Application for a sand extraction concession in exploration zone 4: Baseline studies on the Hinderbanks and future impact monitoring

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Introduction

For the realisation of the ‘Integrated Coastal Security Plan’ (GeïntegreerdKustveiligheidsplan) and extensive works in the harbour and at the coast of Oostende (OW-Plan) a large amount of qualitative sand is needed. Therefore, the Flemish Government - Coastal Division, together with the Maritime Access Division applied for a concession in exploration zone 4 in the Hinderbanks area. In addition, the association of importers and producers of dredged granulates (Zeegra) applied for a concession in this area to maintain their total extracted volume and as such assure the delivery of high quality sand to the market. However, except for the geological evolution (Mathys, 2009), little was known about the composition and sedimentology of the Hinderbanks. To unravel the grain-size distribution of the Hinderbanks, not only on the seabed but also below surface, a high-resolution reflection seismic survey and a vibrocore campaign were carried out in the area. The results of this exploration led to the delimitation of four areas for sand extraction.Meanwhile, the bathymetry, the geomorphology and the nature of the surface sediments of the exploration zone 4 have been investigated with the EM1002 and EM3002D multibeamechosounders installed aboard the RV Belgica. To get an overview of the ecological value of the area, the macrobenthos inhabiting the seabed was sampled with a Van Veen grab on 129 locations in a regular grid. Furthermore, the epibenthos and demersal fish communities were sampled in 7 stations spread over the different sand banks in the exploration area. The combination of all this research establishes, for the first time, the baseline description of an extraction area before the start of the activity. This image will serve as the reference line for the regular monitoring, to assess the impact of extraction in the future.

Geological background

The top part of the seabed, containing the sandbanks, was deposited during the Quaternary. The Quaternary is a period between the present and 2.6 million years ago. This period is divided into the older Pleistocene and the younger Holocene. The Pleistocene was characterised by an alternation of glacial periods (ice-ages) and interglacials, corresponding to sea-level lowerings and sea-level rises. The Holocene started about 10.000 years ago, after the last ice-age, and continues up to present times.

The Quaternary cover in the Hinderbanks area is thin and fragmented, which causes underlying, older layers to be exposed in the swales in between the sandbanks. These layers are of Tertiary age. In exploration zone 4, the Tertiary deposits consist mainly of clay, covered with a gravel lag (10-30 cm thick).

In exploration zone 4, the base of the Hinderbanks consists of Pleistocene deposits from the last interglacial period, the Eemian (115 ka years ago). This layer consists of estuarine and marine sediments deposited in a former valley of the Meuse river which incised during the Saale ice-age (140 ka years ago). The Eemian deposits are covered by a gravel lag. From the analysis of the vibrocores we know that the estuarine deposits consist of very fine sands and silts with high organic content and clay layers. The gravel lag at the Top-Eemian surface is on average 45 cm thick (Mathys et al., 2009).

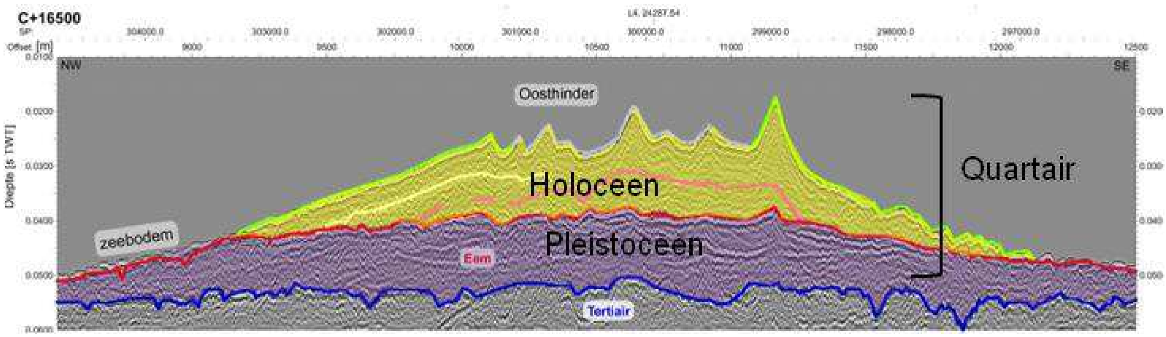


Figure 1: Seismic cross-section through the Oosthinder Bank.

