation of side-scan sonar imagery.

The strength of interpreting side-scan sonar imagery in terms of acoustic facies is also that it can cope with temporal variations. The imagery itself represents surface characteristics and as such, temporal variations are clearly seen. To a certain extent an interpretation towards an acoustic facies integrates small-scale variations. On the other hand, if the imagery of a location gives a complete different acoustic facies, the underlying processes need to be investigated. This can be demonstrated based on the data in the Habitat area. Figure 11 and 12 show the acoustic facies for the imagery of October 1999 and March 2000; Figure 13 gives the variability in acoustic facies between both campaigns.

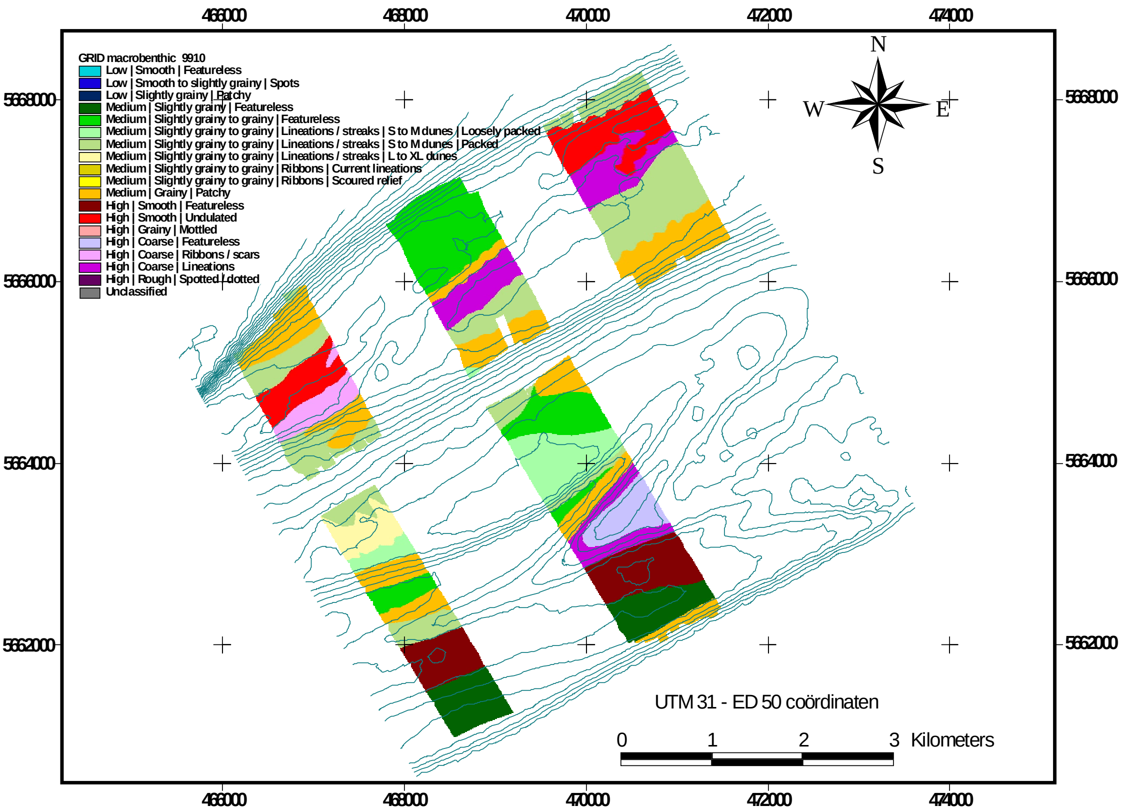

Figure 11. The discrimination in acoustic facies based on the side-scan sonar imagery of October 1999.

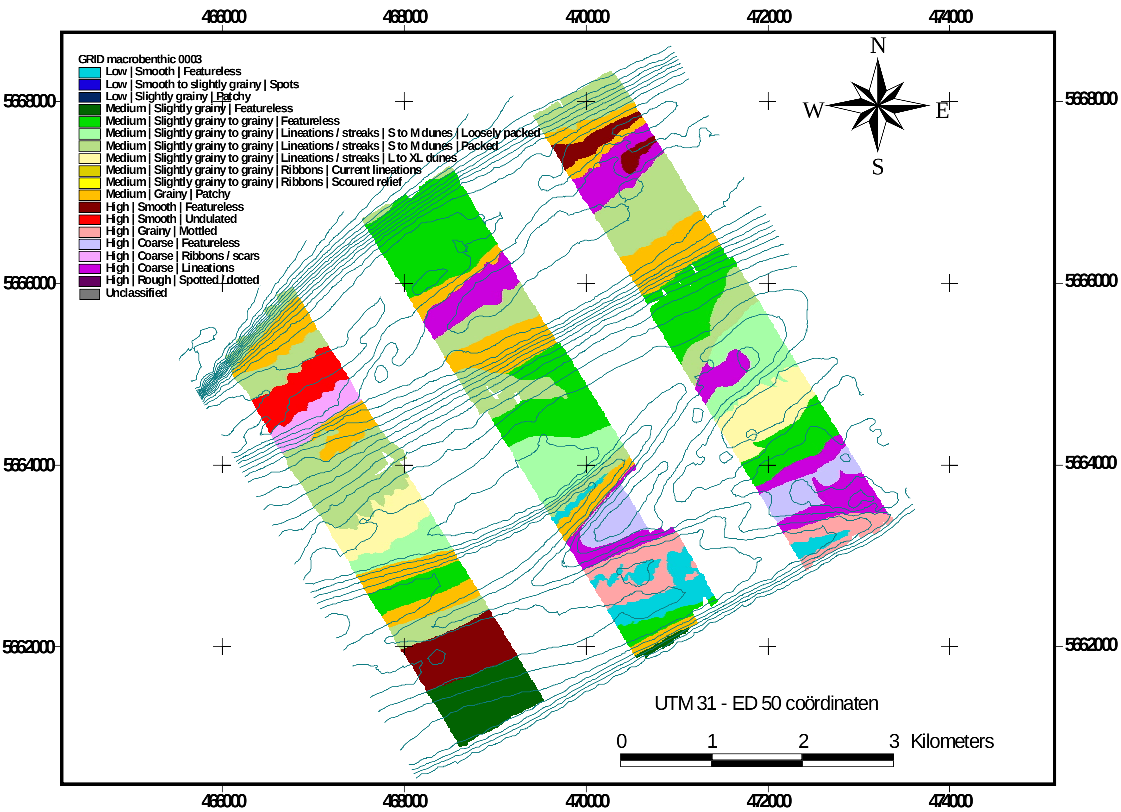

Figure 12. The discrimination in acoustic facies based on the side-scan sonar imagery of March 2000.

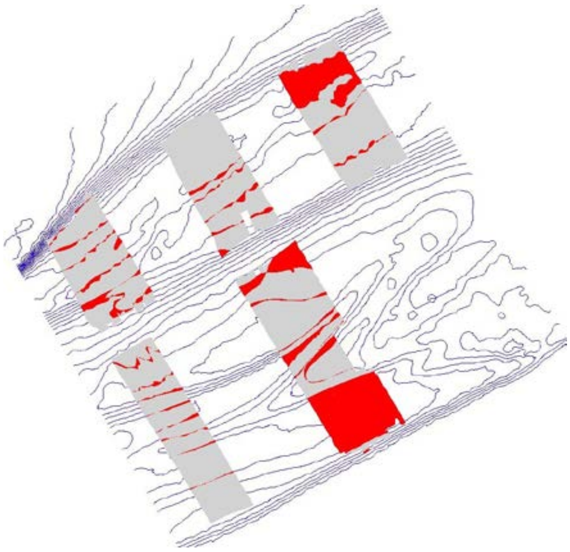

Figure 13. Temporal variability of the acoustic facies. The red colour shows the differences in the interpretation in acoustic facies from March 2000 compared to October 1999 (Vanstaen 2002).

Two major differentiations are seen: the small red lines and the broad red areas. The smaller lines (+/- 50 m in width) occur at the transitions of the acoustic facies and are due to small variations in the delineations. They do show an overall shift in a NW direction and may be due to small topographic changes. The larger red areas are associated with a true change in acoustic facies. In the Potje swale, the featureless, smooth high reflectivity facies changed into a featureless, smooth low reflectivity facies. This was correlated with the presence of a fluid mud layer likely deposited after a period of 4 days of rather mild, but consistent NE wind conditions. Another significant change in acoustic facies is observed along the top of the Trapegeer sandbank (central area) where the zone of small to medium dunes along the topzone was southwards enlarged, but with a decrease of the biologically altered facies (facies 12) that was replaced by a featureless acoustic facies. In the deepest part of the Westdiep swale (E), part of the undulating seafloor had become featureless, though flanked by a biologically altered facies.

To explain the differences in acoustic facies, the hydro-meteorological conditions were analysed for the period preceding the October 1999 and March 2000 campaigns. Figure 14 and 15 give the wind characteristics from a period around both campaigns. From this, it can generally be stated that the October 1999 campaign fell within a period of less pronounced hydro-meteo conditions. All wind directions tend to occur and no strong wind forces were encountered. February and March 2000 did show a preferred wind direction from a SSW to SW direction with more peak winds of more than 10.8 m/s. Modelling of the residual water transport between both campaigns (MUMM model with a 250 m grid) revealed a zonation in the Westdiep swale, delineating the deeper channel from the plateau-like morphology that forms the transition towards the Trapegeer. Interestingly, the zone where the acoustic facies had changed, corresponds with the zone where the highest residual water transport was calculated (see Degraer *et al.* 2002).

From the evidence presented, it can be said that March 2000 was more dynamic than October 1999. Although, no major changes in acoustic facies were observed, the higher dynamics likely explain the extension of the field of small to medium dunes centrally along the Trapegeer. For the Westdiep swale, it should be further investigated whether the dominant SW conditions resulted in more suspended load that was more efficiently trapped by the benthic communities; hence giving rise to a more patchy nature of the acoustic facies.

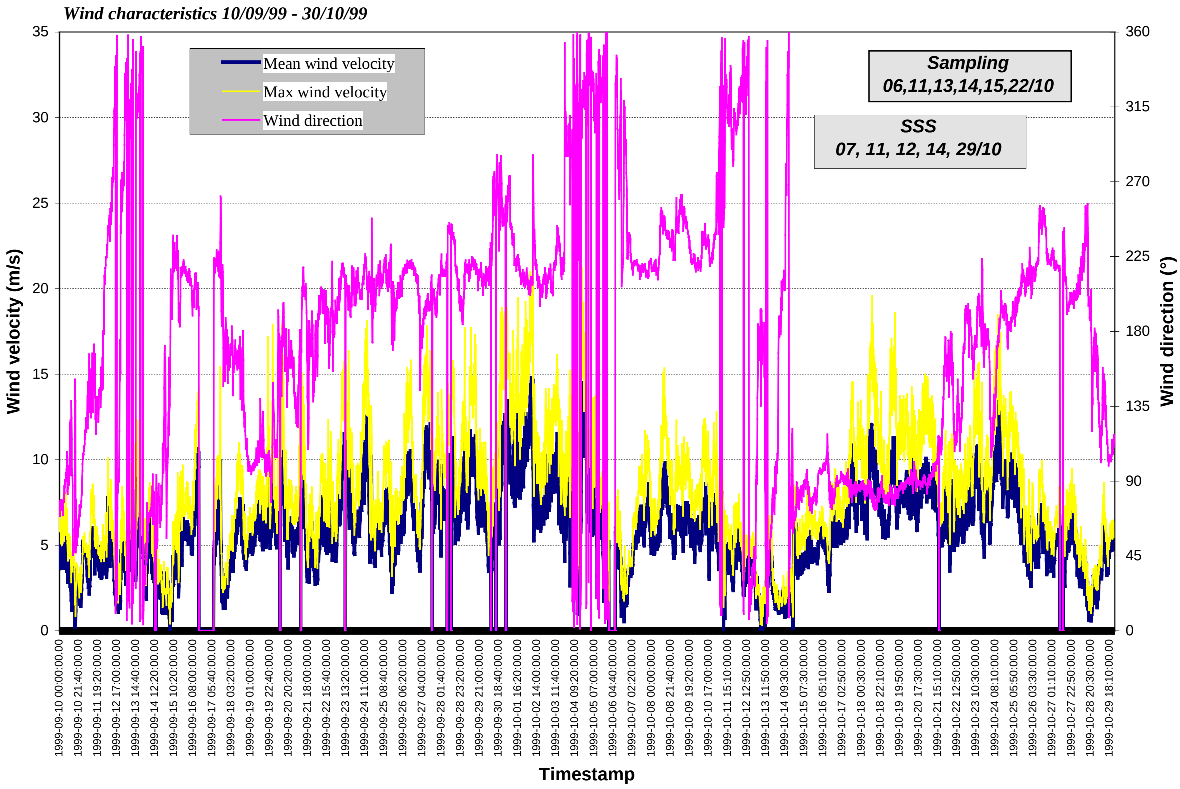

Figure 14. Wind characteristics relevant for the October 1999 campaign (Data source: Ministry of the Flemish Community, Waterways Coast Division).

