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Intensive evaluation of the evolution of a protected benthic habitat (HABITAT)

Summary of the research

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SYNTHESIS

Introduction

The area of the Belgian Western Coastal Banks (3400 ha) consists of some Coastal Banks (Trapegeer, Broersbank, and Den Oever), as well as two swales (Potje and Westdiep) and is characterised by water depths of –15 m to 0 m MLLWS. The geomorphological structure, being the most diverse along the Belgian coast, is directly responsible for the high biological diversity and richness of the area. At first, its ecological importance was demonstrated by the high numbers of bird species wintering in the area (e.g. common scoter *Melanitta nigra*). Because of the abundant occurrence of seabirds, the area is regarded as an area with international importance for waterfowl (Ramsar convention). Furthermore the area fulfils the criteria of the EC-Bird Directive and is proposed as an EC-Habitat Directive area. Hence, the Belgian government is investigating the necessity and possibility to give the Western Coastal Banks the status of a marine protected area (MPA).

Being a food resource for several seabirds and demersal fish species, the macrobenthos is an important component within the ecosystem functioning of the Western Coastal Banks. Therefore, knowledge of the natural spatial distribution and seasonal variation of the macrobenthos is extremely important when setting up a management plan for the proposed MPA.

The general objective of the project includes the provision of data, necessary for the definition and scientific evaluation of a management plan of the future MPA. Due to the crucial role of the macrobenthos within the coastal ecosystem, especially, the distribution of macrobenthic communities in relation to sedimentological, bathymetrical and hydrodynamical characteristics has been determined. Furthermore, time- and cost-efficient evaluation tools of the management plan of the future MPA are developed.

Materials and methods: general

Shiptime was granted by Coastal Waterways, Ministry of the Flemish Community (Oostende XI and Ter Streep). Additional shiptime was provided by the Management Unit of the Mathematical Modelling of the North Sea (MUMM) aboard the R/V Belgica (acoustical doppler current profiler (ADCP) measurements). The research vessels were all equipped with differential global positioning systems (DGPS).

Single-beam as well as multibeam bathymetry was recorded. Both the analogue and digital recordings were corrected for the vertical movement of the ship. A tidal correction was performed.

Side-scan sonar imagery (*in casu* GeoAcoustics dual frequency side-scan sonar at a frequency of 410 kHz) was collected to obtain very-high resolution imagery of the seafloor. During the surveying, an optimal ship speed of 4 knots was maintained.

To obtain full coverage data on the macrobenthos and its physico-chemical environment, a total of 120 sampling stations were uniformly distributed over the study area with a sampling interval of 500 m. At each station, samples for macrobenthos (Van Veen grab sample), sedimentology (Van Veen grab sample), suspended particulate matter, SPM (Niskin bottle sample), nutrient concentrations within the bottom (Van Veen grab sample) and water column (Niskin bottle), as well as pigment concentrations in the water column (Niskin bottle) were collected. Water depth at the time of sampling was measured. Sampling was performed in October 1999, March and November 2000. The samples for the macrobenthos were sieved using a 1 mm mesh-sized sieve and all organisms were identified to species level. Samples for sedimentology were used to determine the sediment's grain size distribution, using a LS Coulter counter and standard sieve grain size analysis. Bottom and water column nutrients (nitrite, nitrate, ammonia, phosphate, and silicium) were measured trough an automatic chain (SAN^{plus} segmented flow analyser, SKALAR). Pigments within the water column (chlorophyll-a, -c and fucoxanthine) were measured: an immediate extraction with aceton was performed prior to chromatography, with a Gilson high-performance liquid chromotography chain using the method of Mantoura & Llewellyn (1983). SPM was measured by filtering water through a GF/C filter and determining the net dry weight of the filter after filtering.

Regional presentation of the macrobenthos and its physico-chemical environment

REVIEW OF THE BENTHIC HABITAT

Because of the supposed high ecological value of the area, indicated by the large numbers of seabirds wintering in the area, the benthic habitat of the Western Coastal Banks already received some scientific attention. A review on the benthic habitat is presented. Here within, special attention is paid to the development of a database and the production of maps, as an orderly tool to present the spatial distribution of different variables.