During the Holocene, about 7000 years ago, the Hinderbanks and intermediate swales started to form on top of this surface (Figure 1). The material needed to construct the tidal sandbanks was derived from the local underlying sediments. The analysis of the vibrocores showed that the bottom part of the Holocene tidal sandbanks mainly consists of very homogeneous medium course sand (210-300 µm). On top of this layer very coarse sands (300-420 µm) occur. Very coarse sand (300-420 µm) also occurs west of the Noordhinder and in the swale between the Noordhinder and Oosthinder. Extreme coarse sands (420-2000 µm) outcropping at the seafloor, occur mainly at the heads of the Westhinder and the Oosthinder.

SEISMIC SURVEY AND VIBROCORE CAMPAIGN

A high-resolution reflection seismic survey was conducted with a line spacing of 500 m (Depret-G-tec, 2009) (Figure 2). The penetration depth of the seismic signal was at least 30 m below the seabed. The obtained seismic profiles are cross-sections through the seafloor. They show the layering and internal structure of the sandbanks, i.e. the seismic stratigraphy. Strong seismic reflectors represent important erosional surfaces (Figure 1).

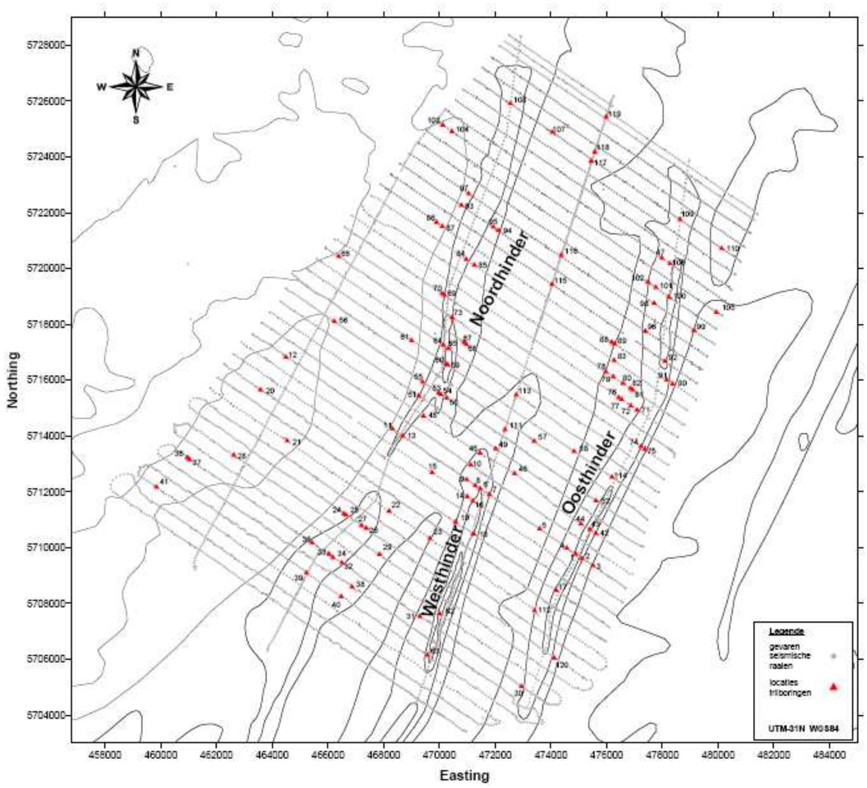


Figure 2: Location of seismic survey and 120 vibrocores.

In order to interpret the seismic stratigraphy in terms of sedimentology, an extensive vibrocore campaign was set up. 120 vibrocores of 4-5 m length were recovered and analysed (Depret-G-tec, 2009). Grain-size distributions (d50, d90), carbonate analysis and lithologs were produced (Depret-G-tec, 2009).

Thanks to the integration of the seismic data and the vibrocore analyses, the seismic units could be interpreted in terms of layers with a certain grain-size. Vibrocore point data were transformed into full-coverage grain-size maps which show the lateral and vertical occurrence and thickness of the sediment layers (Mathys et al., 2009) (Figure 3).

AVAILABILITY OF QUALITATIVE SANDS IN EXPLORATION ZONE 4

For the realisation of the Integrated Coastal Security Plan and the works in Oostende, qualitative sands with a grain-size of at least 300 µm and a carbonate content of less than 30% are needed. Figure 3 visualises the occurrence of the sediments with the desired granulometric characteristics at the seafloor (300-420 µm).