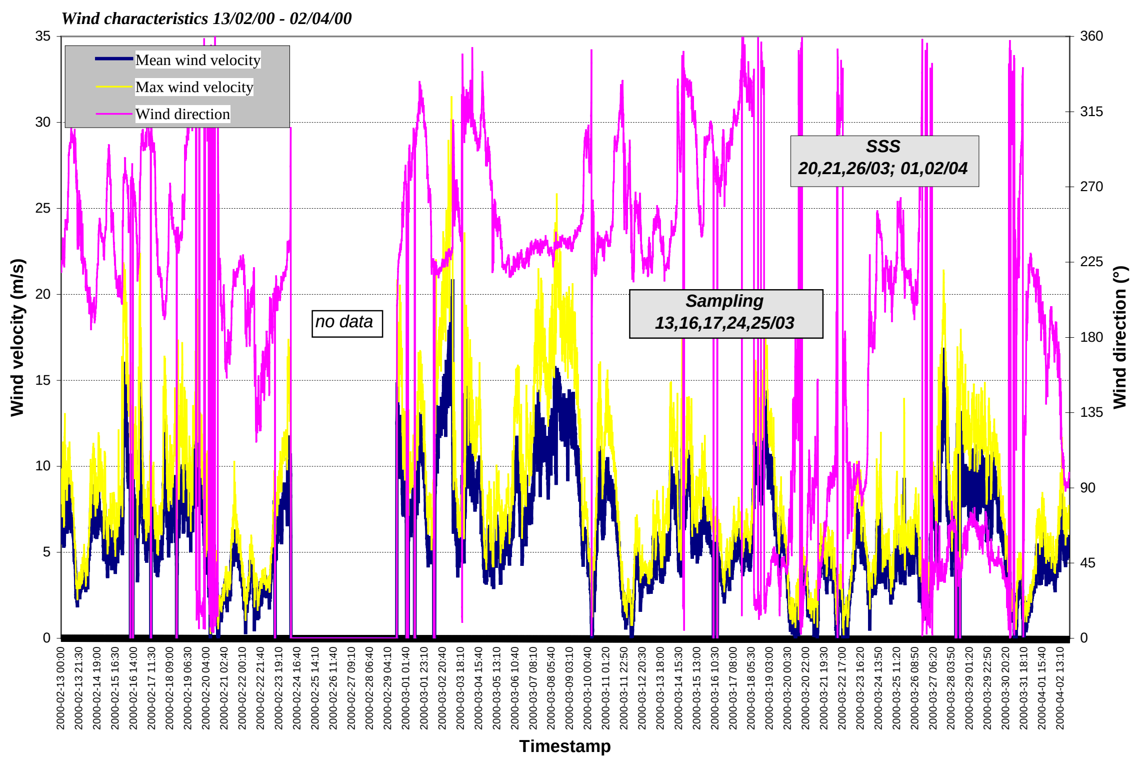

Figure 15. Wind characteristics relevant for the March 2000 campaign (Data source: Ministry of the Flemish Community, Waterways Coast Division).

MACROBENTHIC SIDE-SCAN SONAR INTERPRETATION (MSSI)

In the following sections, the relation is shown between macrobenthos and the sediment nature followed by the relation between sedimentology and side-scan sonar imagery. Based on these relationships, the preferred macrobenthic community can be predicted from side-scan sonar imagery. Evidence will also be presented of direct observations of macrobenthic communities.

Macrobenthos versus sedimentology

The habitat of each community and species association can be discriminated based on basic sedimentological variables (Figure 16). A gradual decrease of the median grain-size from the *O. limacina – G. lapidum* community (1) towards the "new community" (5) was found. Generally, an inverse trend of the sediment's mud content within the five communities, only disturbed by the relatively high mud content in the *O. limacina – G. lapidum* community, was found.

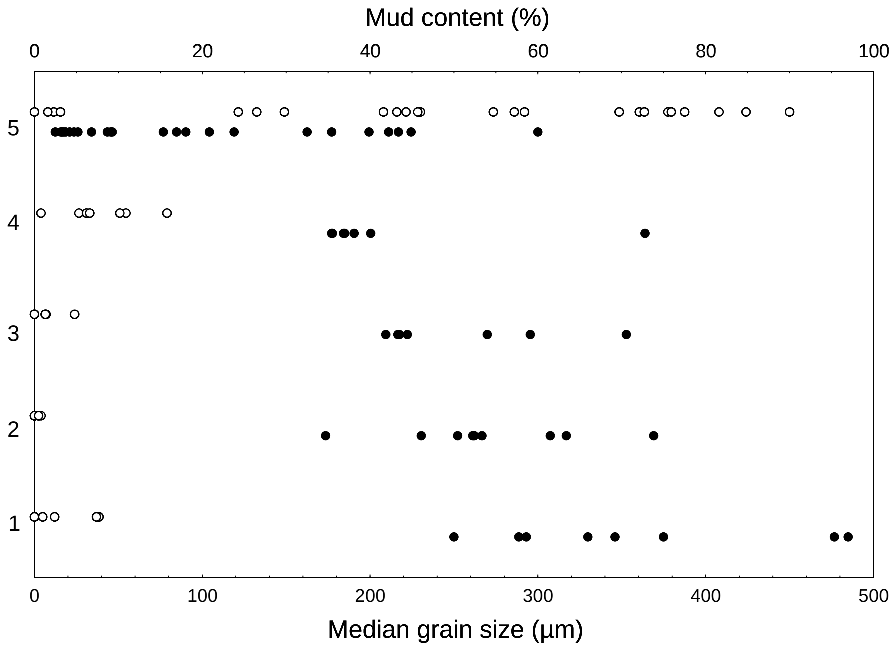

Figure 16. Distribution of the median grain-size (closed circles) and mud content (open circles) of the sediment of each of the five species associations. 1, *O. limacina – G. lapidum* community; 2, *N. cirrosa* community; 3, *M. johnstoni* species association; 4, *A. alba – M. bidentata* community; 5, new community.

Side-scan sonar versus sedimentology

Interpreting the sediment texture of side-scan sonar recordings is not an easy task and much is dependent on the dynamics of the area. Normally high reflective sediments tend to be associated with coarse sediments whilst finer sediments normally induce a low backscattering of the acoustic signal. However, the compaction of sediments is of higher priority to determine the backscatter. Areas with sediments with higher silt-clay percentages such as in the swales have a higher degree of compaction, which is translated into a higher reflectivity.

In Vanstaen (2002), an analysis has been made of the acoustic facies against the median grain-size based on the observations along the Western Coastal Banks and including as well the October 1999 as the March 2000 data (Figure 17).

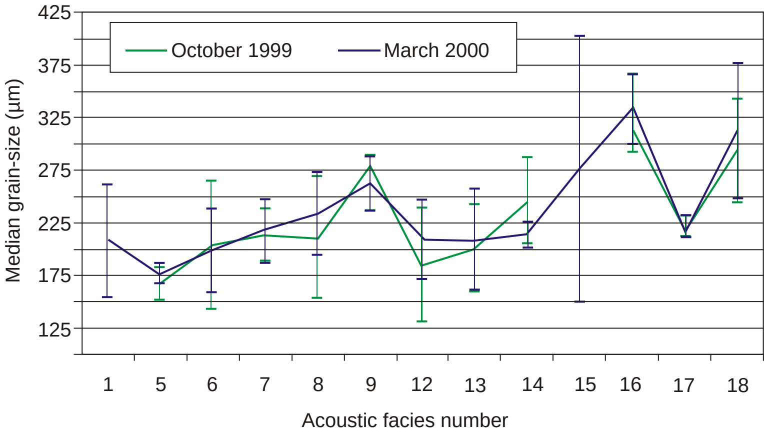

Figure 17. The acoustic facies numbers relevant for the October 1999 and March 2000 dataset in the Habitat area against the median grain-size with an indication of the sample standard deviation (Vanstaen 2002).

The figure shows a clear trend in the acoustic facies and confirms that generally the higher the reflectivity, the coarser the sediments are, albeit with bias imposed. The same kind of analysis has been done on the dataset of October 2000 and is represented in Figure 18. The same trends are clearly seen, regardless of the completely different depositional environments. Although, more ground-truthing is necessary for a sound statistical analysis, this confirms the validity of the Table to predict sediment grain-size.

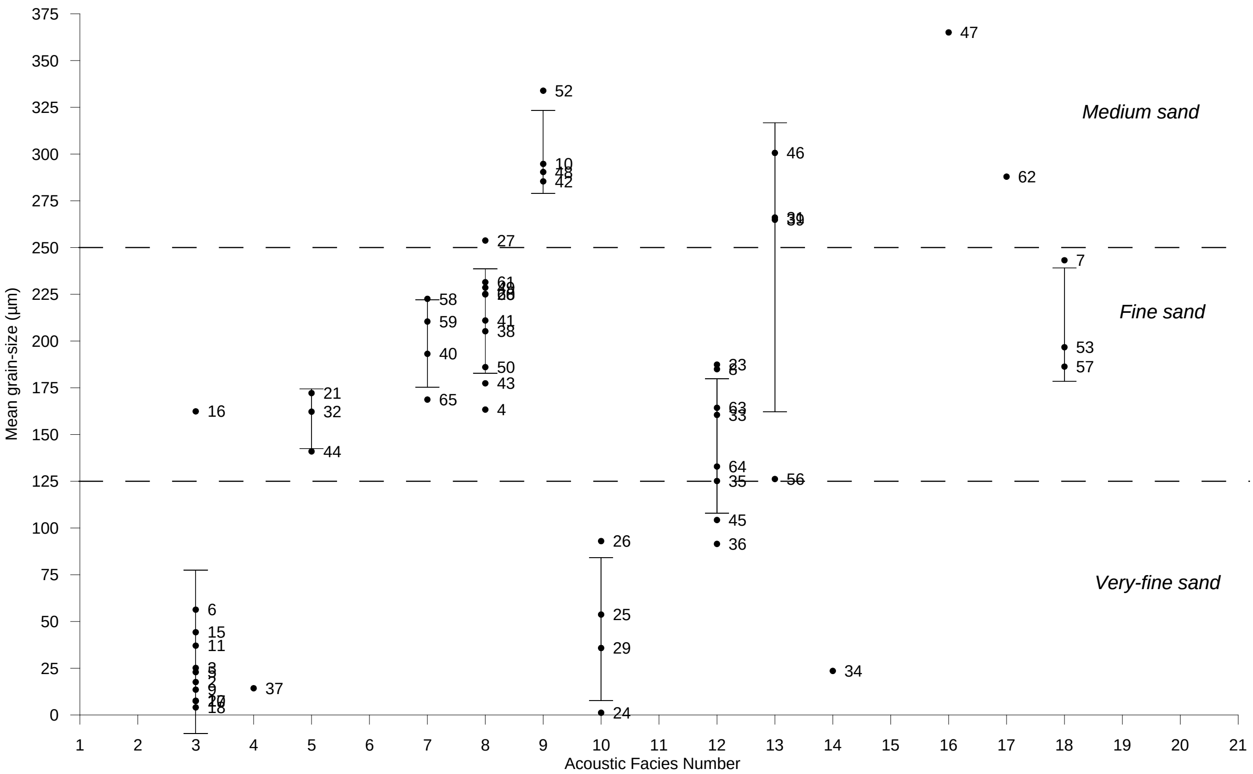

Figure 18. The acoustic facies number relevant for the October 2000 dataset against the mean grain-size with an indication of the sample standard deviation. The annotation refers to the sample number.

Figure 18 shows a plot of the acoustic facies number against the mean grain-size with an indication of the sample standard deviation. From this, a general coarsening trend is shown with an increasing number of acoustic facies or with increasing reflectivity, albeit with a break in the trend from acoustic facies 10 onwards. This break is due to the fact that the reflectivity is also function of the packing of the sediments. As such compacted very-fine to fine sands have a higher reflectivity than recently deposited medium sands.

Acoustic facies 3 is clearly representative of sediments with a mean grain-size within the very-fine sand range; the silt-clay percentage is generally high. Still, it needs emphasis that the low reflectivity facies are difficult to quantify as the muddy upper surface absorbs all energy whilst the sampled sediments, reflecting the upper 10 cm, do not necessarily completely constitute of mud. A consistent increase in grain-size is clearly seen for the medium reflectivity acoustic facies 5 to 9 showing that the largest bedforms constitute of medium sands. Acoustic facies 10 and 11 are difficult to quantify as they correspond with an alternance of higher and lower reflectivity bands implying that the grain-size is largely dependant on the band in which the sample was taken. A coarsening trend is again seen for the acoustic facies 10 to 13. For the acoustic facies 14 to 18 only a minority of samples is available and as such no conclusive statement can be made.

Side-scan sonar versus macrobenthos

In Degraer *et al.* (2002), it was already mentioned that the ability of side-scan sonar technology to directly predict the occurrence of macrobenthos is largely related to the density of the species involved. In particular, it was shown that dense fields of the tube-building polychaete *Lanice conchilega*, an abundant species of the *A. alba* – *M. bidentata* community, gave rise to a medium to high reflectivity patchy to mottled texture on the sonar imagery (acoustic facies 12). This pattern could be found along the whole Belgian coast and was often much more pronounced than the facies described for the Western Coastal Banks. Figure 19 is a zoom into this acoustic facies and clearly shows the particularities in texture and pattern that can not be related to known physical processes.

From the quantitative analysis of the acoustic facies versus its physical meaning (Vanstaen 2002), it was most striking that acoustic facies 12 can be correlated with slope environments. Figure 20 demonstrates this for the data in the Habitat area. This sheds new light on the understanding of the habitat preferences of macrobenthic communities and further research is needed on the structuring controls.

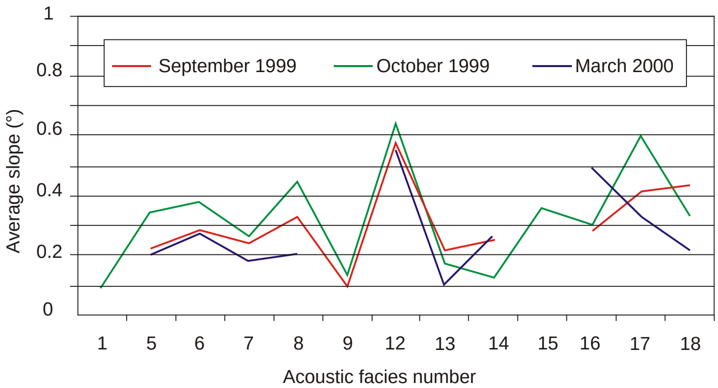

Figure 20. Relation between the acoustic facies number and the average slope of the seafloor based on the data in the Habitat area (Vanstaen 2002).

