Use of multibeam echosounder surveys in relation to designating and managing Marine Protected Areas

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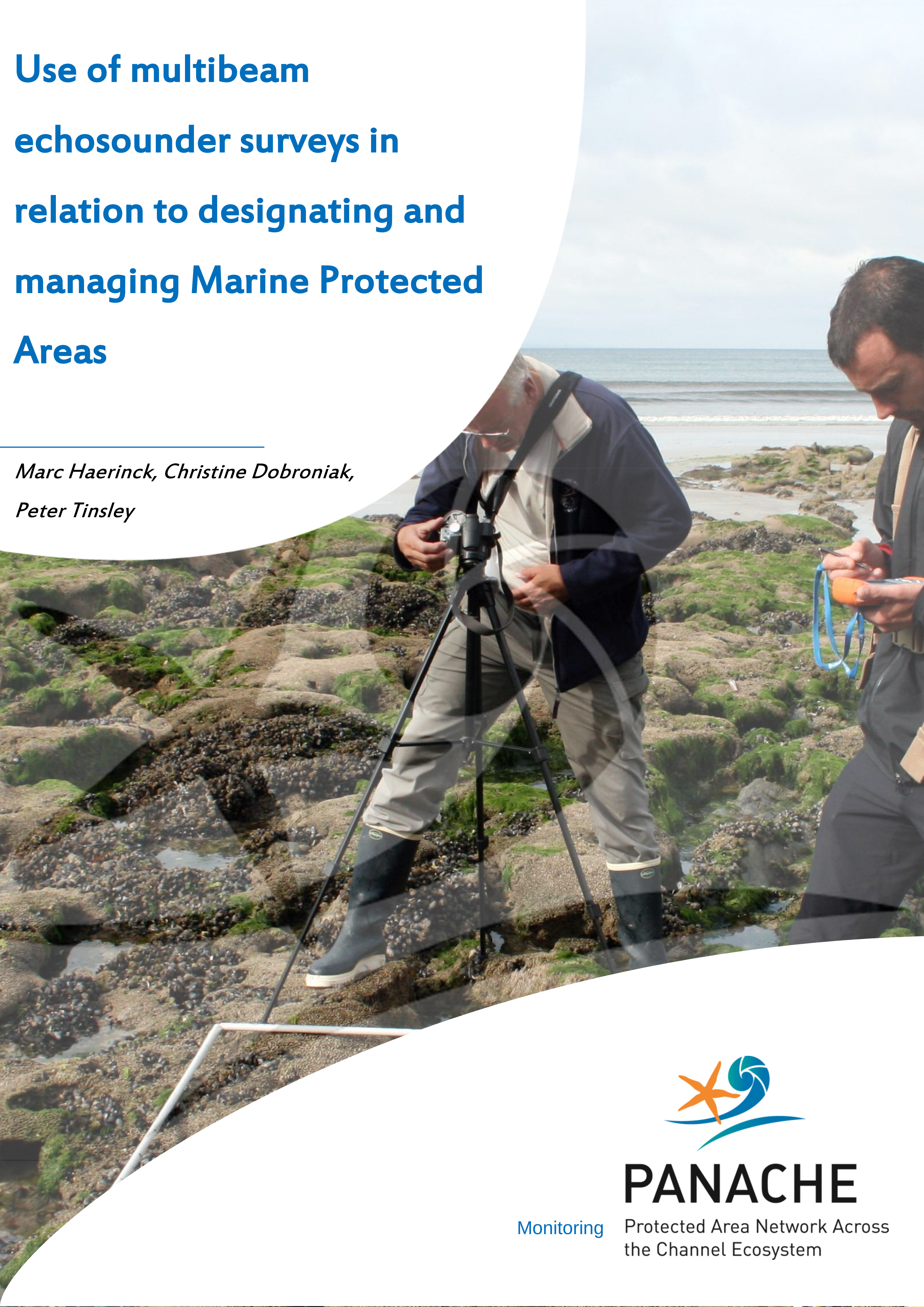

Monitoring

PANACHE
Protected Area Network Across the Channel Ecosystem

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Monitoring

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Use of multibeam echosounder surveys in relation to designating and managing Marine Protected Areas

Utilisation du sondeur multifaisceaux comme outils pour la désignation et la gestion des aires marines protégées

ABSTRACT

This report looks at the use of multibeam echosounder survey (MBES) as a tool for designating and managing MPAs through two case studies. The first looks at how MBES data, often collected for other purposes, influenced site selection and boundary decisions during marine Special Area of Conservation and Marine Conservation Zone designation in English waters of the Channel and how MBES has been used to support management of marine protected areas, from mapping of protected features to raising awareness and public support.