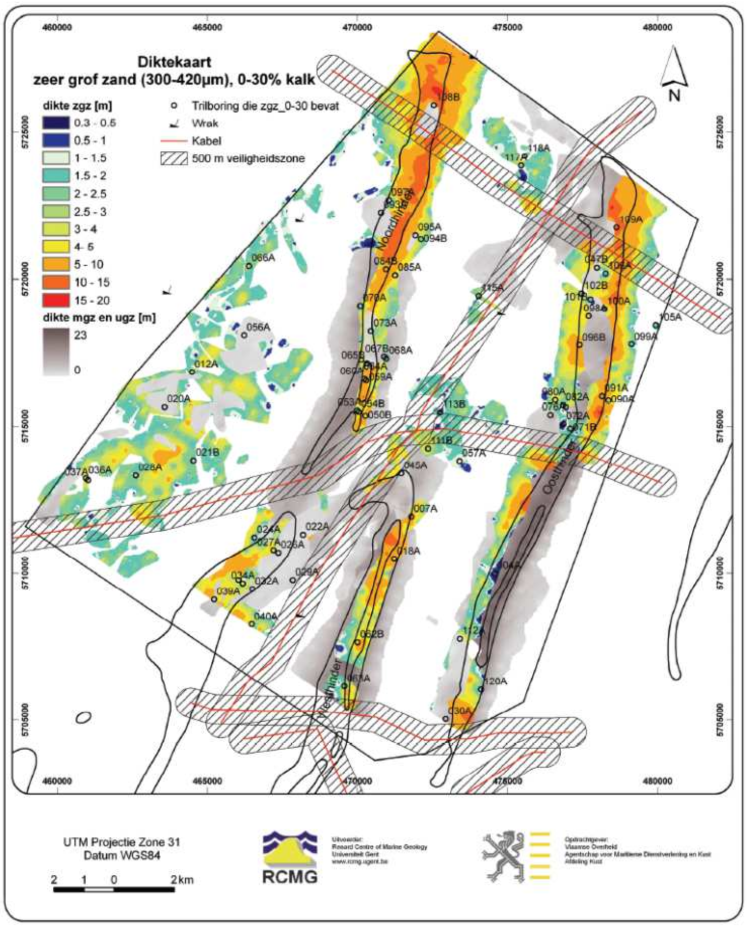


Figure 3: Thickness map of very coarse sand (300-420 µm) at the seafloor in exploration zone 4 (coloured areas).

Economically, the most interesting areas for future extraction are those where the thickness of these layers is at least 5 m, which corresponds to the present-day legislative extraction depth. Such areas occur in the north of the Noordhinder, the Oosthinder and the Westhinder, and at the western flank in the southern part of the Oosthinder.

However, care has to be taken not to destroy biological valuable areas (discussed further on).

In the Environmental Impact Assessment report an optimisation process resulted in the definition of four extraction sectors (Figure 4), taking into account amongst other things the availability of required granulometric characteristics and avoidance of biological valuable areas (De Sutter and Mathys, this volume).