In a first phase, maps were drawn on the basis of existing data, both from literature and reports. This included a compilation and integration of bathymetrical, morphological, sedimentological, hydrodynamical and macrobenthos data and provided a better characterisation of the benthic habitat of the study area. Each map is the result of a compilation of the available information, structured in a database. The database allows integrating and superposing newly gathered data and thus provides a tool to visualize the natural evolution of the area. This tool is of direct use when defining the present situation (t_0-situation) of the ecosystem of the Western Coastal Banks.

A bathymetrical-morphological map, comprising the occurrences of bedforms and their relative asymmetry, was set up. The area is characterized by an alternation of sandbanks and swales of varying depths. Sand dunes of different sizes are superimposed on the large-scale bathymetry. Due to the shallowness of the area, the seabed is highly vulnerable to the hydrodynamic forces, which is best illustrated on the basis of bedform occurrences. A digital very-high resolution side-scan sonar reconnaissance survey (September 1999) confirmed the presence of those bedforms and gave evidence of the highly diverse and complex nature of the seafloor.

The surficial sediments are dominated by fine to medium sands with a coarsening of sediments towards the top of the bathymetric highs. The sand bank areas are generally coarsest, often characterised by coarse shell hash whilst the surficial sediments of the swales can have high percentages of the silt-clay fraction.

Semi-diurnal tides of macrotidal range (5.4 m) dominate the area. The tidal currents, characterised by asymmetrical tidal current ellipses, are highly rectilinear with a dominance of the flood current (NE-ENE) that can amount up to 1.32 m/s in the Westdiep swale. Numerical modelling (mu-BCZ) on a 750 m grid showed the highest current velocities in the Westdiep swale and near the foot of the slope of the Trapegeer. From sediment transport calculations, it was shown that the surficial sediments are mainly mobile during Spring and Mid tide, from generally 1 hour before up to 1 hour after High Water. In the Westdiep swale and the Noordpas swale the ebb tidal current is also able to resuspend sediments. To gain insight into the tidal current propagation throughout the study area, numerical modelling was performed on a 250 m grid taking into account the complex bathymetry. Although the results still need further validation, they do show the current variability in function of the large-scale morphology and give evidence of a reinforcement of the current velocity in the swales.

Only little information about the macrobenthos of the Western Coastal Banks from the period before 1999 is available (32 stations). The historical data are restricted to the Trapegeer, Broersbank, Den Oever and Potje. Almost no information about the Westdiep swale was available. Total macrobenthic density ranged from about 100 to over 26000 ind./m², while the number of species per sampling surface area of 0.1 m² (N_0) ranged from 4 to 28 species. Generally, lower densities and species richness were found at the tops of the sandbanks Trapegeer and Broersbank compared to the deeper parts of the area. Three macrobenthic communities, spread over the area were distinguished. The macrobenthos-rich *Abra alba* – *Mysella bidentata* community (syn. *Lanice conchilega* community) is mainly found in the deeper parts of the Potje swale and along the northern slope of the sandbank Trapegeer, while the *Ophelia limacina* – *Glycera lapidum* community (syn. *Mytilus edulis* community) prefers the shallowest sites (e.g. top of the Broersbank). On top of the sandbank Trapegeer and in the area of the Broersbank, the *Nephtys cirrosa* community was found. The spatial distribution of seven macrobenthic species is presented. Although these data provide a first view on the community structure and macrobenthic spatial distribution within the area of the Western Coastal Banks, they should be interpreted with caution. For a geomorphological very diversified area as the Western Coastal Banks, the data, derived from only 32 stations, should be regarded as 'point data': spatial extrapolation of any macrobenthic characteristic was impossible.

MACROBENTHIC HABITAT: SPATIAL DISTRIBUTION

Because of its important trophic function, as a food resource for seabirds and demersal fish, the macrobenthos comprises an extremely important component within the ecosystem functioning of the Western Coastal Banks. Therefore, at first, knowledge of the spatial distribution of the macrobenthos is indispensable when setting up a management plan for the proposed MPA. To update and extend the knowledge on the spatial variation within the macrobenthic habitat, three sub areas, with a maximum geomorphological diversity, were intensively investigated for their physico-chemical environment and macrobenthos in October 1999.