The second case study looks at using repeat MBES surveys to detect morphological change in sediment habitats on the French Channel coast. The high cost of collecting MBES, mostly due to ship time, means that collaboration between agencies collecting MBES for different purposes is necessary, with the caveat that data from hydrographic surveys may have less than optimum quality backscatter information, which can reduce the value of the data for delineating seabed habitats and therefore for detecting change in condition or extent of conservation features.

RÉSUMÉ

Ce rapport porte sur l'utilisation de l'enquête de l'échosondeur multifaisceaux (SEMF) comme un outil pour la désignation et la gestion des AMP à travers deux études de cas. Le premier s'intéresse aux données issues des echosondeurs multifaisceaux, souvent collectées à d'autres fins, qui peuvent influencer le choix du périmètre des AMP lors de leur désignation dans les eaux anglaises de la Manche et, qui peuvent aussi être utilisées dans le cadre de la gestion des AMP grâce à une cartographie fine, notamment pour la sensibilisation du public.

La deuxième étude de cas porte sur l'utilisation régulière des sondages multifaisceaux pour détecter les changements morphologiques dans les habitats sédimentaires des côtes françaises de la Manche. Le coût élevé de la collecte par SEMF, principalement du à l'exploitation du navire en mer, engage à la collaboration entre les différentes agences scientifiques pour mettre en commun les données SEMF collectées à des fins différentes. Toutefois, il faut noter que les données de levés bathymétriques n'ont pas forcement la qualité nécessaire pour délimiter les habitats des fonds marins et donc pour détecter les changements d'état ou l'étendue des objectifs de conservation.

KEYWORDS: multibeam, MBES, hydrographic, marine protected area, MPA, seabed habitats, sediment facies, monitoring,

MOTS-CLÉS : éhosondeur multifaisceaux, SEMF, aire marine protégée, AMP, fonds marins, dynamique sédimentaire, suivi

Content

1. Introduction

The PANACHE INTERREG IV project, which aims for greater coherence between marine protected areas located in the CHANNEL between France and England, involves several key topics that are discussed by the many partners taking part in the initiative. One of the missions inherent to the PANACHE project consists in sharing best practices and actions to achieve a more coherent approach to monitoring MPAs and in testing innovative monitoring techniques.

This mission aims to bring to light practices that have already been tested by certain partners and which could be used by all MPAs in the area.

1.1 Multibeam Echosounder Surveys (MBES) as a monitoring tool

The difficulty of directly accessing the seabed, even in relatively shallow water, makes survey and monitoring of marine protected areas especially challenging. Remote sensing techniques necessarily play a large part in any marine survey and monitoring strategy. Multibeam echosounder survey (MBES) is widely used as it is relatively cost-effective, capable of collecting detailed data from broad swathes of seabed. It is still an expensive survey method but there is considerable opportunity to make use of data collected for other purposes (e.g. hydrographic survey for the production of navigational charts) for seabed habitat mapping and monitoring.

Coupled with a GPS, multibeam echosounders are bathymetric sounders completed by an imaging function. Information about the seabed's depth and nature can be simultaneously acquired. The principle is based on a crossed beam technique: the tone burst is emitted and the signal reflected by the sea bed is received by perpendicular beams. The seabed area explored is the intersection between the beams emitted and received (**Erreur ! Source du renvoi introuvable.**1). The multibeam echosounder emits several beams at the same time (from a dozen to several hundred), in several directions, which guarantees a high spatial resolution.

Corrections are applied to the data received by the echosounder in relation to: the ship's movements (heave, pitch, roll); the tide; and also the velocity of the beam in the water column which varies according to different parameters such as temperature, current and salinity.