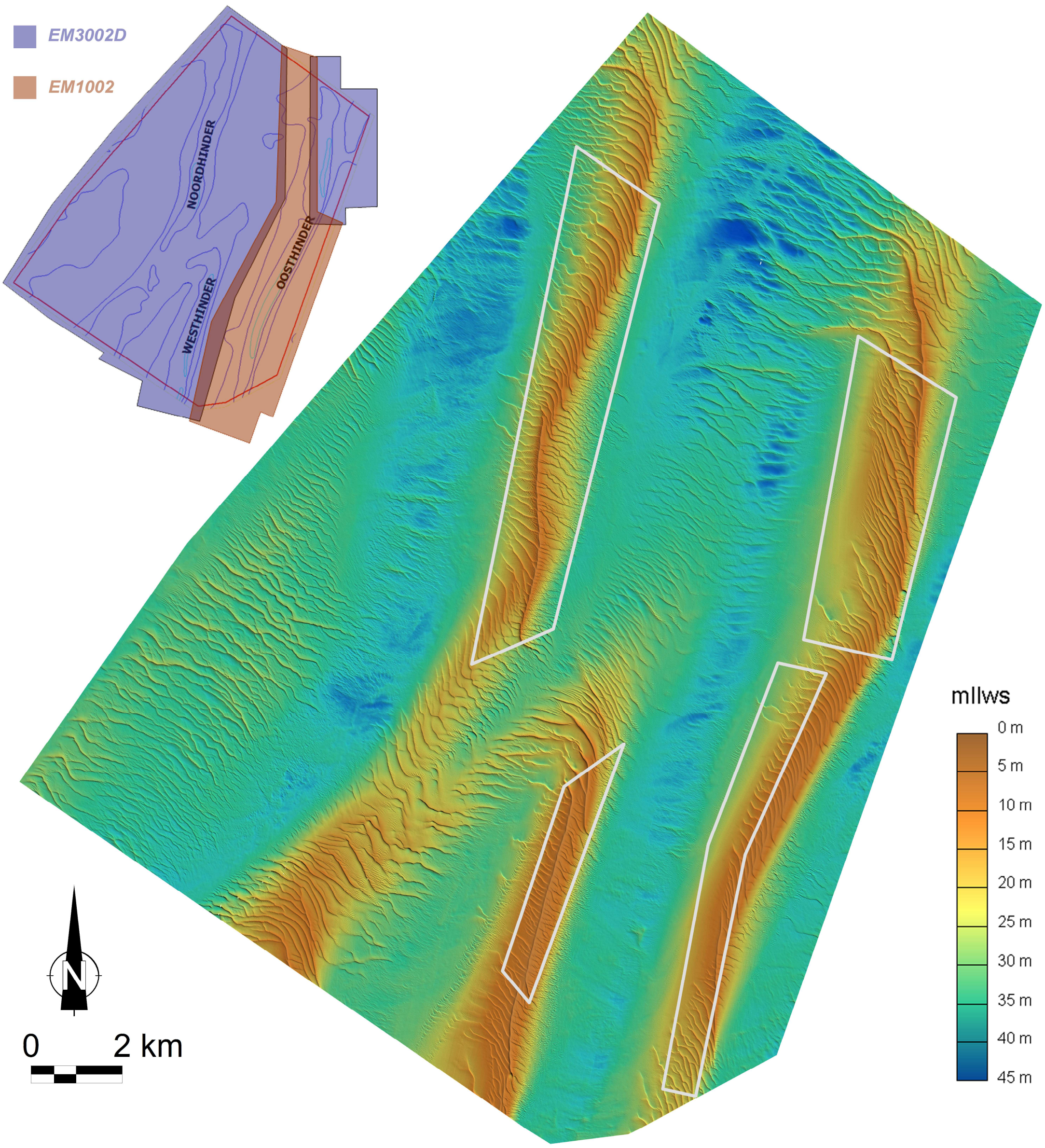


Figure 4: EM1002 and EM3002D multibeamechosounder coverage of exploration zone 4. Digital Terrain Model with 2x2m resolution of the bathymetry and geomorphology of the exploration zone 4 (with delimitation of the four extraction sectors).

PRESENT-DAY BATHYMETRY-GEOMORPHOLOGY

In order to cartography, with a high resolution, the bathymetry and the geomorphology of the exploration zone, 4 surveys with the EM1002 multibeam echosounder were completed by the FOD Economy from 2004 till 2006. This first dataset covers a large part of the Oosthinder bank. The cartography of the rest of the exploration zone 4, the Noordhinder and Westhinder banks and the gullies, was completed with a suite of 5 surveys with the EM3002D multibeam echosounder in 2009.

The set of filtered and tide corrected soundings resulting from the postprocessing of all these acoustic data allows the modeling of the bathymetry at different resolutions. The digital terrain model at the resolution of 2x2m (Figure 4) is the reference model, the <u>baseline</u>, for the future monitoring of the impact of extraction on the bathymetry in the four extraction sectors.