Within the subareas, full-coverage very-high resolution side-scan sonar imagery was obtained that allowed to study the intrinsic nature of the seafloor in relation to the large-scale morphology. The combination of reflectivity, texture and patterns was translated into specific acoustic facies that could be primarily interpreted in terms of the small-scale morphology and bedform occurrences, distribution of sediments and their relative compaction superimposed with hydrodynamical effects.

Sediment samples confirmed the highly variable nature of the sediments and this often on very short spatial intervals. On the sandbanks, the distribution of the surficial sediments is hydrodynamically determined: the currents are strong enough to distribute the sediments. In the swales, a variety of sediments is deposited. This is mainly due to the high availability of fine-grained sediments that can settle out during slack water. On the contrary, the Westdiep swale is generally characterised by coarser sediments. As confirmed by side-scan sonar imagery, this swale should be regarded a high-energy depositional environment.

Along the foot of the slope of the Trapegeer sandbank, acoustic doppler current meter results confirmed the highly rectilinear nature of the tidal currents with a predominance of the flood current. Yet, the correlation between the high spatial variability and the hydrodynamical numerical model results still needs further investigation.

The knowledge on the macrobenthic community structure, based on historical data (see above), was confirmed by the detailed investigation. Next to one transitional species association (*Magelona mirabilis* transitional species association), three of a total of four subtidal macrobenthic communities discerned at the BCS were found within the area of the Western Coastal Banks: *A. alba* – *M. bidentata*, *N. cirrosa* and *O. limacina* – *G. lapidum* community. Each community or species association is restricted to a very specific physico-chemically defined habitat. Although the communities were spread all over the area, zonation, related to depth amongst others, was demonstrated. The *A. alba* – *M. bidentata* community proved to be an ecologically highly valuable macrobenthic community on the BCS. The community is characterised by the highest macrobenthic densities (average: 7589 ind./m²) and diversity (average N_0: 37 spp.). Furthermore, many bivalve species are found in high densities within the community (e.g. on average *A. alba*: 992 ind./m² and *Fabulina fabula*: 273 ind./m²). These bivalves are known to be an important food resource for larger epibenthic predators (e.g. cod *Gadus morus* and sole *Solea solea*) and benthos-eating diving seaducks (e.g. common scoter *Melanitta nigra*). Because of (1) the local sediment stabilization by dense patches of *Lanice conchilega* and (2) the increasing habitat complexity due to the extending upper parts of the tubes, the tube-building polychaete *L. conchilega*, primarily occurring within the *A. alba - M. bidentata* community, probably fulfills an important habitat-structuring role within the ecosystem. Indeed, a positive correlation between the macrobenthic density and N_0, on the one hand, and the density of *L. conchilega* on the other hand was found. Both other communities and the transitional species association contribute substantially to the overall macrobenthic diversity of the Western Coastal Banks: 74 % of all macrobenthic species, recently (since 1994) found on the BCS, were detected within the study area. Furthermore, macrobenthic densities and diversity were generally high, compared to other ecological regions on the BCS. The Western Coastal Banks should thus be considered as a hotspot for macrobenthic life on the BCS.

MACROBENTHIC HABITAT: TEMPORAL VARIATION

The macrobenthic communities of shallow coastal waters are subjected to a variety of physical and biological disturbances that vary in frequency and intensity, as well on a temporal as on a spatial scale. The natural variation within the macrobenthic communities should help to explain issues fundamental to ecology, but also to the conservation and management of the marine benthic habitat. To study the temporal variability within the macrobenthic habitat of the Western Coastal Banks, the multi-disciplinary study of October 1999 was repeated in March 2000.

On a sedimentological level, the temporal variability was minimal and generally, the differences were within the error imposed by the analysis. In both months, the sediments mainly consisted of fine and medium sand (both about 40 %) and had an average median grain size of about 270 µm. The side-scan sonar imagery shows more variability as it reflects the upper seafloor characteristics. Most striking was the presence of white reflectivity bands in the deepest parts of the swales that could be interpreted as fluid mud layers superimposed on fine sandy sediments. Still, in terms of an interpretation towards an acoustic facies, hardly any differences were observed indicating that a standardised side-scan sonar interpretation is valid on a temporal basis.