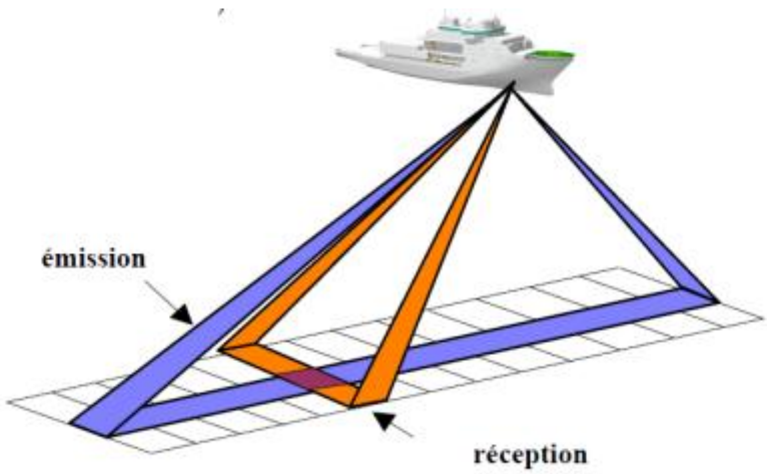


Figure 1: Principle of operation of the multibeam echosounder (IFREMER)

The result is a dense set of bathymetric points which can be used to create a digital terrain model (DTM) of the seabed. This in itself can provide a great deal of information about the nature of the seabed with prominent features such as reefs and sandwaves being recognisable.

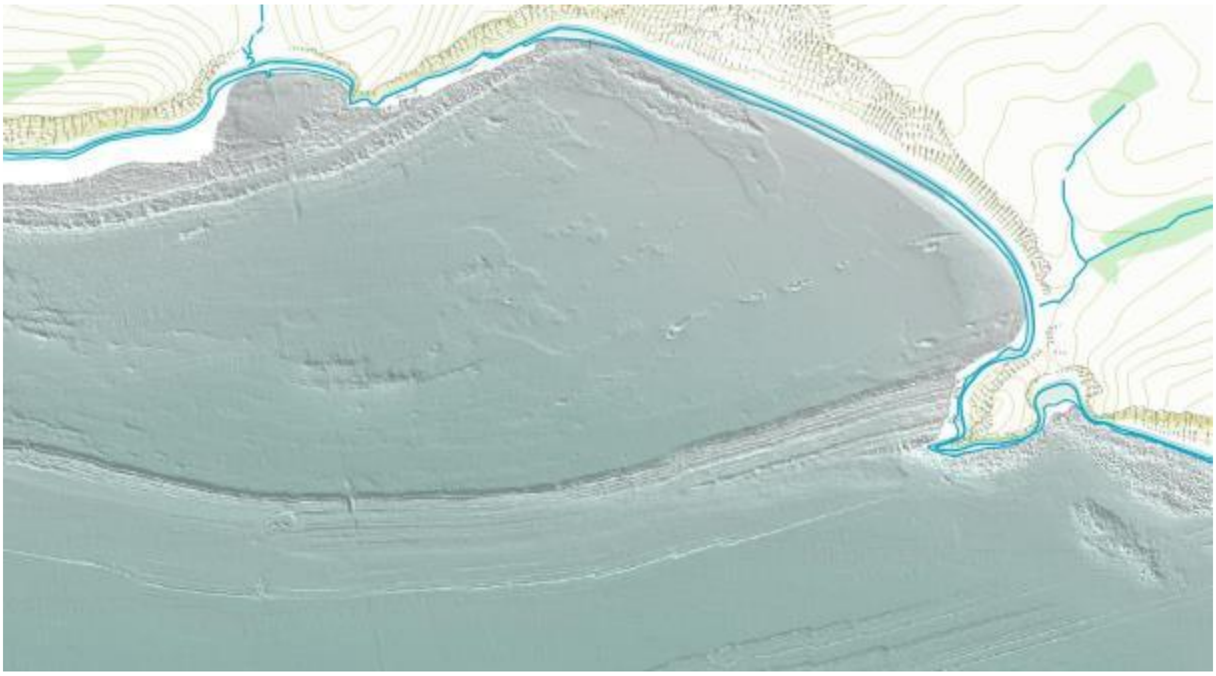


Figure 2 : Bathymetry from multi-beam echsounder data – 1m grid. Small details, including outfall pipeline, are clearly visible. Contains Ordnance Survey data © Crown copyright and database right 2014. Contains MCA data ©Crown Copyright. Not to be used for navigation

Many of these features can be mapped by eye directly from the DTM and can lead to the sort of seabed texture sheet shown below.