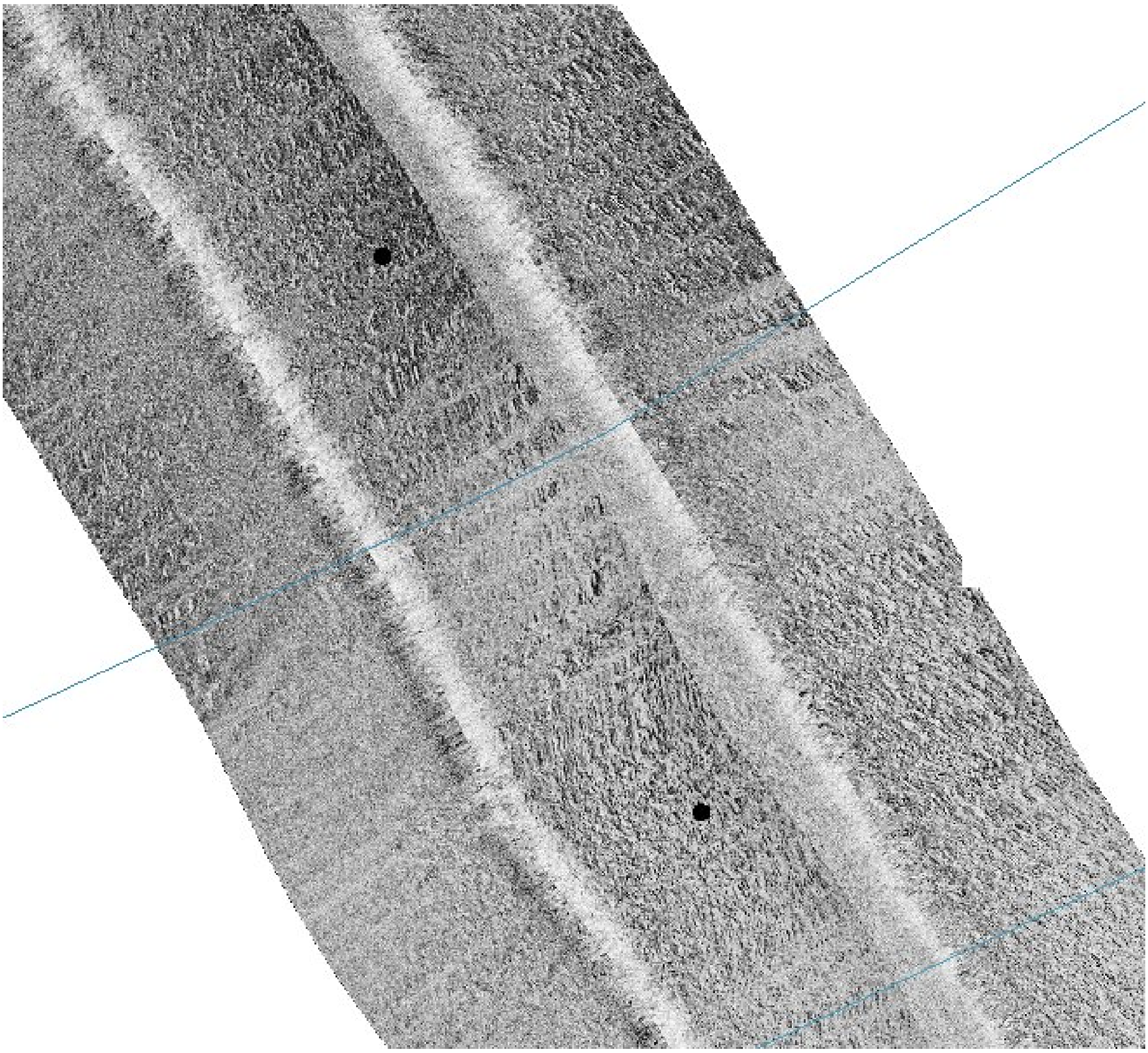

Figure 19. An example of the texture and pattern of acoustic facies 12. The imagery was acquired along the transition zone from the Kleine Rede to the shoreface. The upper black dot is sample number 36; the lower one 35. The blue contour line represents – 9 m MLLWS.

If the macrobenthos data acquired in the present study, and covering the whole Belgian coast, is plotted against the acoustic facies they occur in, it becomes clear that indeed acoustic facies 12 is very rich and dense in macrobenthos. This confirms that this facies is indeed strongly biologically influenced. The facies is in particular related to the occurrence of the *A. alba – M. bidentata* community (Figure 21).

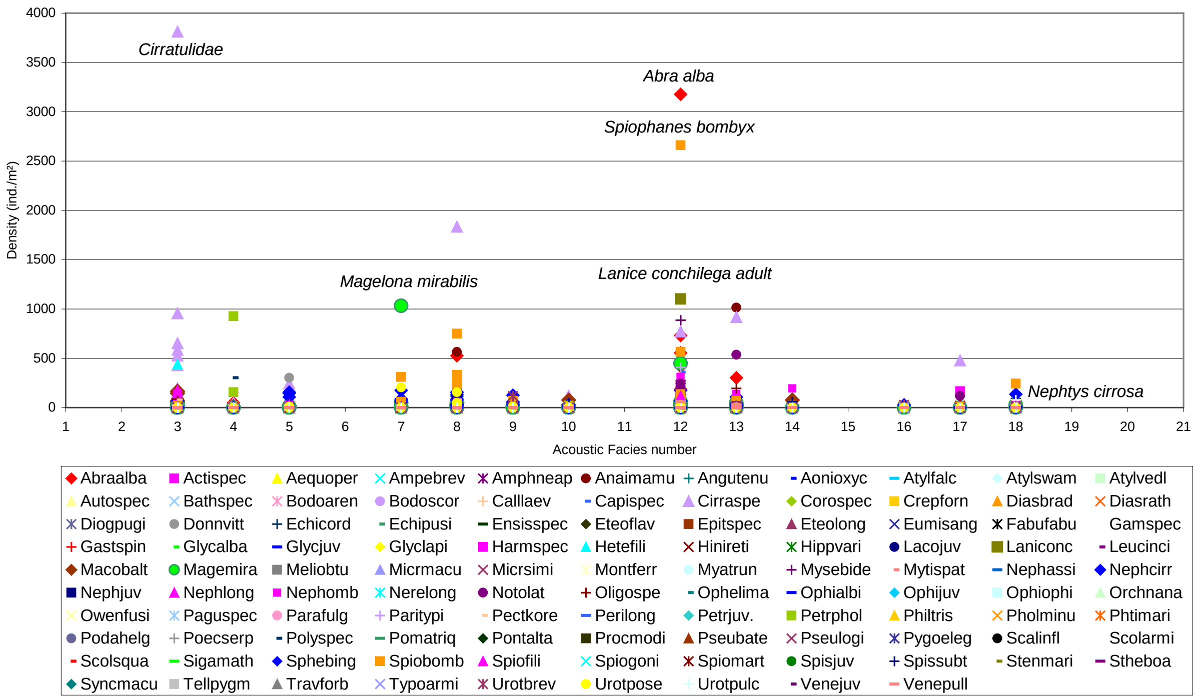

Figure 21. The acoustic facies number against the densities in individuals per m² . An annotation is given for the species with the highest densities.

Interestingly, acoustic facies 13 is also relatively rich; although it is characterised by a featureless to slightly undulating pattern. Probably, it can be regarded a transient zone.

The acoustic facies 7 to 9 are those representative of zones with bedforms ranging from small to medium dunes up to very-large dunes. The richest is clearly acoustic facies 8 and demonstrates that dune areas can be quite diverse and rich in macrobenthos. Acoustic facies 9 is clearly inferior in macrobenthos occurrence. This facies especially characterises the very-large dunes that are associated with high dynamic environments and coarser sediments.

Most intriguing, is the correlation of the high density of the polychaete *Cirratulidae* with the acoustic facies 3. This facies is correlated with the occurrence of loosely packed silt to fine sand and dominates the eastern nearshore area of Belgium. The sediments have a high silt-clay composition and muddy appearance.

Towards the higher reflectivity imagery, acoustic facies 17 and 18 are most striking. Apparently, the species are adapted to the strong bottom tidal currents characterising these facies. More samples are however needed for a good validation of these facies.

Figure 22 represents the macrobenthic community against the acoustic facies for the data acquired in October-November 2000 along the transects in the near coastal zone also including the 2 transects in the Habitat area. From this, it is clear that an acoustic facies does not represent a unique macrobenthic community, but merely indicates a preferred community. It needs to be mentioned that a discrimination into acoustic facies is an integration of several parameters, hence a straightforward correlation may be blurrred.

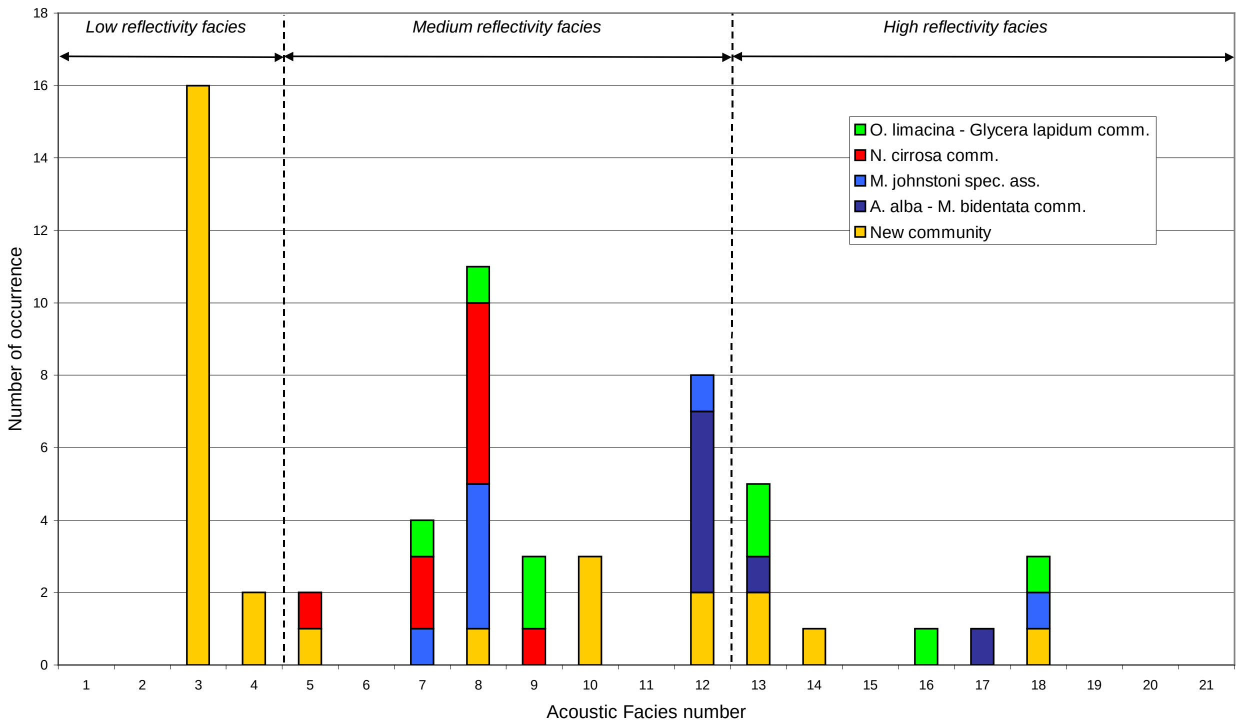

Figure 22. Acoustic facies against the macrobenthic community differentiation for the transects sampled in November 2000 and spread along the coastal zone.

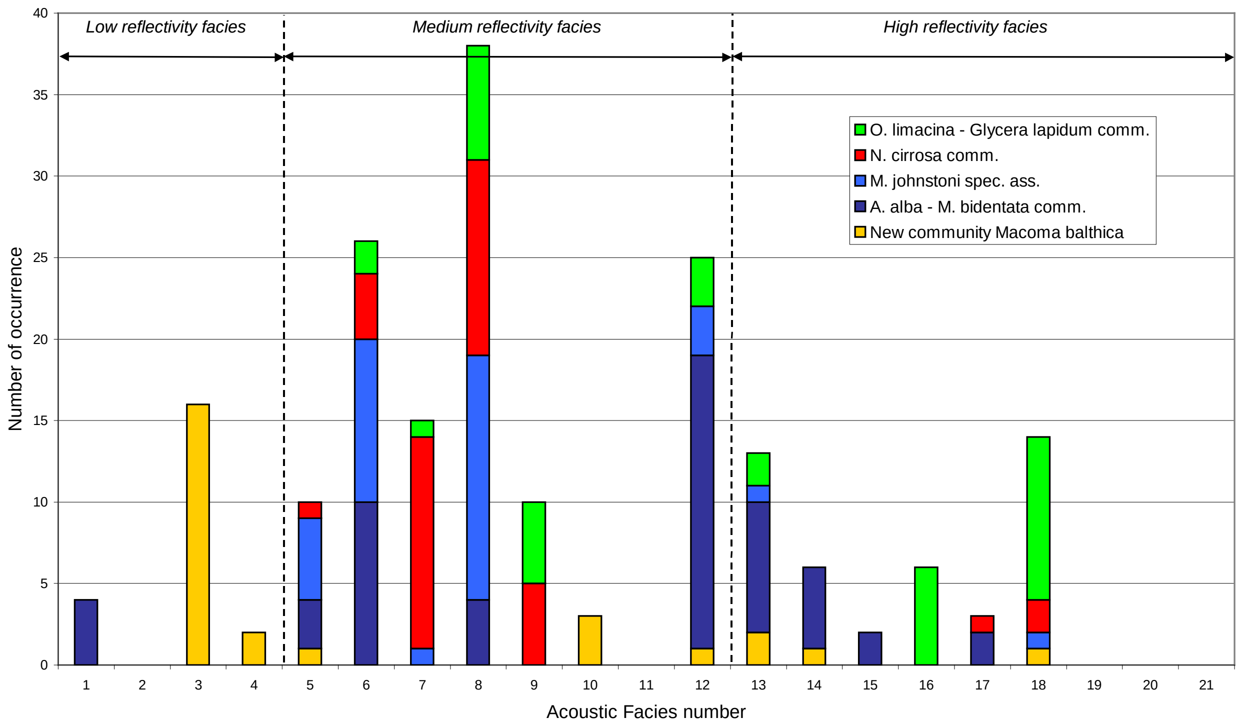

Figure 23. Acoustic facies against the macrobenthic community differentiation for all the data within the Belgian coastal zone.

Although, the new community '*M. balthica'* is uniquely associated with the low reflectivity facies, it is clear that it also occurs in the different ranges of acoustic facies; as such it becomes predominantly present in the coastal zone. The association with the low reflectivity facies correlates well with the biological findings relating this community to muddy sediments. Still, it may not be bound to a specific habitat, defined by bottom characteristics, and it might be that a frequent overtopping by non-permanent muddy sediments is already responsible for creating a habitat niche for this community.

If also the data from the previous Habitat project (Degraer *et al.* 2002) is included in the analysis (Figure 23), a more straightforward correlation is found between the acoustic facies and the preferred macrobenthic community. Still, it is interesting that the acoustic facies that also show the occurrence of the '*M. balthica'* community are associated with a silt-clay enrichment (Acoustic facies 12, 13, 14) or with depositional environments where material in suspension is frequently bypassed (Acoustic facies 5, 18) (see Table VIII).

A synthesis of the preferred macrobenthic community based on the side-scan sonar imagery is given through Table VIII.

An overview of the interpretation of the acoustic facies and the occurrence of macrobenthic communities is given in the Figures 24 to 27. In the Figures 28 to 38, the bathymetry together with the side-scan sonar imagery, the main sediment characteristics and the macrobenthic community are shown.

Table VIII. Standardised side-scan sonar interpretation into acoustic facies.