In both months, polychaetes and bivalves dominated the macrobenthos. Although the community structure changed within all macrobenthic communities, the communities, detected in October 1999, were still present in 2000: 50 to 90 % of the most abundant species of each community was identical in both months. Because of the relative low temporal variation of the structure of the three communities, the temporal variation does not overrule the “basic” structure of each community. It was demonstrated that different macrobenthic communities show different temporal dynamics. The temporal variation was most obvious in the *A. alba – M. bidentata* community. A significant decrease in macrobenthic density and diversity (N_0) was observed from October 1999 to March 2000: from 7589 to 3264 ind./m² and from 37 to 27 species, on average. Furthermore, 85 % of the indicative and abundant species within the community showed a significant decrease in density. Only minor, non-significant changes within the density and diversity were detected within the *N. cirrosa* and *O. Limacina – G. lapidum* community and the *M. mirabilis* species association. Because of the spatial stability of the ecologically most relevant physico-chemical environment (e.g. sedimentology and depth) at the sampling stations, 71 % of the stations harboured the same community in October 1999 and March 2000. A high spatial distributional stability of the macrobenthos was found within the area of the Western Coastal Banks.

<u>Development of methodologies for the creation of time- and cost-efficient monitoring tools for the future MPA</u>

HABITAT MODEL

The 'macrobenthic potential' of a habitat is defined as the dynamics of the macrobenthic community structure (e.g. species composition, diversity, and densities) within the habitat. When, within a certain area, information is available about (1) the different macrobenthic communities present, (2) their seasonal variability and (3) their habitat preferences, information on the biologically relevant, physico-chemical parameters of a site within the area allows to predict the ‘macrobenthic potential’ of that site. Within this part of the study, at first, the 'macrobenthic potentials' of the different habitats were assessed. Secondly, the HABITAT model, aiming at modelling the correlations between the macrobenthos and its physico-chemical habitat, was set up. The HABITAT model will allow evaluating the ‘potentials’ of non-studied places within the protected area on a time- and cost-efficient base.

The 'macrobenthic potential' of a habitat/community, as illustrated by their respective 'potential species list' in this study, revealed the extraordinary ecological value of the *A. alba - M. bidentata* community relative to both other communities. Being a transition between the *A. alba - M. bidentata* and the *N. cirrosa* community, the *M. mirabilis* species association had an intermediate ecological value. Hence, when valueing the different habitats of the Western Coastal Banks, the habitat of the *A. alba - M. bidentata* community is clearly ecologically superior to all other habitats. Yet, this should not be interpreted as the other habitats being ecologically unimportant. Both within and in between habitat biodiversity, resp. alfa- and beta-diversity, are important within the ecosystem functioning.

The HABITAT model consists of eight classification function sets derived from multiple discriminant analysis. Each set of classification functions takes into account a different series of environmental variables. Based on the macrobenthos data of October 1999 and March 2000 (three communities and one transitional species association), 78 % of the classification functions revealed a community specific and overall *a posteriori* and *a priori* accuracy of at least 70 %. These accuracies can be drastically improved if only the three macrobenthic communities are taken into account. Comparing the community specific accuracy of each classification function set, no set can be put forward as superior to the other sets. As a result of a test of the HABITAT model, using data collected in November 2000, further testing and refinement of the models is advised.

STANDARDIZED MACROBENTHIC INTERPRETATION OF SIDE-SCAN SONAR IMAGES (MSSSI)

Two approaches were followed in the interpretation of side-scan sonar imagery in terms of the occurrence of macrobenthic communities.

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 presence of dense fields of the tube-building polychaete *Lanice conchilega*. If the density of this polychaete worm is indeed high enough, local sediment accumulations, detectable by side-scan sonar technology, can be formed. Interestingly, the occurrence of this acoustic facies is highly correlated with slope environments leading to the assumption that these environments have a high input of suspended matter.

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 is put forward through the set-up of a table with different criteria and interpretation keys. This table provides a discrimination of acoustic facies into a maximum of classes, which are finally linked to a macrobenthos community preference.