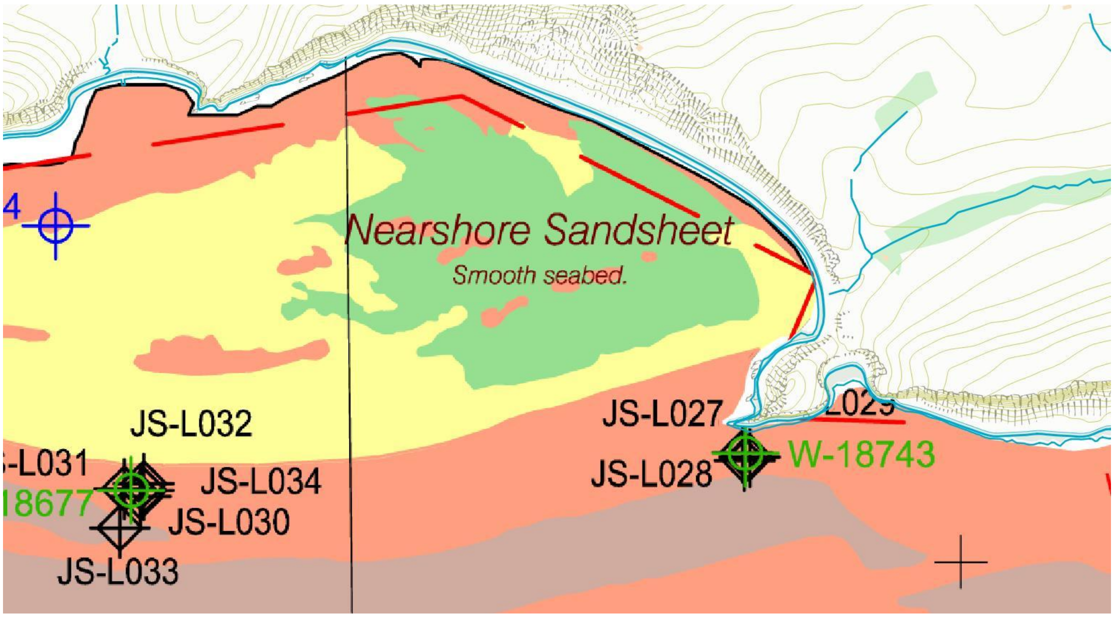


Figure 3 : Example of seabed texture sheet derived from multibeam dataContains Ordnance Survey data © Crown copyright and database right 2014. Contains MCA data ©Crown Copyright. Not to be used for navigation

To make the delineation of these features easier, it is possible to extract characteristics from the DTM, such as slope, which highlights ridges and ledges – but it still takes a trained eye to distinguish sandwaves from rock ledges.