SIDE-SCAN SONAR										
DESCRIPTION				**INTERPRETATION**						
REFLECTIVITY	**TEXTURE**	**PATTERN**	**PRIMARY DESCRIPTOR**	**PACKING**	**BEDFORMS**	**SEDIMENT**	**PROCESSES**	**LIKELY ENVIRONMENT**	**CLASS**	**COMMUNITY PREFERENCE**
LOW	SMOOTH	Featureless		Loose		Fluid mud		Swale, flat environments, low seafloor gradient	1	NA
				Loosely packed		Mud (mainly surficial)			2	NA
	SMOOTH TO SLIGHTLY GRAINY	Spots incl.		Loosely packed		Silt to fine sand			3	E
	SLIGHTLY GRAINY	Patchy		Loosely packed		Silt to fine sand			4	E
MEDIUM	SLIGHTLY GRAINY	Featureless		Packed		Fine to medium sand with silt/clay enrichment		Shoreface	5	A (B) (E)
	SLIGHTLY GRAINY TO GRAINY	Featureless		Packed		Fine sand		Swale	6	A-B
		Lineations / streaks	Fields of aligned straight to sinuous lineations of higher reflectivity with associated acoustic shadow	Loosely packed	Small to medium dunes	Fine to medium sand	Important bedload	Flanks, areas associated with higher relief in swales	7	C
				Packed					8	A-C
				Loosely packed / packed	Large to very large dunes / compound dunes	Medium sand		Topzones	9	C-D
		Ribbons	Alternance of higher and lower reflectivity bands	Loosely packed / packed	Current lineations	Sand veneers on packed sediments	Sheet flow conditions	Channelised swale areas	10	(E)
					Scoured relief				11	B E
	GRAINY	Patchy	Circular to elongated patches with slightly different reflectivity	Packed		Very-fine to fine sand	Biologically altered	Mostly flanks of the topographic highs (high seafloor gradient)	12	B (E)
HIGH	SMOOTH	Featureless		Compact		Sand with silt/clay enrichment and high shell hash amount	Strong bottom tidal currents	Swales	13	B (E)
		Undulated							14	B (E)
	GRAINY	Mottled				Sand with silt/clay enrichment and high shell hash amount	Biologically altered / Strong bottom tidal currents	Sandbank slope / swales	15	B
	COARSE	Featureless				Coarse sand / shells		Top zone sandbanks	16	D
		Ribbons / scars	Straightlined areas with alternance of higher and lower reflectivity		Elongated bands		Current induced lag erosion / Strong bottom tidal currents	Swales	17	B
		Lineations / streaks	Irregular, small to medium dunes, straight sometimes double crested	Packed		Medium to coarse sand and shell hash	Current and/or wave induced Strong bottom tidal currents	Top zone sandbanks, higher areas in the swales, shoals	18	D (E)
						Sorted shells / shell hash			19	D
	ROUGH	Spotted / dotted	Point source reflector i.e. high reflectivity spots or speckles	Hard		Localised shell accumulations, shell hash	Strong bottom tidal currents	Small depressions	20	
						medium to gravelly coarse sands; gravel; abundant coarse material		Swales	21	

NA: Not applicable; A: *M. johnstoni spec. ass*.; B: Abra alba - *Mysella bidentata community*; C: *Nepthys cirrosa community*; D: *Ophelia limacina - Glycera lapidum community;* E: *M. Balthica community;* (): less likely

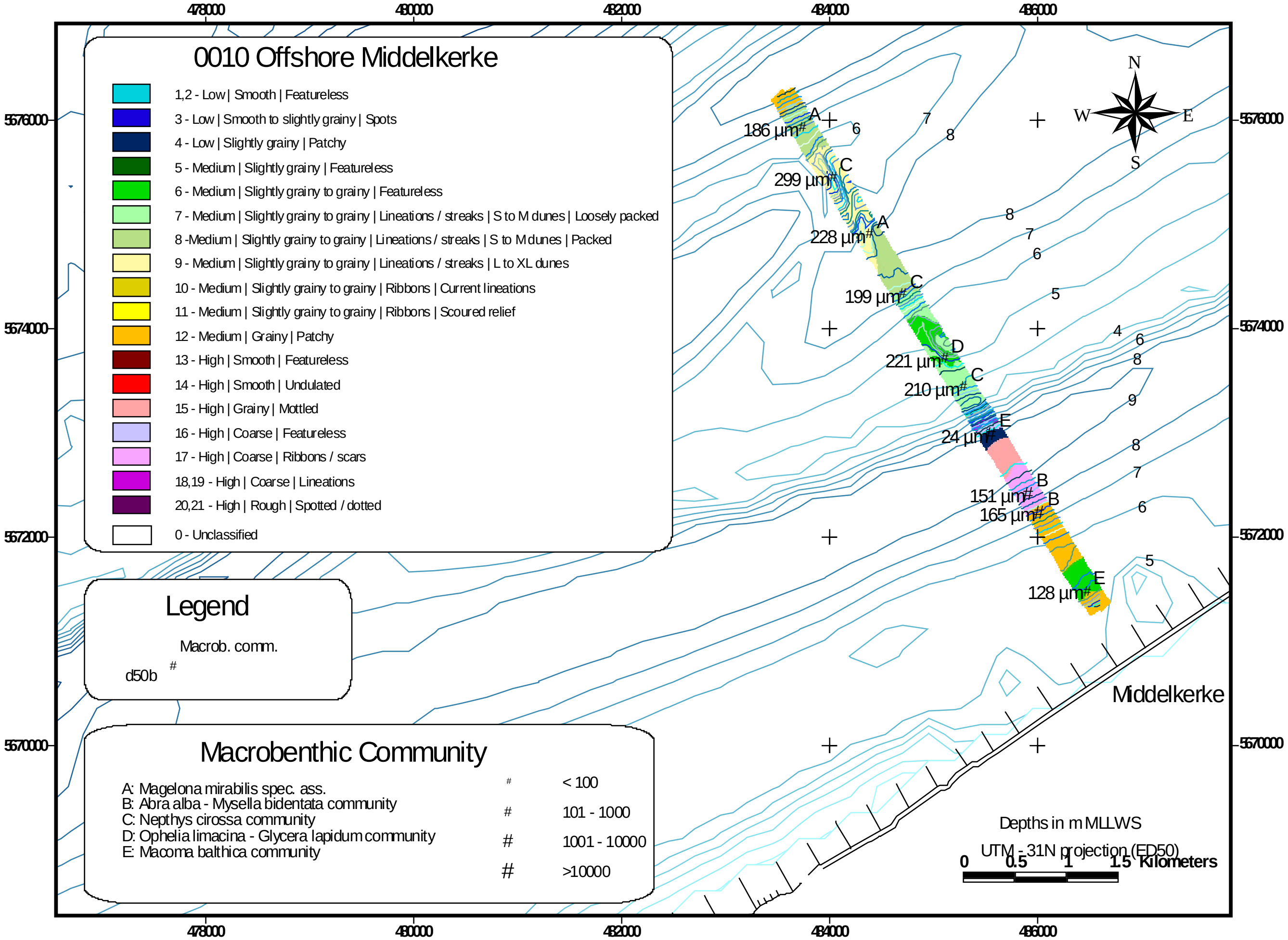

Figure 24. Standardised side-scan sonar interpretation offshore Middelkerke superimposed with the sample information.

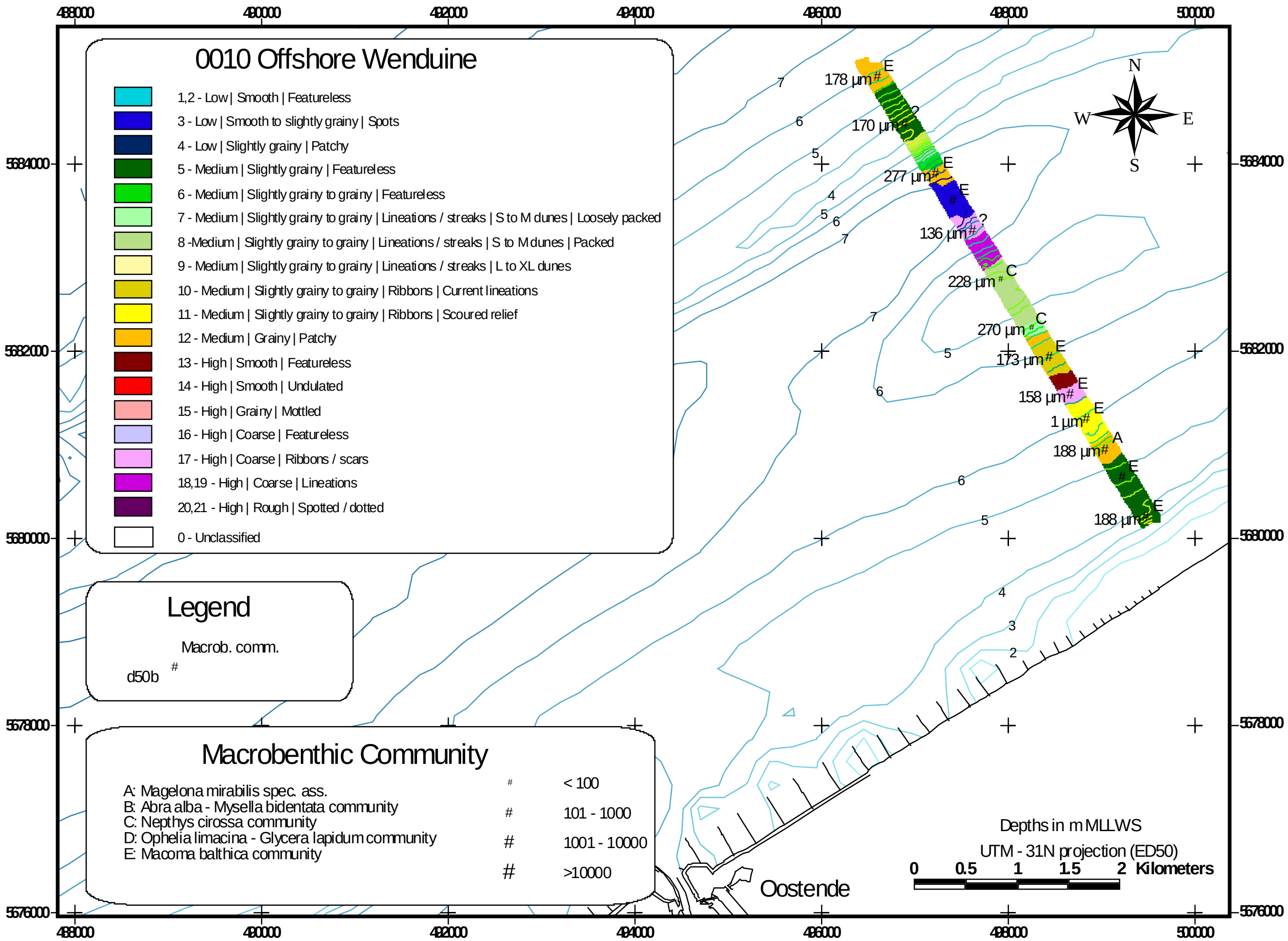

Figure 25. Standardised side-scan sonar interpretation offshore Wenduine superimposed with the sample information.

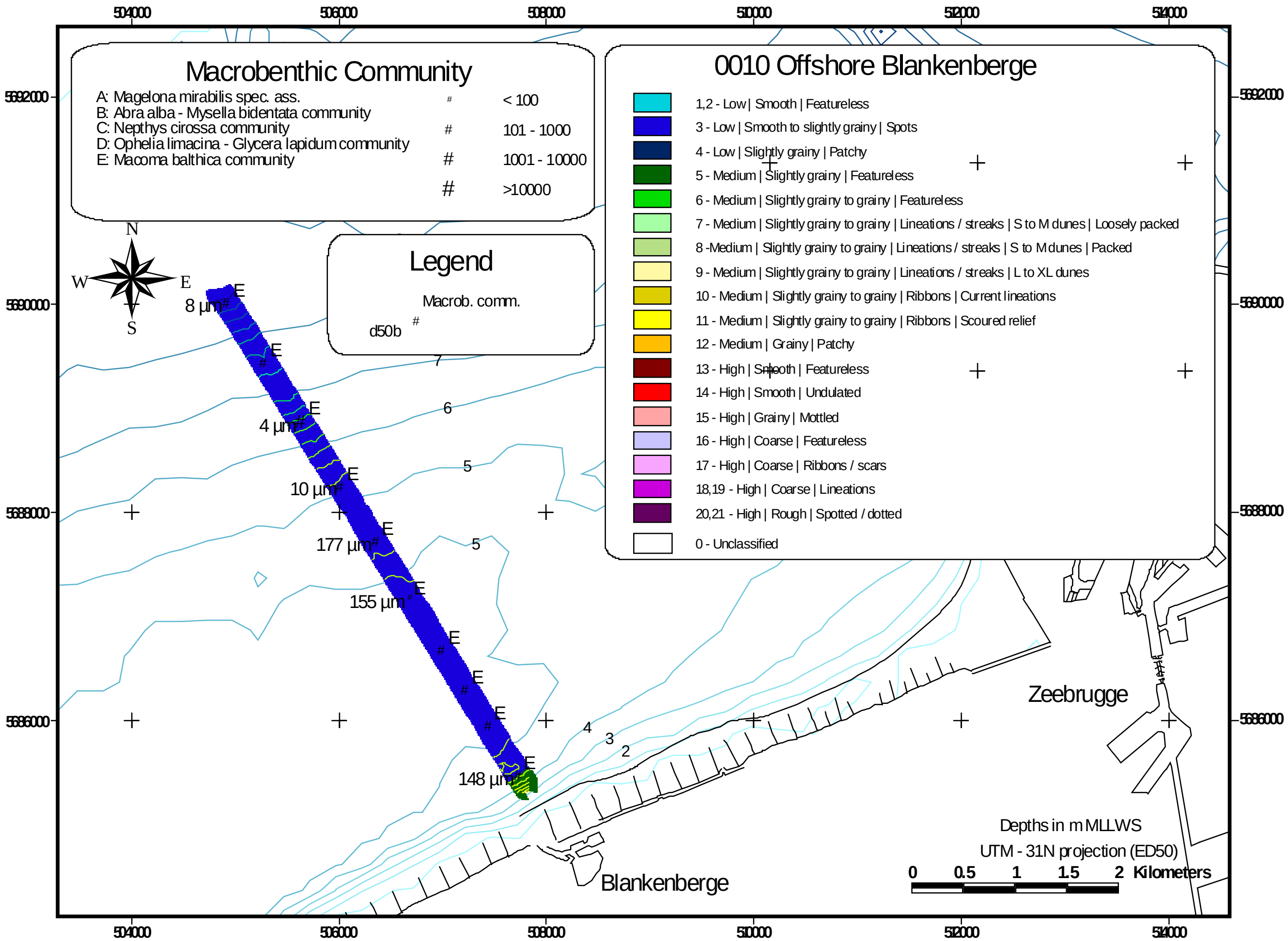

Figure 26. Standardised side-scan sonar interpretation offshore Blankenberge superimposed with the sample information.