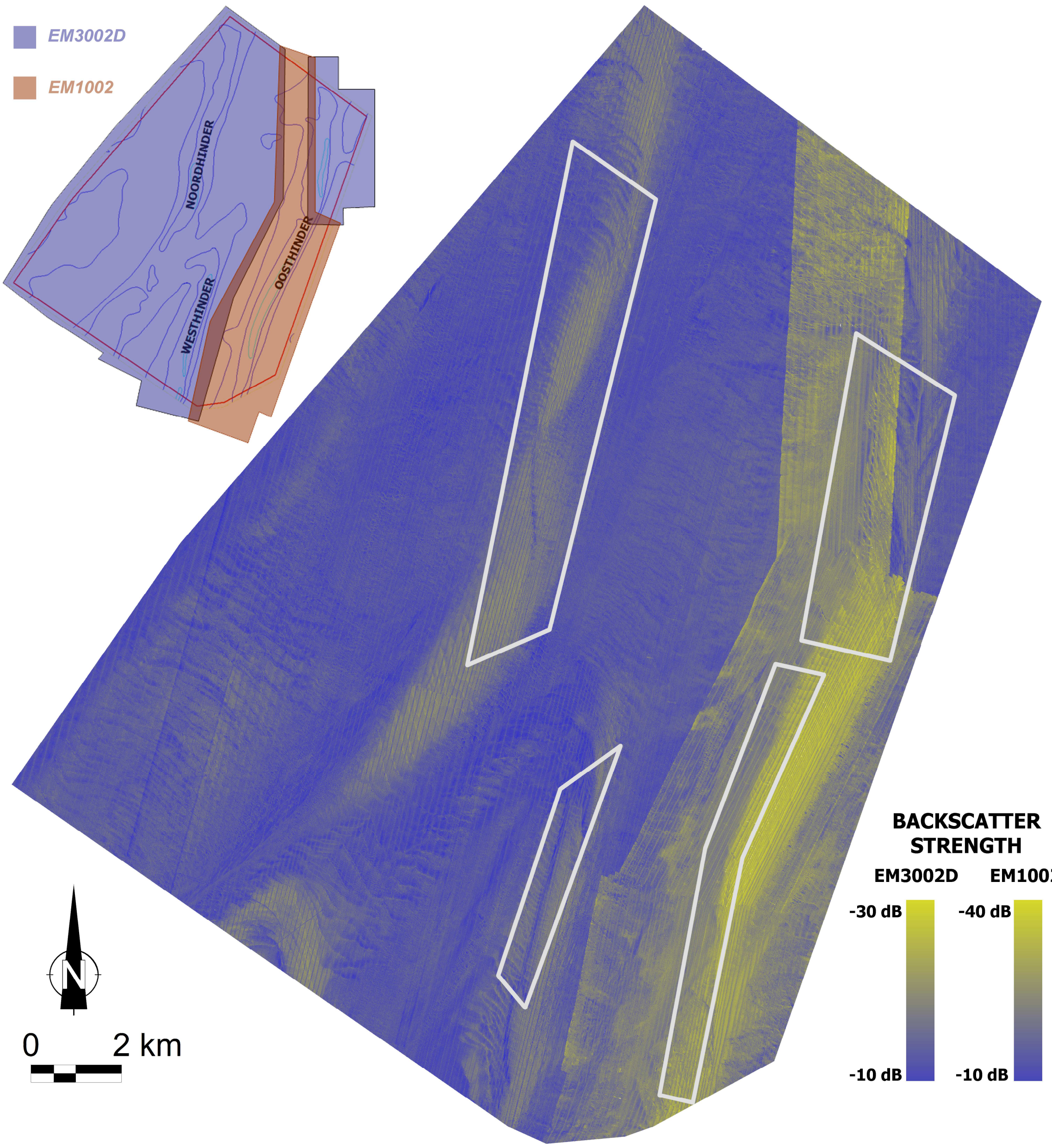


Figure 5: EM1002 and EM3002D multibeamechosounder coverage of exploration zone 4. Backscatter Strength model with 2x2 m resolution (Blue = relatively coarse – rougher sedimentary interface; Yellow = relatively fine – smooth sedimentary interface).

Multibeamechosounder technology also perceives the seabed as a physical interface backscattering (reflection back to the source) the acoustic energy from the echosounder. The amplitude of the backscatter reflects the nature of the seabed sediment. Coarse sediments such as gravel backscatter much more acoustic energy that fine sediments. The acoustic data recorded with the two multibeamechosounders, EM1002 and EM3002D, were treated following a strictly standardized procedure using SonarScope software, developed by IFREMER. Due to the different characteristics (frequency, pulse length and geometry) for each echosounder, the values of backscatter cannot be mixed and must be treated separately during data processing (calibration, angular correction, masking of angular sectors...). Therefore the derived map (Figure 5) of the backscatter values can only be used to evaluate the relative coarseness and roughness of the seabed.

TOTAL AVAILABLE SEDIMENT VOLUMES

Based on the high resolution model of the bathymetry and without taking into account the quality of the sediment, the total amount of material available within the four extraction sectors is ca. 229.10^6 m³. This amount is calculated from the area surface of the sectors and the present-day legal extraction depth of 5 m below the present-day bathymetry.

An alternative option to limit the extraction depth is to use a fixed erosional surface, such as the Top-Pleistocene/Base-Holocene or Top-Tertiary, and to safeguard a certain thickness of sediment above that surface against extraction. This approach should prevent the bank to be removed completely. As demonstrated for exploration zone 4 such reference surfaces must be determined by high-resolution reflection seismic surveys. A project to do this for the already exploited control zones 1 and 2, is under consideration by the Continental Shelf of the Federal Service Economy.

Between the Top-Tertiary surface and the present-day bathymetry, a volume of 790.10^6 m³ of material is present within the 4 extraction sectors. This material consists, however, not only of qualitative sands but also of very fine sands, silts, clays and thin gravel beds.