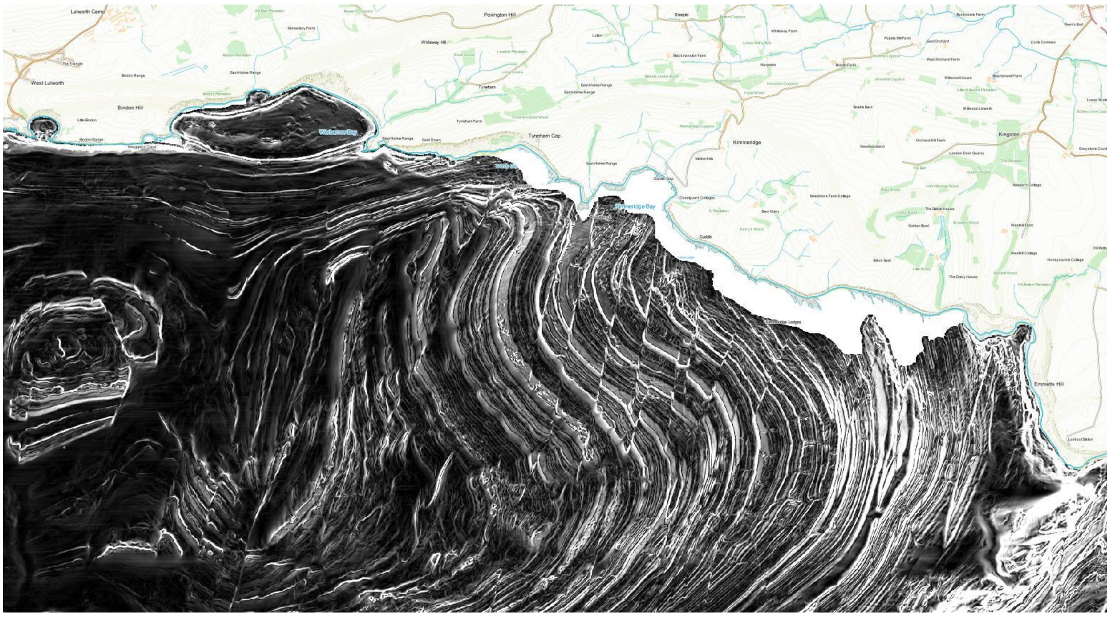


Figure 4: Slope derived from DTM – lighter areas show steeper ground. Contains Ordnance Survey data © Crown copyright and database right 2014. Contains MCA data ©Crown Copyright. Not to be used for navigation

A further extracted characteristic is terrain profile index (TPI) which is a measure of how much any given spot depth differs from its surrounding neighbours. This can be used to characterise “landforms” such as ridges, depressions and plains. It is still unable to distinguish sandwaves from rock ledges, but useful for helping to characterise areas.

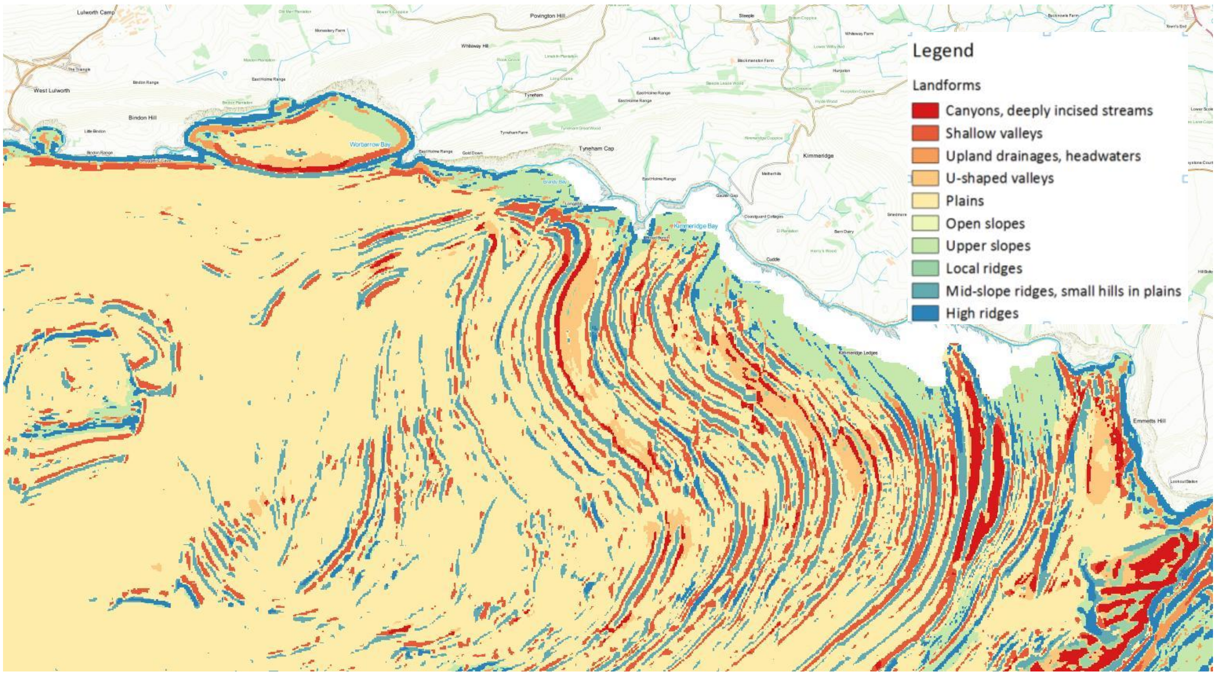


Figure 5: « Landforms » derived from Terrain Profile Index. Contains Ordnance Survey data © Crown copyright and database right 2014. Contains MCA data ©Crown Copyright. Not to be used for navigation

One of the advantages of multibeam is that it provides co-located backscatter (reflectivity) data with the bathymetry. The backscatter gives an indication of the hardness and/or roughness of the seabed, which can give the clue needed to distinguish different sediment types, for example, that show up in the DTM as identical flat areas. The image below shows backscatter superimposed on the DTM – this helps to delineate the area of fine sand (dark – high reflectivity) in the east end of the bay. Unfortunately, backscatter quality can vary throughout a survey and is especially susceptible to poor weather conditions – you can see some artefacts in the backscatter (dark stripes near the bottom of the image) caused by the roll of the survey vessel. See p12 for further discussion about backscatter.