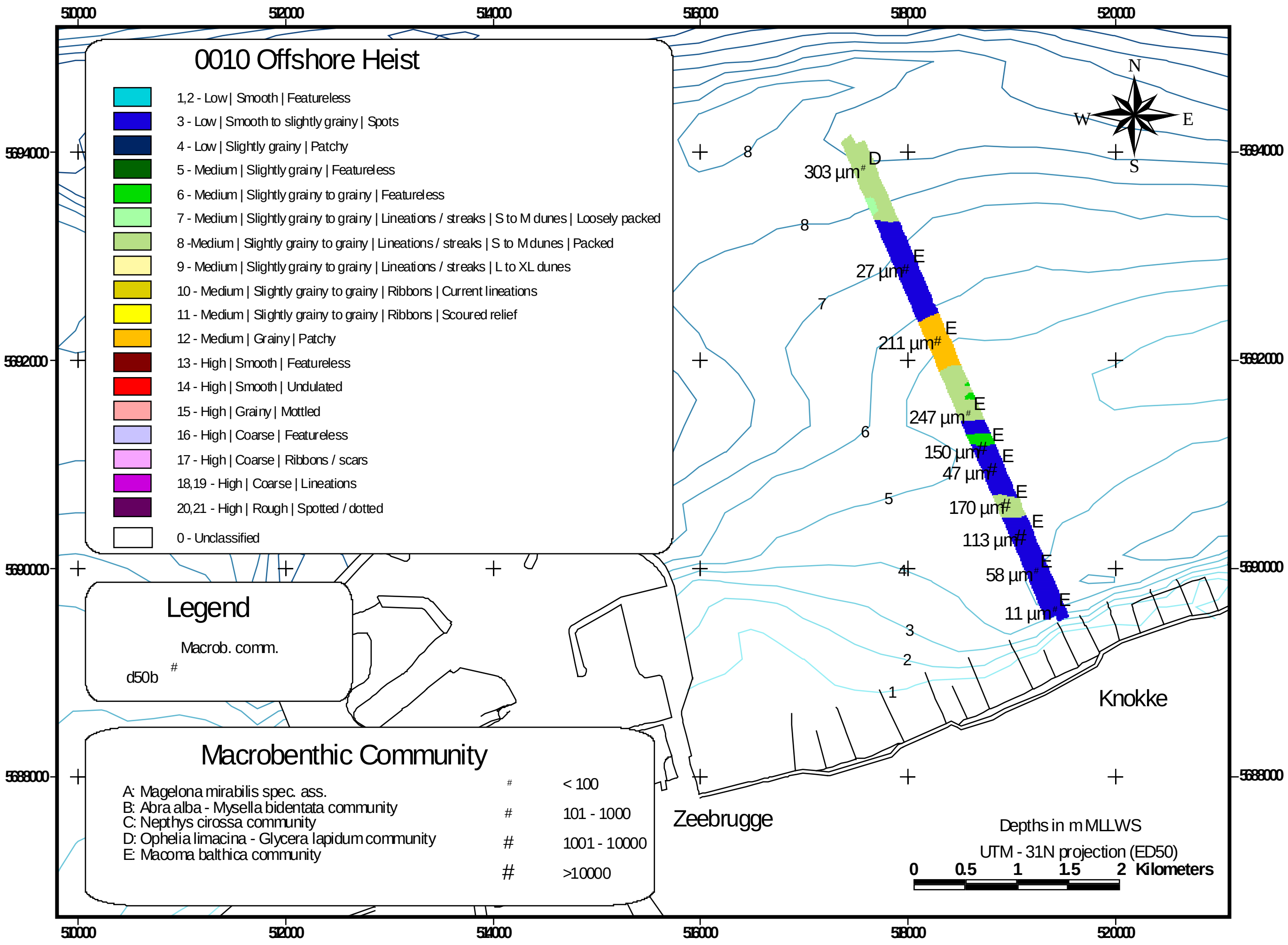

Figure 27. Standardised side-scan sonar interpretation offshore Heist superimposed with the sample information.

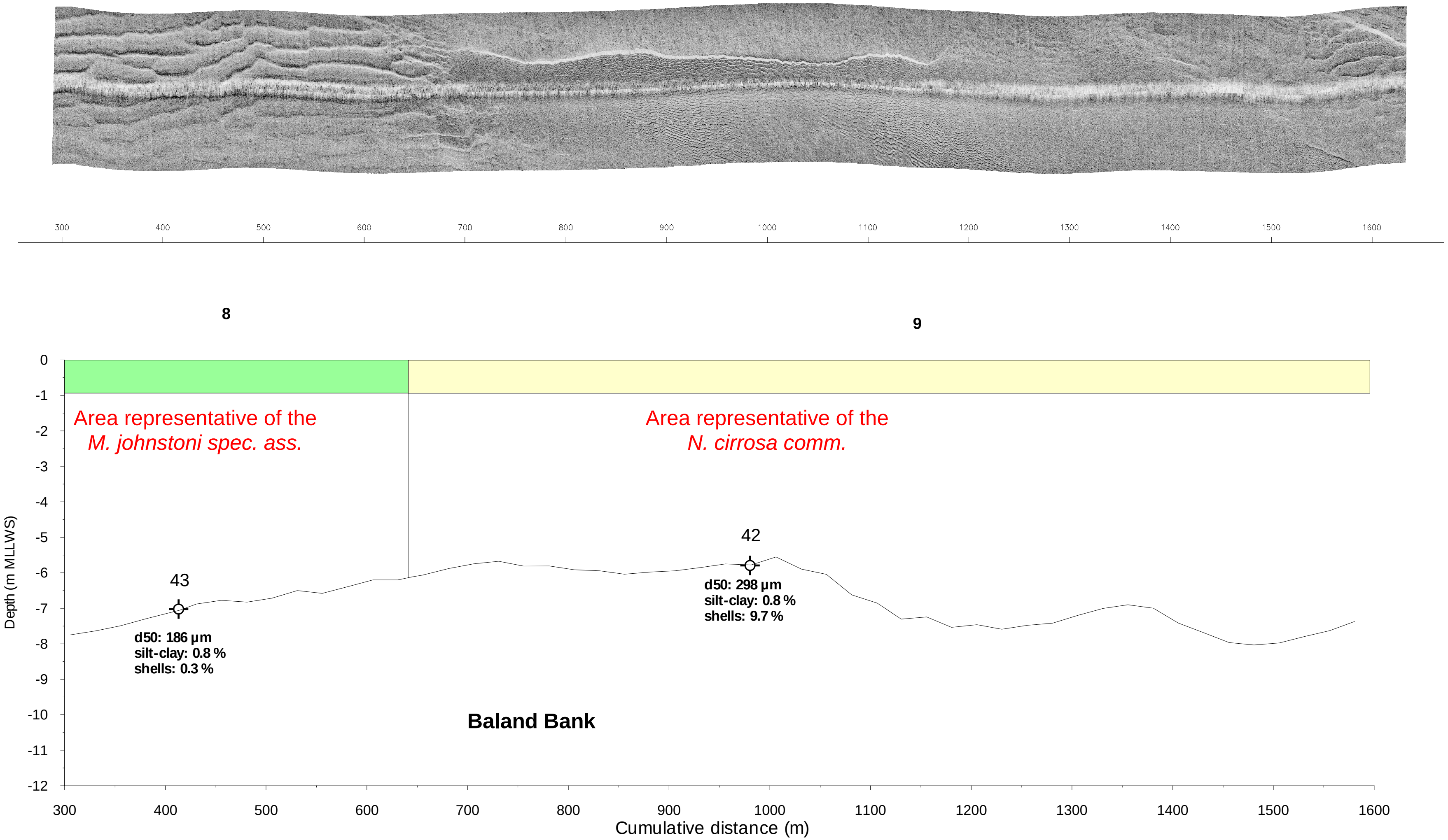

Figure 28. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Middelkerke (*see Figure 2 for the corresponding cumulative distance*).

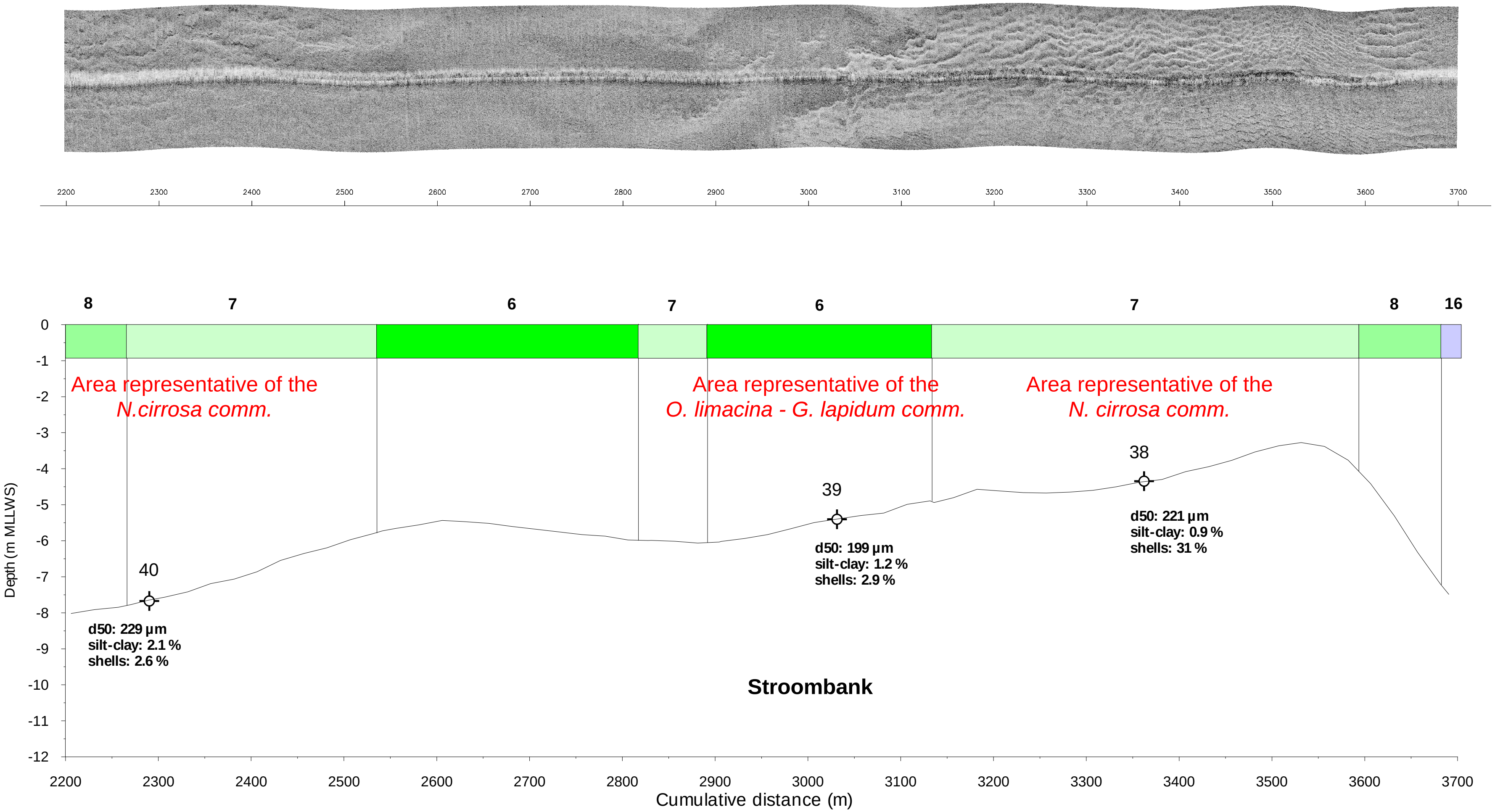

Figure 29. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Middelkerke (*see Figure 2 for the corresponding cumulative distance*).

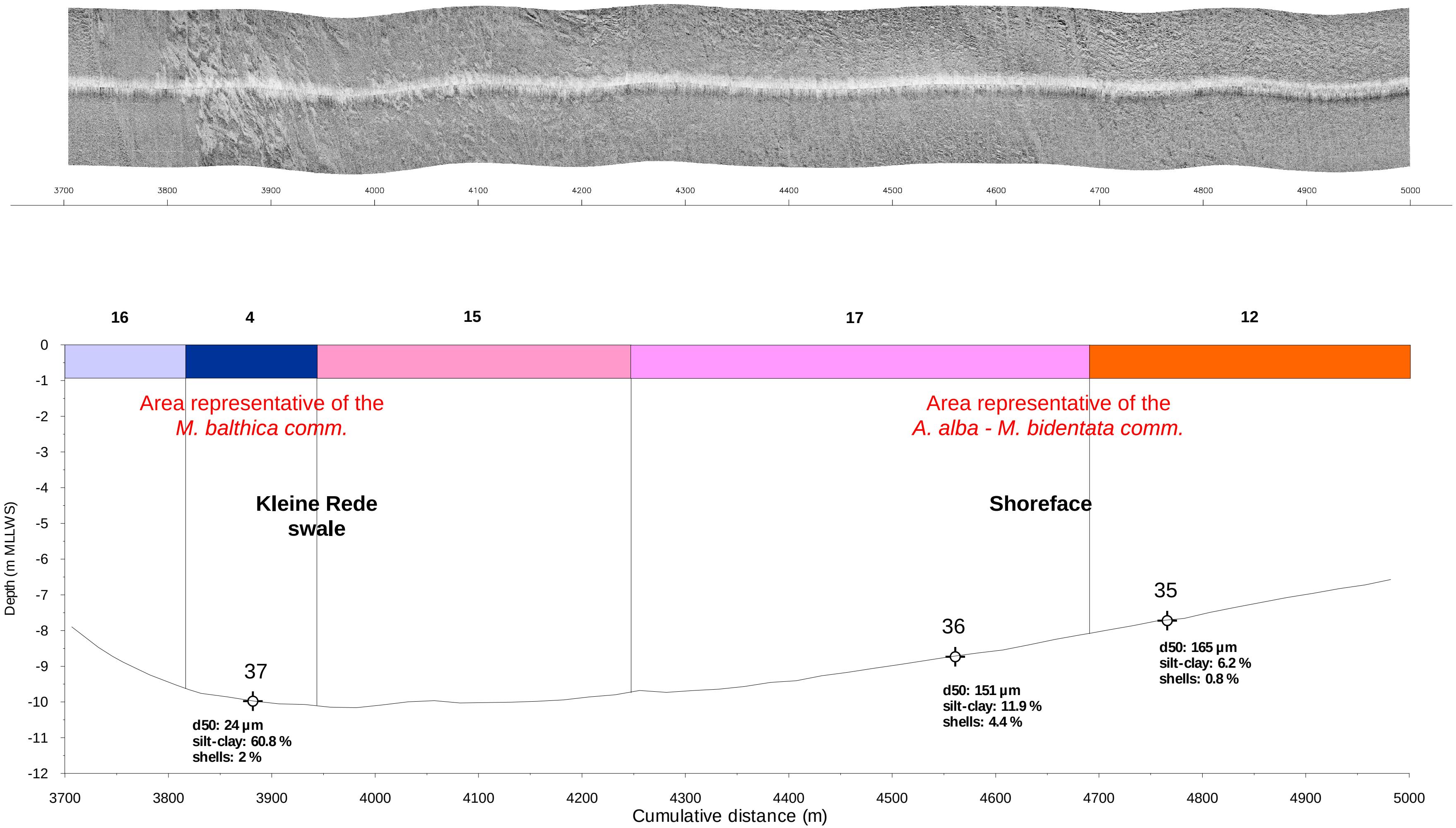

Figure 30. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Middelkerke (*see Figure 2 for the corresponding cumulative distance*).