HABITAT STRUCTURE MAP

To be able to set up a scientifically approved management plan for the Western Coastal Banks and to allow a good future decision making, it is necessary to have as much data as possible on the ecosystem. An overview of the data, summarizing their basic significance, will thus add to the usefulness of the projects outcome. This part of the study specifically aims at the development of a ‘habitat structure map’ from the database, which combines all available information on the benthic habitat of the Western Coastal Banks.

As such, the 'habitat structure map' reflects the present knowledge on the bathymetry, sediment nature, the acoustic facies and the occurrence of the macrobenthic communities. This approach visualises the interactions between the physical environment and the macrobenthos and is a tool for a scientifically sustained evaluation of this unique ecosystem. Together with the other maps, the habitat structure map reflects the situation of the ecosystem before the effectiveness of a support plan. Knowledge on the t_0-situation is of primary importance for the evaluation of the effects of the policy decisions. Because of the standardized methods and the uniform production of maps, a future integration of all information into a Geographical Information System (GIS) or a thematical atlas is possible.

Implications for future management and monitoring

Spatial extrapolation of point-data

So far, knowledge on the spatial distribution of the macrobenthos was restricted to the description of the macrobenthos present at the sample stations. In most studies, full-coverage spatial extrapolation between the sample points proved to be unreliable. Yet, full-coverage knowledge on the spatial distribution of the macrobenthos would allow to better manage the benthic habitat within the future MPA. To retrieve time- and cost-efficient, full-coverage knowledge on the spatial distribution of the macrobenthos, based on the results of the HABITAT projects, two methods are put forward.

Since the collection of data to retrieve a detailed bathymetric-sedimentological map of an area is less time-consuming than the collection of those for a detailed macrobenthic map, the HABITAT model provides a powerful time- and cost-efficient tool to retrieve a full-coverage view on the spatial distribution of the 'macrobenthic potentials'. Through the macrobenthic side-scan sonar interpretation, (MSSSI) very-high resolution side-scan sonar imagery can be used to predict the occurrence of the macrobenthic communities and bioherm structures, such as *Lanice conchilega* 'bumps'. This technique thus provides insight into the full-coverage delineations of communities and bioherms and thus allows evaluating the ‘macrobenthic potentials’ of non-studied places within the protected area on a time- and cost-efficient base.

Stratified random sampling strategy based on remote sensing

If no information on the macrobenthic habitat of an area is available, a random sampling design provides a good strategy to study the benthos. Yet, a major disadvantage of a random sampling strategy is the fact that a high number of samples is needed to retrieve a representative view on the macrobenthic spatial distribution. If a stratified random sampling strategy can be applied, each set of macrobenthos samples, collected within a stratum, is considered to consist of replicate samples of that stratum and should provide a representative view on the macrobenthos of the stratum. The application of a stratified random sampling design already leads to a decrease in the number of samples needed to achieve a representative view of the macrobenthic community structure. Since remote sensing techniques (e.g. side-scan sonar) (1) provide a full-coverage view of the benthic habitat and (2) are known to be related to the macrobenthic community structure, remote sensing provides an extremely useful tool for the delineations of ecological relevant strata. Thus, a stratified random sampling design for the study of the macrobenthos, based on the delineation of strata through side-scan sonar images, will not only decrease the numbers of samples needed (= time- and cost-efficient), but will further provide a reliable, full-coverage view on the temporal variation of the macrobenthos within the area.

Strategies for future monitoring

To allow a time- and cost-efficient monitoring of the ecosystem after the implementation of a management plan, it is important to select the optimal monitoring strategy and techniques for a given situation. Three steps are proposed for the monitoring of the macrobenthos of the Western Coastal Banks: (1) selection of ecologically relevant strata, based on the available side-scan sonar recordings, (2) monitoring of the macrobenthic habitat, through the investigation of the macrobenthos (bottom samples) and its physico-chemically environment (remote sensing and bottom samples) based on a stratified random sampling design, and (3) full-coverage monitoring of the macrobenthic habitat, using remote sensing. Following this strategy, a fast evaluation of measures, taken within the framework of the management plan for the area of the Western Coastal Banks, is possible.