ECOLOGICAL VALUE OF THE HINDERBANKS

Biological background

In general, the macrobenthic biotope in the exploration area of the Hinderbanks consists of the two most dominant biotopes in the Belgian Part of the North Sea i.e. the *Ophelia limacina* biotope and the *Nephtyscirrosa*biotope (Degraer*et al.* 2009). Both biotopes are characteristic for resp. coarse to medium and medium to fine sand (Van Hoey*et al.* 2004). They are characterised by lower species numbers, densities and diversity compared to for instance the *Abra alba* biotope, and are as such evaluated as less valuable biotopes in the BPNS (Derous*et al.* 2007), which is true when looking at the sample level. However, on biotope level, the number of species encountered in this area is relative high, and there occur species that are quite rare for the Belgian Part of the North Sea. The epibenthos and demersal fish community occurring in the Hinderbank area is a typical off shore community characterised by lower densities compared to the coastal communities but with relatively high diversity. Dominant species are lesser weever, hermit crabs and the small brittle star (Vandendriessche*et al.* 2009). On the other hand, the Hinderbanks are also known for the (potential) occurrence of gravel beds, especially in the gullies and around the Westhinder (Houziaux*et al.* 2008).

These gravel beds are (potentially) ecologically very valuable and they are characterised by a high and unique species richness for both infauna between and epifauna on the stones (Degraer*et al.* 2009). These gravel beds are historically also known for the formation of European oyster beds (*Ostreaedulis*) that form an important spawning area for herring (*Clupeaharengus*). However, due to the heavy bottom disturbing fisheries (beam trawling), most of these ecologically valuable areas disappeared with occasionally some fragmentary gravel beds remaining in less disturbed areas.

Baseline studies by ILVO

Small-scale macrobenthic knowledge on this area was lacking in 2004 when the area was allocated as an exploration area. Therefore, to get a detailed overview on the macrobenthos in the exploration area, ILVO-Fisheries sampled 129 locations in a regular grid over a period of four years (2004-2008) with a Van Veen grab (0.1 m² sample) (Figure 6). Furthermore, recent knowledge on epibenthos and demersal fish was completely lacking and therefore, 6 fish tracks were allocated spread over the different bank systems (Oost-, West- and Noordhinder) and 7 extra stations were sampled on the adjacent Bligh Bank outside the area as potential reference stations (2005-2008) (Figure 6).

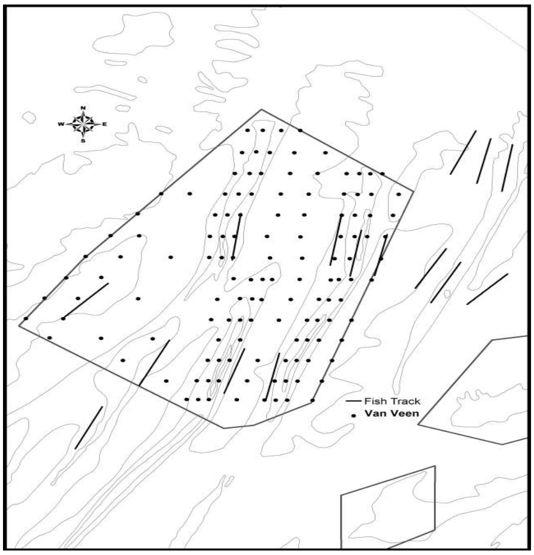
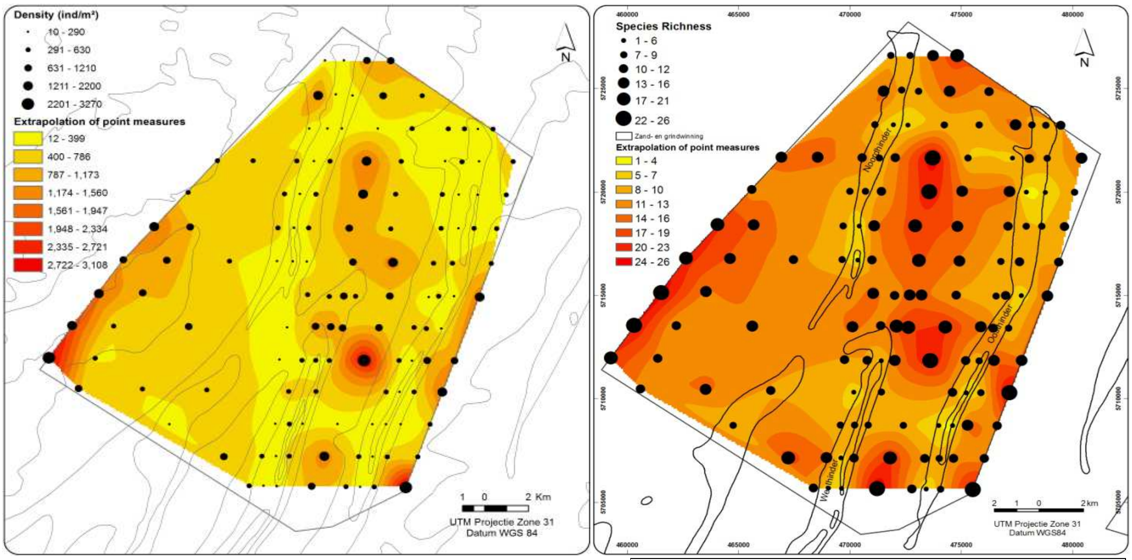


Figure 6: Overview of sampling locations for macrobenthos (Van Veen) and epibenthos/demersal fish (fish tracks).