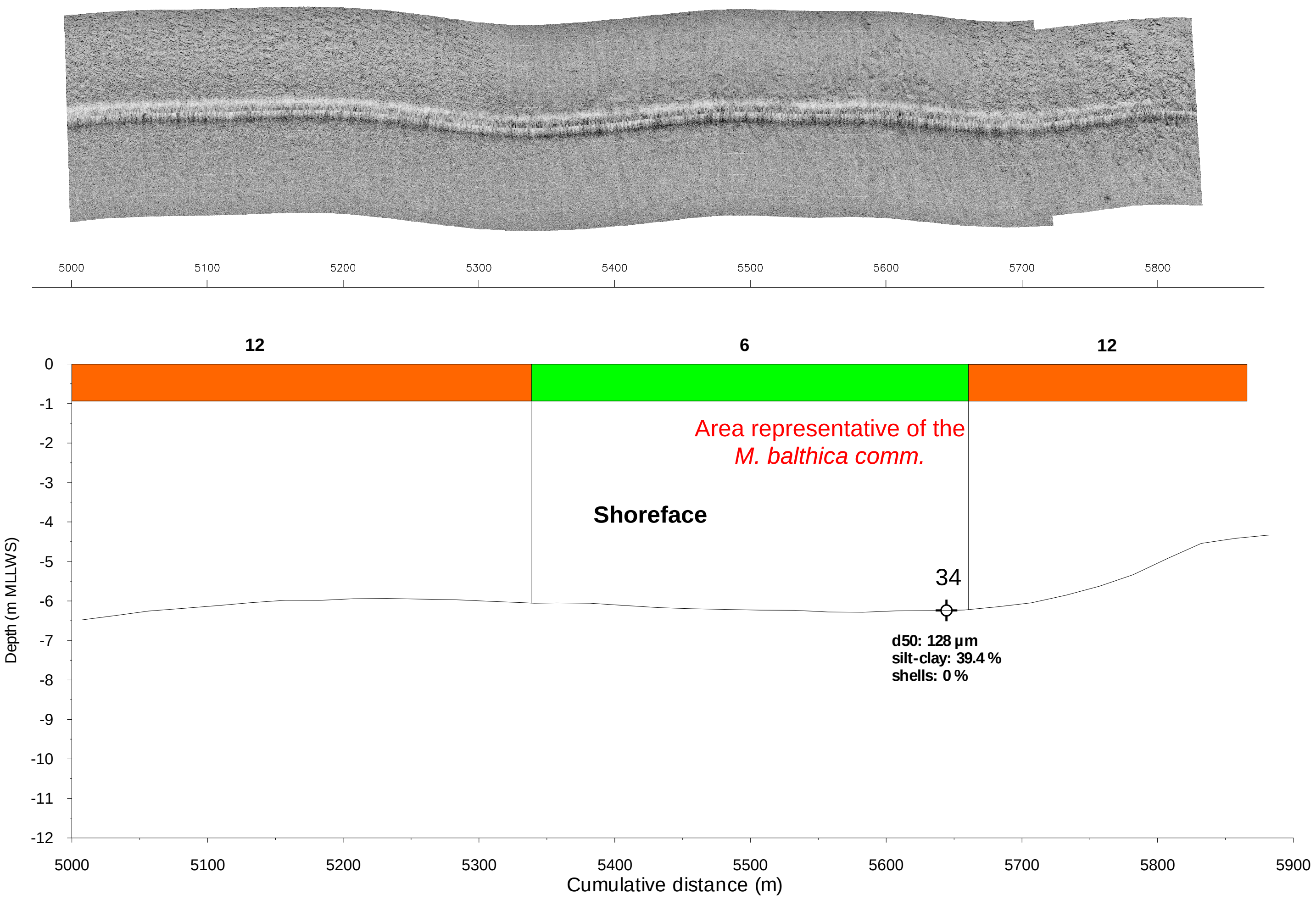

Figure 31. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Middelkerke (*see Figure 2 for the corresponding cumulative distance*).

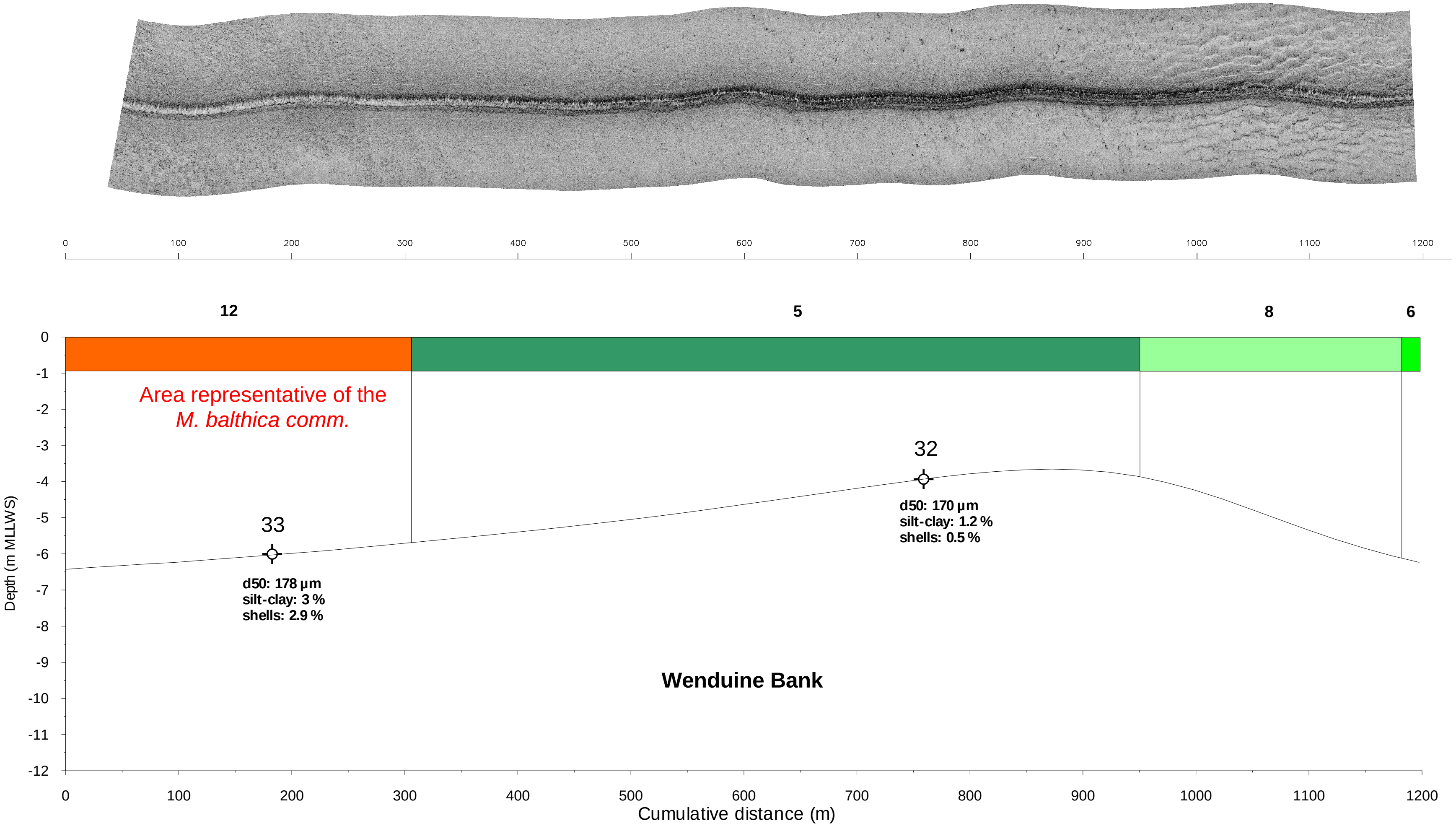

Figure 32. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Wenduine (*see Figure 4 for the corresponding cumulative distance*).

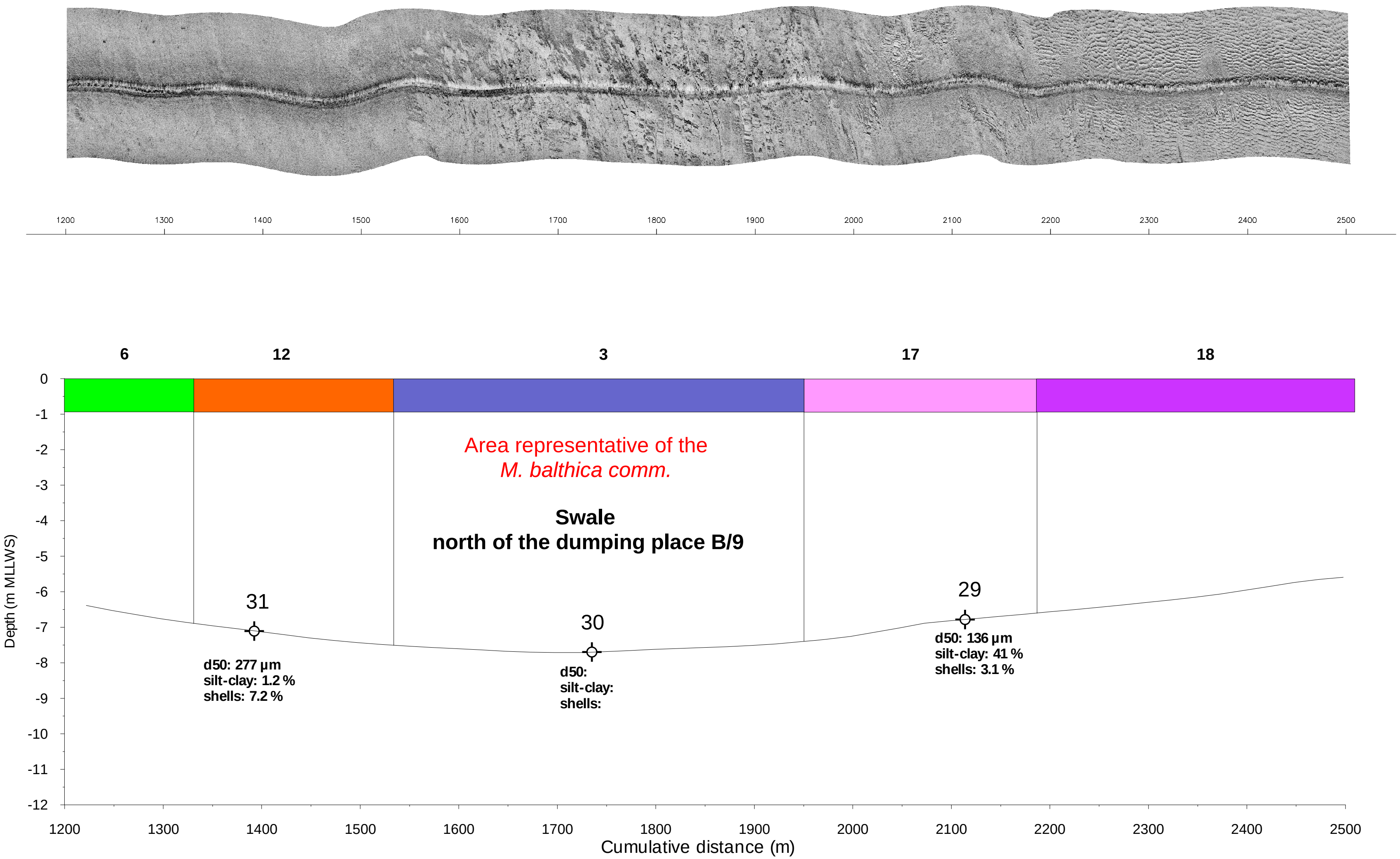

Figure 33. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Wenduine (*see Figure 4 for the corresponding cumulative distance*).