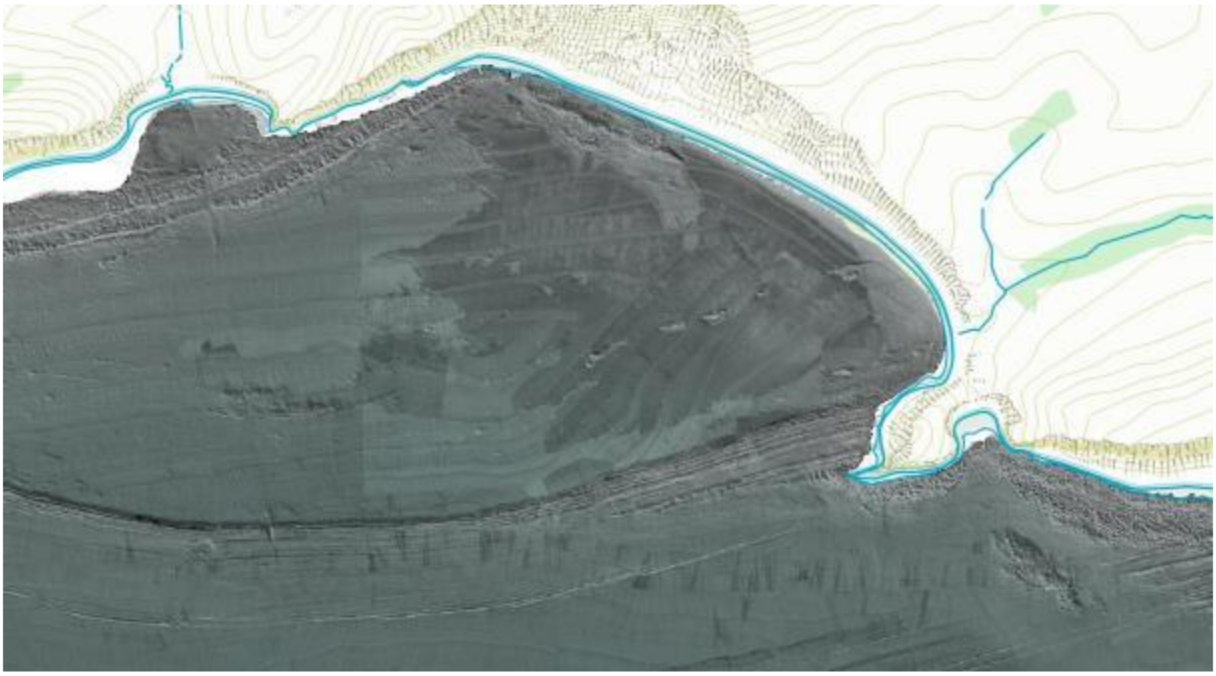


Figure 6: Bathymetry with multibeam backscatter overlaid. Contains Ordnance Survey data © Crown copyright and database right 2014. Contains MCA data ©Crown Copyright. Not to be used for navigation

Despite being one of the more cost-effective methods of gathering seabed data, MBES is still costly as it involves a great deal of ship-time. It is difficult to provide a simple cost per area for multibeam survey as there are many variables, especially the depth of water, but HI1154 (the survey contract for DORset Integrated Seabed survey (DORIS)) covered 683km^2, to within 1m depth range or less. This created a total of over 11000km of survey lines, equating to nearly 70 days of ship time and cost £329,000 in 2008

Figure 7: Area covered by HI1154 at a cost of £329,000 in 2008. Contains Ordnance Survey data © Crown copyright and database right 2014

The biggest use of MBES is charting the seabed for navigational purposes and there are international standards that stipulate how the data should be collected and processed. For example IHO order 1A requires 100% coverage of the seafloor and the ability to detect objects as small as a 2m cube on the seabed. To reduce costs, MBES surveys collected for habitat mapping purposes often don't attempt to meet these high standards - they may use a corridor approach rather than full seabed coverage, for example and the quality control may be lower. The downside to this approach is that it reduces the value of the data collected to other parties, such as the UK Hydrographic Office or the French Naval Oceanographic and Hydrographic Service (SHOM). This may well mean that one of the latter organisations will end up repeating a survey to meet IHO specifications – a waste of time and resources. Generally, MBES data collected for navigational purposes will be useful for habitat mapping, but the reverse is often not the case.