For the macrobenthos, 116 different taxa were identified but many species were restricted to one (33 sp.) or two (16 sp.) samples. Dominant species (occurring in > 75% of the samples) were the bristle worm *Nephtyscirrosa* and the interstitial species *Hesionuraelongata*and *Polygordiusappendiculatus*. Furthermore, the Hinderbanks are characterised by some typical, interstitial and rarer species on the BPNS such as different species of Syllidae (a family of bristle worms), which is due to the presence of coarser sands. Community structure was influenced by the position of the sample on the sand bank (gully, slope or top) (Figure 7) with the richest communities occurring in the gullies. Also the univariate community measures species richness, density and diversity are predominantly influenced by depth. The gullies and slopes are the areas characterised with highest values of density, species richness and diversity (Figure 7).



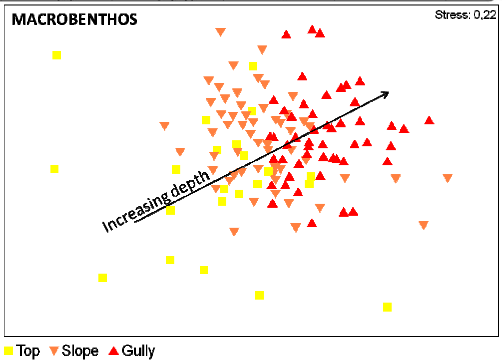


Figure 7: Macrobenthos density (ind./m², left) and species richness (middle) for each sampling station with extrapolation of the point measurements based on the nearest neighbour technique. MDS plot (right) showing the multivariate pattern of all samples with indication of the position of the sample on the bank. Depth influences the observed pattern.

In the fish tracks, 31 epibenthic species with dominance of hermit crabs, flying crab, brown shrimp and brittle stars were identified and 25 demersal fish species with dominance of lesser weever, dab, whiting and reticulated dragonet. Interannual variation for epibenthos and demersal fish is much higher compared to the macrobenthos. For instance, in 2005 and 2006 there was an exceptionally high dominance of brown shrimp in off shore areas. As for macrobenthos, although there were only 3 samples on top of the sand bank, there is an indication that community structure is influenced by depth. Densities are as well much higher in the gullies and on the slopes, which again indicates the presence of a gully-bank gradient (Figure 8). From this baseline study, we can also conclude that the chosen reference samples on the Bligh Bank can be considered as representative for the future extraction zone for both epibenthos and demersal fish.

From a biological point of view, we can conclude that extraction should concentrate on the top of the sand banks, while the gullies should be avoided since these are the most diverse zones with highest densities, species numbers and diversity for the three ecosystem components.

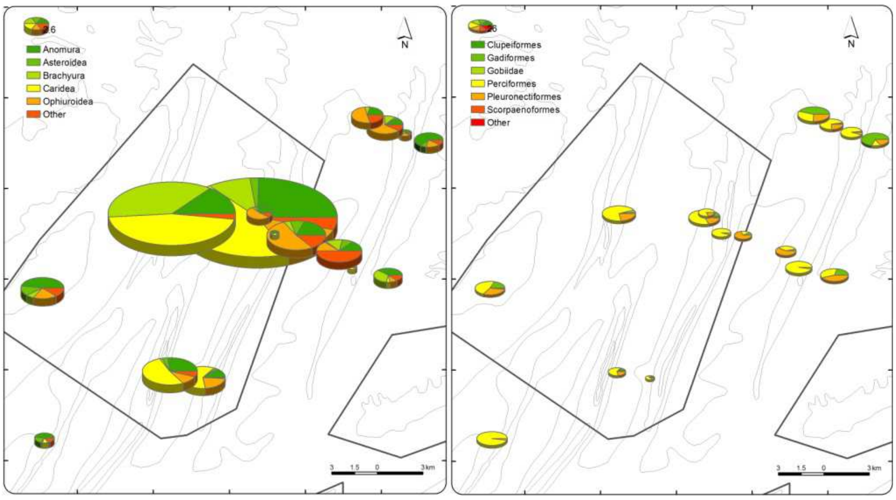


Figure 8: Epibenthos density (ind/1000m², left) and demersal fish density (ind/1000m², right) with relative distribution of the different taxa from spring samples between 2005 and 2008.