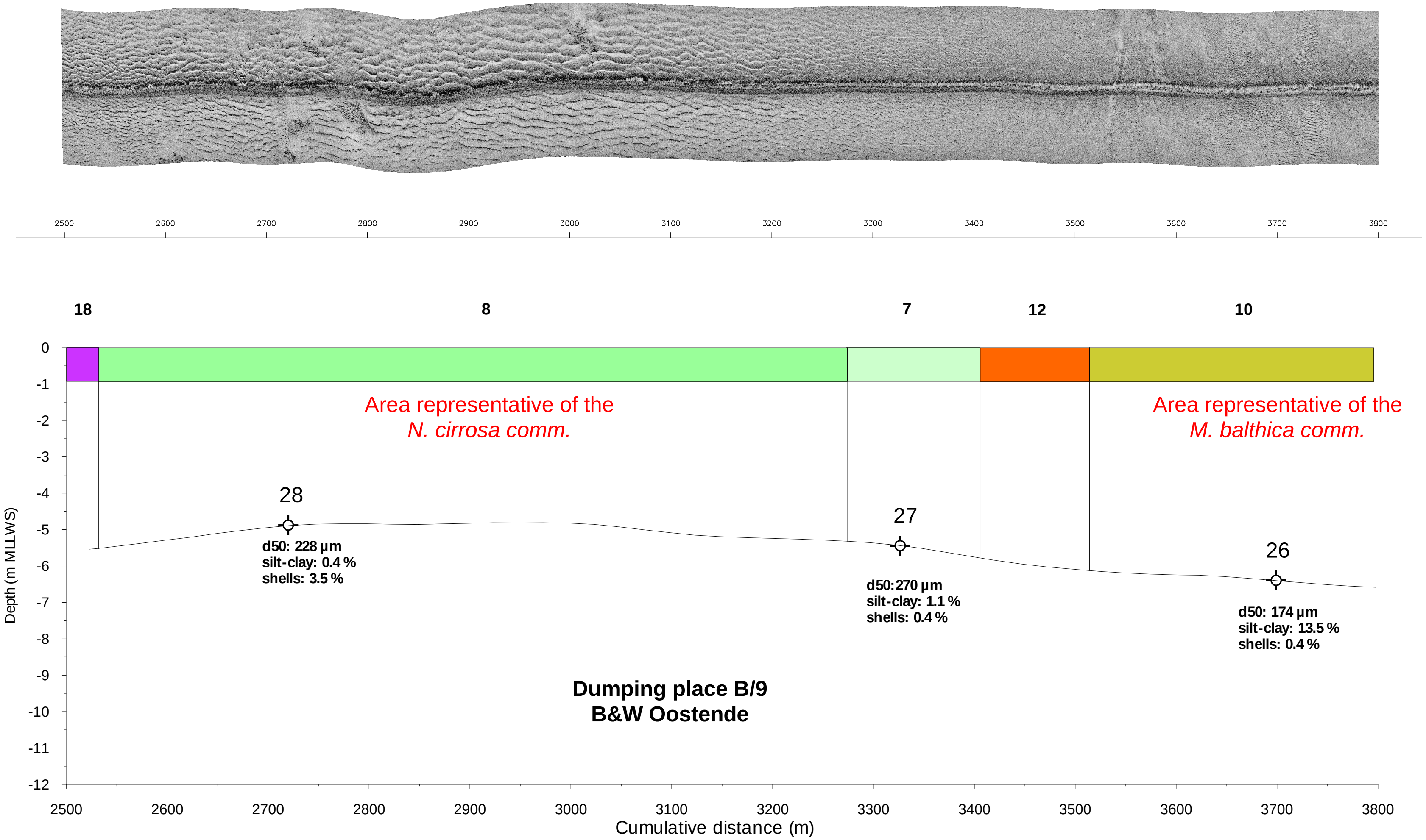

Figure 34. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Wenduine (*see Figure 4 for the corresponding cumulative distance*).

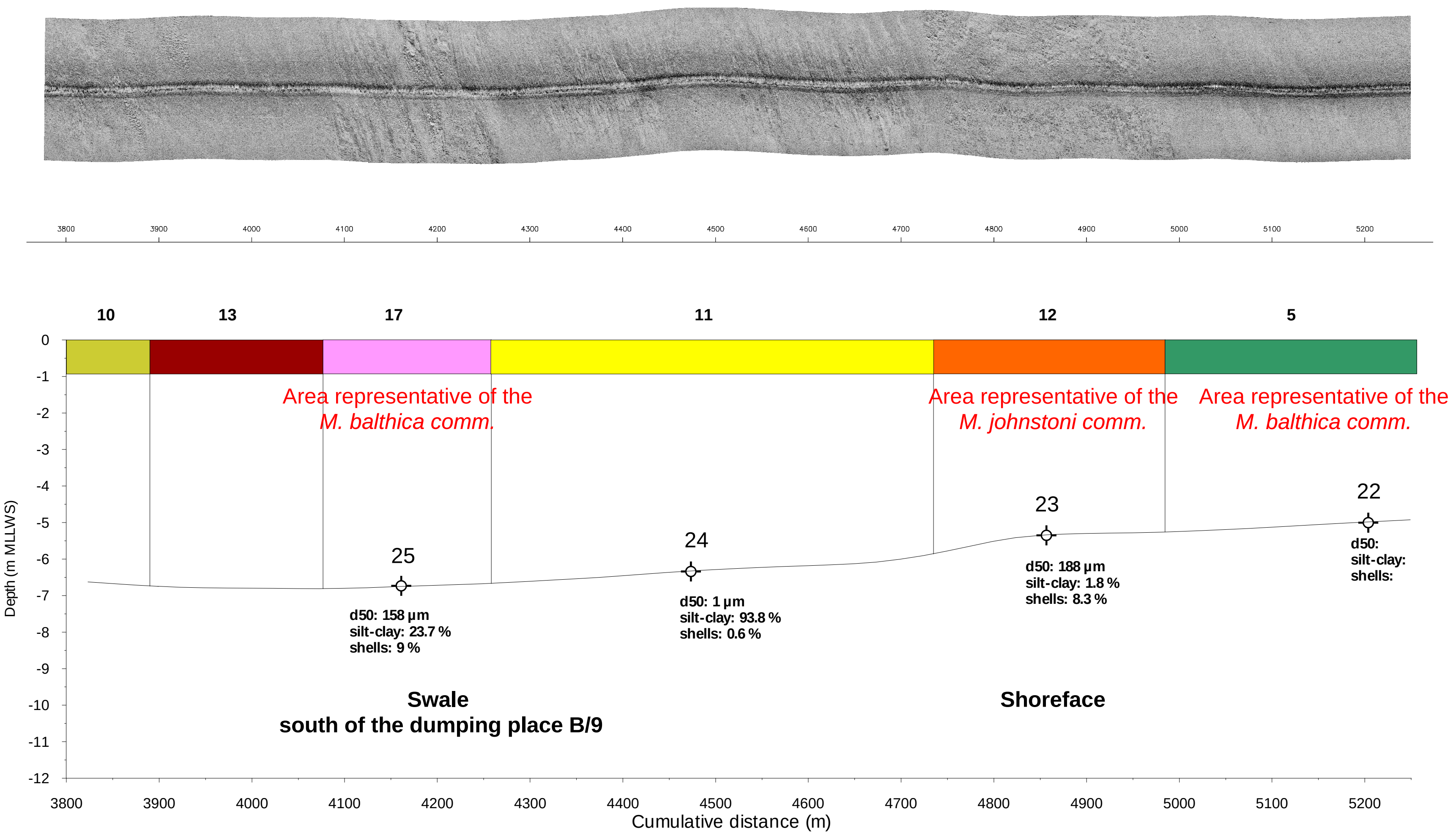

Figure 35. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Wenduine (*see Figure 4 for the corresponding cumulative distance*).

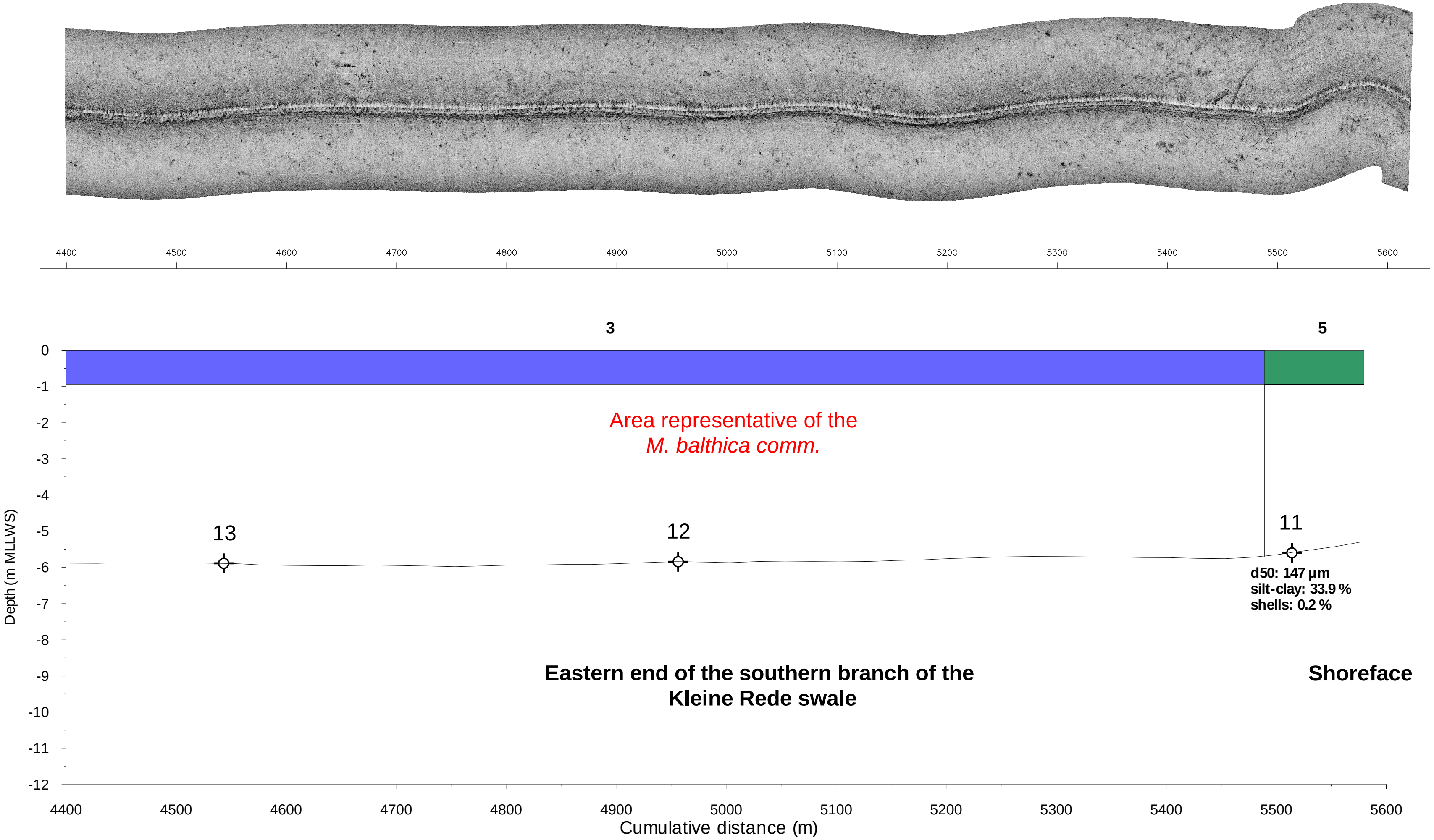

Figure 36. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Blankenberge (*see Figure 6 for the corresponding cumulative distance*).

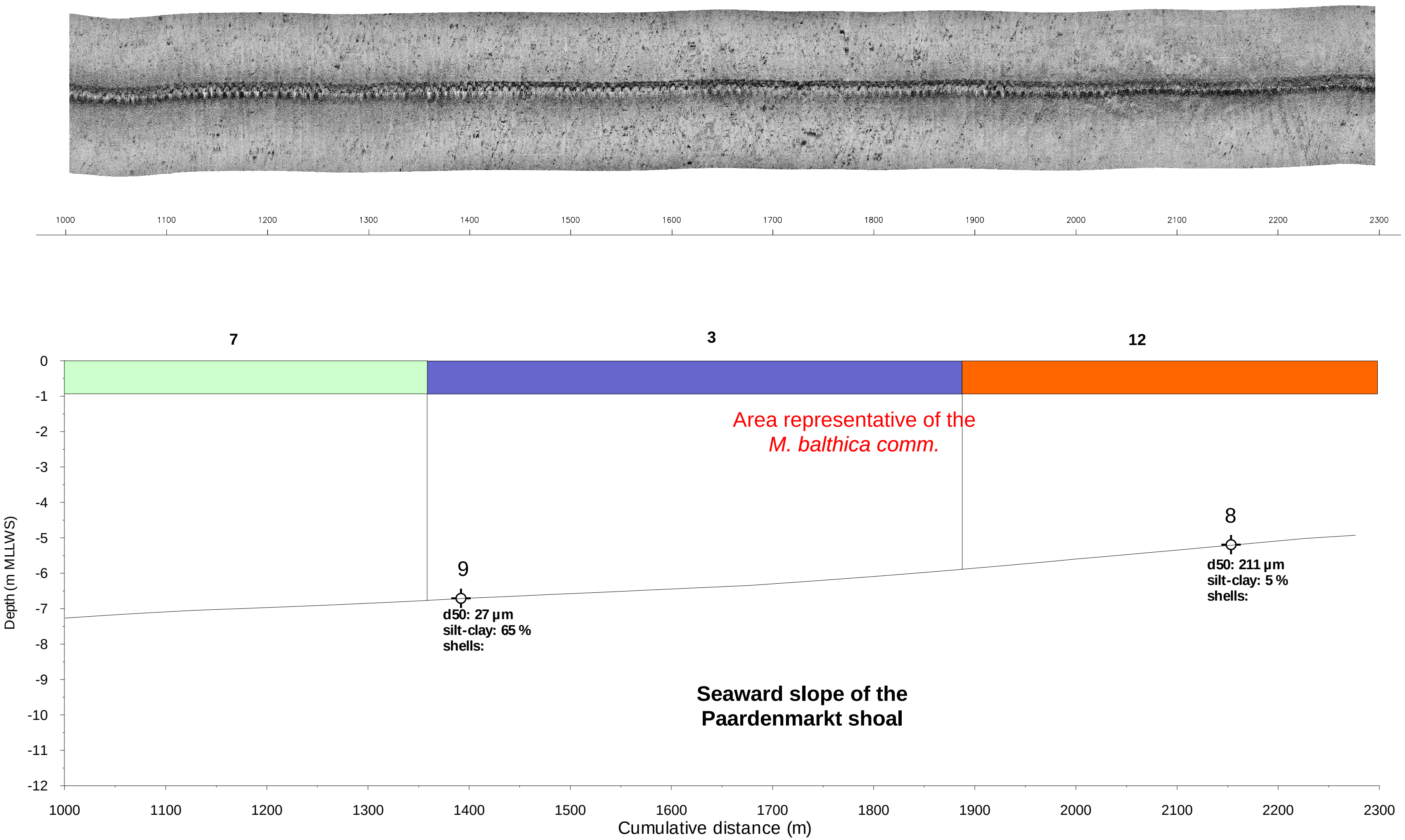

Figure 37. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Heist (*see Figure 7 for the corresponding cumulative distance*).