It is becoming increasingly important to seek partnership opportunities when planning survey programmes. In the UK, the Civil Hydrography Program is the biggest commissioner of multibeam survey with an annual budget of £5m, the aim being to update navigational charts. Some of this work is re-survey, in areas subject to rapid change, the rest is planned according to a medium to long term programme, based on urgency and reliability of existing data (some of which may still be lead soundings). In France, SHOM shares two of its survey vessels with IFREMER – the French Research Institute for Exploitation of the Sea.

Recognising the advantages, especially cost-savings, of collaboration, the UK has recently drawn up a pan-government hydrographic data agreement aimed at sharing bathymetric and backscatter data and collaborating on data collection. This extends previous ad-hoc agreements such as DORIS and JIBS. A relevant example from the Channel MPA region was the bringing forward of the survey of the area of the Lyme Bay Reefs proposed SAC in order to have the data in time for the designation – the survey was funded by Natural England, carried out as part of the CHP through the Maritime and Coastguard Agency, to full IHO 1a specification and the data made freely available to all government organisations. As a further freeing up of data, all UK hydrographic data are now available under an open-government licence for widespread use and can be downloaded from the UKHO INSPIRE Portal and Bathymetry DAC - http://aws2.caris.com/ukho/mapViewer/map.action.

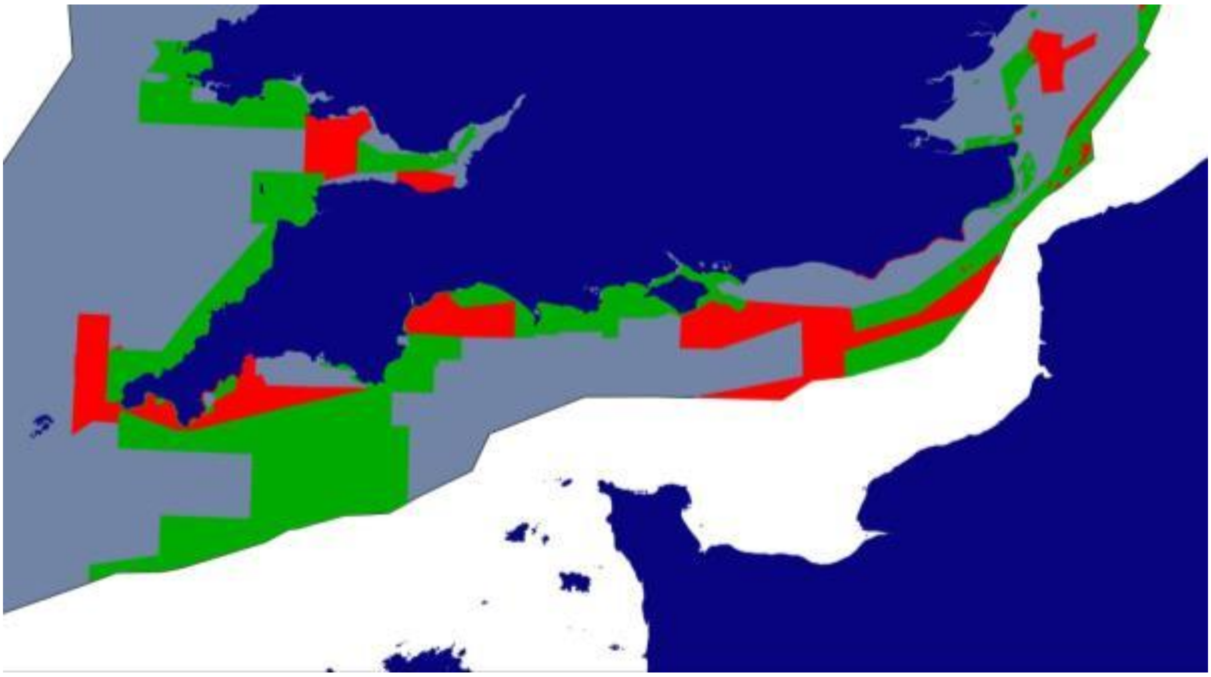


Figure 8: Areas covered under UK Civil Hydrography Programme. Green areas are completed, red areas are planned in the near future.