Current biological (Before) impact monitoring

In 2010, samples have been taken in the 4 demarcated extraction areas to monitor the macrobenthos and epibenthos/demersal fish fauna. Simultaneously several reference stations have been sampled on the Hinderbanks outside the (future) extraction areas and on the Bligh Bank (Figure 9). Analyses of the macrobenthos samples from 2010 showed no significant differences between impact and reference samples before the impact has started (Figure 9). This proves that the stations are well chosen, and that we for the first time in biological impact monitoring for sand extraction have a sound before impact-control (B(A)CI) design! The recent fish track samples have not been analysed yet but those were already incorporated in the baseline study and we could conclude that the reference samples are representative for the impact samples (see above).

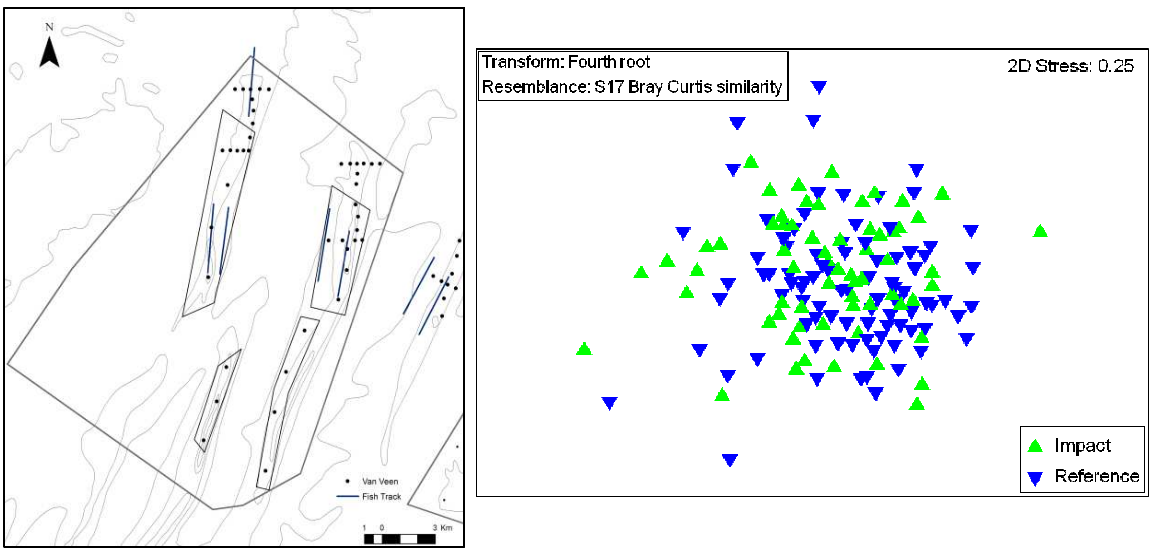


Figure 9: (Left) Macrobenthos and epibenthos/demersal fish sampling stations within and outside the (future) extraction areas. Sampling started in 2010. (Right) MDS plot for macrobenthos samples with indication of impact and reference samples.

The same monitoring strategy will be continued in the coming years after extraction has started and the sampling effort will be increased in the areas which are actually extracted based on the black box data. In the future, with this type of sampling design, it will be possible to use benthic indicators such as BEQI to assess the impact following the Marine Strategy Framework Directive (MSFD).

Conclusions

Integration of a reflection seismic study and extensive vibrocore analyses offers a detailed insight in the grain-size distribution of the subsurface and provides the opportunity for focussed sediment extraction. Seismic profiles also reveal the presence of erosional surfaces which mark important evolutionary stages in the formation of the sandbank and which can serve as future reference levels for restricted sand extraction. The approach of combining seismics with core data is recommended for all extraction areas on the Belgian Part of the North Sea.

The bathymetry, geomorphology and acoustic backscatter cartography of the entire exploration zone provides a detailed base for all future impact studies. This high resolution cartography is the ideal tool for the monitoring of the impact of extraction on bathymetry and surface sediments.

The baseline studies executed by ILVO-Fisheries gave a detailed view on the biological value of the Hinderbanken area, which contributed to the demarcation of the effective extraction areas. Extraction is avoided in the most diverse areas. Furthermore, it is the first time that we have been able to sample before extraction took place, which makes the Hinderbanken area a very interesting case for further impact monitoring.

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