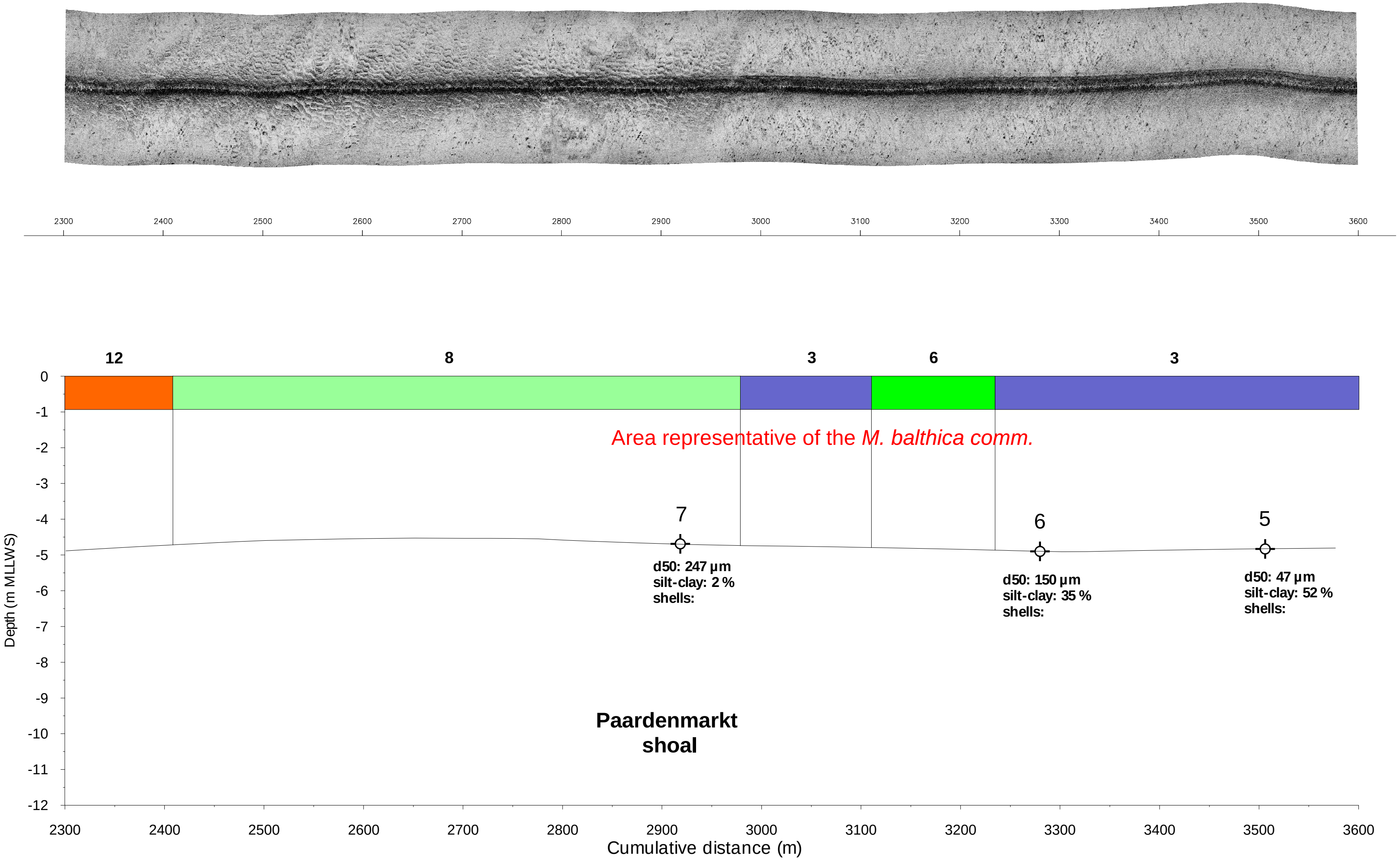

Figure 38. Macrobenthic side-scan sonar interpretation along a section of the profile offshore Heist (*see Figure 7 for the corresponding cumulative distance*).

Conclusions

It has been evaluated to what extent side-scan sonar can be regarded a cost-benefit and time-efficient monitoring tool for the follow-up of macrobenthic communities. In Degraer *et al.* (2002), it was already shown that 2 approaches could be followed: on the one hand a direct observation if the communities are relatively rich and create secundary effects that can be seen on the side-scan sonar imagery, on the other hand an indirect correlation based on the already known relationships between the macrobenthos and its geo-environment. This approach was facilitated through the set-up of a classification scheme that was refined in the present study and tested along the whole Belgian coast. For a more quantified approach and unbiassed testing of the scheme, the data was structured into a Geographical Information System and enabled an assessment of the physical and biological meaning of the acoustic facies.

It needs emphasis that the Habitat area was an ideal environment for the set-up of a classification scheme. On the one hand, it is sedimentologically, geomorphologically and biologically the most diverse area enabling to define classes in the range fine to coarse sandy to gravelly sediments. On the other hand, the hydrodynamics are strong enough to induce an intense flow-topography interaction and a high sediment availability prevails. This means that a good correlation or coupling is expected between the ruling hydrodynamics, sediment processes and the preferred occurrence of macrobenthic communities. Modelling of the acoustic facies in terms of its sediment characteristics, associated depth/slope and in terms of the occurrence of macrobenthic communities gave good results. Still, deposition of mud may mask the true acoustic facies and prevent any further prediction of variables. However, generally, the standardised interpretation towards an acoustic facies seemed to be valid on a temporal basis.

The evaluation of the acoustic classification table along the whole Belgian coast showed more bias. This is likely due to the increasing importance of mud deposition towards the east mainly associated with the predomination of suspended load. Since, also the ruling hydrodynamical forces gradually decrease, a less intense flow-topography coupling is assumed. The relationship between the acoustic facies and its depth or slope was largely blurred, still it could be shown that acoustic facies 12, representative of the most diverse and rich macrobenthic community, correlates with slope environments. Better results were shown for the acoustic facies versus its sedimentological characteristics, especially the median or mean grain-size and the relative percentage of silt-clay and shelly material.

The prediction of macrobenthic communities from the acoustic facies is not straightforward and no unique correlation exists. Most peculiar is the occurrence of the new benthic community "*M. balthica*" that, apart from a clear association with the low reflectivity facies, also correlates with a range of acoustic facies. Further research is needed to what extent this community is associated with areas that are under the influence of high turbidity waters or where a high suspended load is bypassing. As such the macrobenthic community preference of the acoustic facies may be restricted to a community that can support these events.

CONCLUSIONS AND VALORISATION OF THE RESULTS

Main conclusions

From the morpho-sedimentological characterisation, it is clear that the sediments are clearly differentiated along the coastal zone. Side-scan sonar imagery and sediment samples confirmed the highly variable nature of the sediments and this often on very short spatial intervals. Generally, it can be said that the surficial sediments along the Belgian coastal zone fine in a NE direction, still it is clearly demonstrated that this is largely dependent on the interaction between the morphological features that may cause an enhanced flow-topography interaction. The diversity in nature and dynamics along the coastal zone were most clearly demonstrated on the basis of the different acoustic facies.

Although for the characterisation of the macrobenthic communities along the Belgian coastal zone small differences within the habitat preferences and the community structure of the *A. alba – M. bidentata*, *N. cirrosa*, and *O. limacina – G. lapidum* community and the transitional *M. johnstoni* species association, described from the Western Coastal Banks (Degraer *et al.*, 2002) and detected in this study, can be found, it is clear that the same communities can be distinguished along the full Belgian Coast. Only one new community (the *M. balthica* community), associated with *very*-fine sandy sediments along the eastern Belgian Coast, was detected in this study.

Although being useful within the area of the Western Coastal Banks, the HABITAT model cannot be applied outside the area, as demonstrated by (1) the low prediction accuracies for the communities taken into account in the HABITAT model and (2) the impossibility to predict the presence of communities not taken into account in the model. Therefore, a dataset, including samples from all over the BCS, was used to set up a new model. This model, taking into account all communities (incl. the *M. balthica* community), has an overall *a posteriori* accuracy of 78 %. Further testing (i.e. evaluation of *a priori* prediction accuracies) is necessary to validate this new model.

The standardised interpretation of side-scan sonar imagery in terms of its physical and biological meaning was evaluated along the coastal zone. The relation of the acoustic facies with the sediment characteristics gave good results, however towards the prediction of the occurrence of macrobenthic communities, a less straightforward relationship was found than for the Habitat area. This was largely due to the domination of the *M. balthica* community that tend to be associated with a range of acoustic facies. Still, a clear correlation was found with the low reflectivity acoustic facies, representative of the finest sediments. Further research is needed to what extent this community is associated with areas that are under the influence of high turbidity waters or where a high suspended load is bypassing. Still, the most diverse and macrobenthos-rich *A. alba - M. bidentata* community gives rise to a well-defined acoustic facies that is relatively easy to recognise on side-scan sonar imagery.

Valorisation of the results

FUTURE RESEARCH

Both the 'Habitat model' and the standardised side-scan sonar interpretation are of wide scientific interest and as such it is worthwile to use, validate and fine-tune them in present and future perspectives.

On a national level, both techniques will be further validated and fine-tuned through the OSTC project 'Marebasse' (*Management, research and budgeting of aggregates in shelf seas, related to end-users,* Van Lancker *et al.* 2002b). Through multidisciplinary measurement campaigns, remote sensing techniques will be further validated for their ability to detect macrobenthic communities aided by visual ground-truthing (video) and quantitative sampling (i.e. Hamon grab). This comprises the testing of automated classification systems (a.o. multibeam) for the detection of benthic diversity and community localisation. The dataset will enable to further set-up and validate quantitative relationships between the physical aspects and the occurrence of macrobenthic communities and as such the macrobenthic side-scan sonar interpretation will be validated and fine-tuned at key locations. Since remote sensing techniques allow larger-scale/efficient mapping and stratified sampling approaches, other acoustic facies and communities can be detected and described (i.e. estuary/dumping site related macrobenthos and gravel bed macrobenthos).

The experience gained on the habitat preferences of macrobenthic communities will largely aid the set-up of a 'Habitat structure map with indication of macrobenthic potentials' on the scale of the Belgian part of the North Sea foreseen in the OSTC project 'GAUFRE' (*Towards a spatial structure plan for the sustainable management of the sea,* Maes *et al.*). This will be done through an *indirect* assessment of sedimentological/morphological/hydrodynamical data in combination with existing macrobenthos data (Figure 39). The map will be used as a basis for the evaluation of the impact of the different use-functions on the seafloor environment.

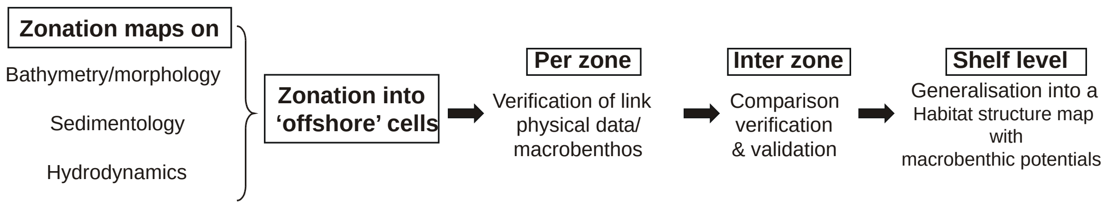

Figure 39. Scheme of the set-up of a 'Habitat structure map with indication of macrobenthic potentials'.

On an international level the detail, integration and representation of the data into a 'Habitat structure map' was set as an example of '*holistic habitat mapping'* and has been included in the proposals for the biodiversity committee of OSPAR on how to progress with habitat mapping. Moreover, the results gained a wide scientific interest.

SCIENTIFIC OUTPUT OF THE RESULTS

This study closes a series of investigations dealing with the macrobenthos habitat in the Belgian coastal zone, all of which were funded by the Coastal Waterways (Ministry of the Flemish Community) and the Federal Office of Scientific, Technical and Cultural Affairs. The following list provides an overview of the scientific presentations during which the results of any of these investigations were presented.

- Symposium 'North Sea 2000 - 14th International Senckenberg Conference on Burning Issues of North Sea ecology ' with oral presentation Degraer, S., M. Vincx, P. Meire, V. Van Lancker, G. Moerkerke, P. Jacobs & J.-P. Henriet. 'Macrobenthic community dynamics and stability in a future marine protected area', Wilhelmshaven (D), 8-12 May 2000.
- ICES 2000 Annual Science Conference with oral presentation Degraer, S., V. Van Lancker, G. Moerkerke, M. Vincx, P. Jacobs & J.-P. Henriet. 'Intensive evaluation of the evolution of a protected benthic habitat: HABITAT', Brugge (B), 27-30 September 2000.
- Symposium 'Annual Meeting of the Geological Association of Canada', with a special session 'Geology of Marine Habitat' with oral presentation Van Lancker, V.R.M., G. Moerkerke, S. Degraer, P. Jacobs, J.-P. Henriet & M. Vincx 'Definition of evaluation tools for the follow-up of a macrotidal, shallow-marine benthic habitat', St.-John's, NFLD (CA), 27-31 May 2001.
- OSTC symposium ‘Duurzaam beheer van de Noordzee. Presentatie van de onderzoeksresultaten’, with oral presentation: Degraer, S., V. Van Lancker, G. Moerkerke, G. Van Hoey, M. Vincx, P. Jacobs, J.-P. Henriet 'Intensive evaluation of the evolution of a protected benthic habitat, HABITAT', Brussel (B), 22-23 January 2002.
- LITTORAL 2002 Sixth International Conference ‘The Changing Coast’, with oral presentation: Degraer, S., V. Van Lancker, G. Moerkerke, G. Van Hoey, M. Vincx, P. Jacobs & J.-P. Henriet 'Intensive evaluation of the evolution of a protected benthic habitat: HABITAT'. Porto (P), 23-26 September 2002.
- ‘OSPAR Marine Habitat mapping workshop’ with oral presentation: V. Van Lancker ‘Mapping the Belgian continental shelf. Status of activities’. London (UK), 28-30 October 2002.
- EMSAGG (European Marine Sand and Gravel Group) where the relevance of the results are outlined towards resource prospecting in general. Oral presentaton: Van Lancker, V., Deleu, S., Moerkerke, G., Vanstaen, K., Verfaillie, E., Degraer, S. & Van Hoey, G. ‘The use of sonar techniques for a standardised resource evaluation and its ecological value’. Delft (NL), 20-21 Februari 2003.
- Coastal Sediments '03. 5th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes "Crossing Disciplinary Boundaries". U.S. Geological Survey. Oral presentation: Van Lancker, V.R.M., Moerkerke, G., Vanstaen, K., Degraer, S. & Van Hoey, G. ‘Development of a multidisciplinary side-scan sonar-based environmental assessment tool applicable for shallow marine waters’. Florida (USA), 19-23 May 2003.

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