French multibeam data is stored at the National Bank Of Bathymetry : Multibeam Echo-Soundings, hosted by IFREMER but most of the bathymetric data are of restricted access due to multiple regulations (UNCLOS, French Law, Defense...)

1.2 Issues with quality of backscatter

Hydrographic surveys are carried out to high specification, producing very good quality datasets that are valuable for seabed habitat mapping, but there are a couple of issues that can reduce their value – mostly around the collection of backscatter. Hydrographic surveys are primarily interested in the quality of the bathymetric data – driven by the need for certainty on the depth of water at any given point.

The accompanying backscatter is of lesser importance for navigational surveys but can be crucial for distinguishing seabed habitats. The following issues may be encountered when using datasets acquired primarily for hydrographic survey :

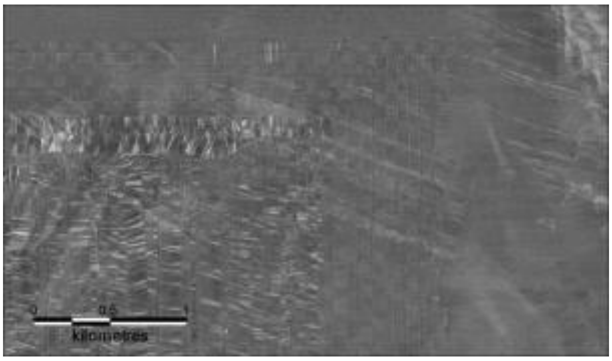
Loss of data

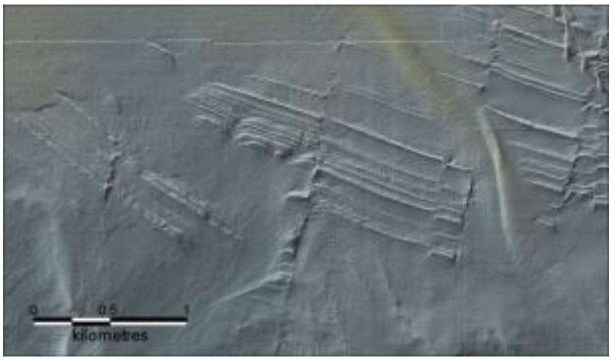
Backscatter is of lesser importance for navigational survey and can be treated with less care. The DORIS survey used four different vessels and two contractors. All of the bathymetry data were delivered to the project, but some strips of backscatter were irretrievably lost

Quality of data

The IHO specifications effectively restrict the weather conditions during which survey vessels can operate as sea conditions affect the quality of the data gathered. The effect of poor weather is much greater on backscatter than bathymetry. Days lost to weather can be costly to survey companies so they will work in conditions that are just suitable for bathymetric data but beyond that where any useful backscatter can be collected. See Figure 9

Depending on the system used, it may be possible for the operator to adjust the gain which can cause problems later when trying to compare backscatter from different tracks or survey days – especially if the adjustments are not noted in the survey logs





a – very poor quality backscatter (bottom left) collected by small vessel operating offshore in poor weather

b – bathymetry data from the same area

Figure 9: Effect of poor operating conditions on backscatter and bathymetry data from MBES

1.3 Repeat surveys – measuring change

Apart from areas where the seabed changes regularly and rapidly, hydrographic surveys are not regularly repeated but, where this is done, changes to the seabed shape, volume and composition can be detected. An example is the monitoring of operations such as dredging (of aggregates or for channel management for ports) and disposal of sediments and other material on the seabed. For example, the Grand Port Maritime de Dunkerque (Port of Dunkirk - GPMD), France's third largest port, routinely uses a multibeam sonar to detect the bathymetric variations of the sea bed. This equipment, which the GPMD acquired in 2001, provides the port services with information about the growth status of its docks and the various traffic lanes that ships take to reach the GPMD's quays. As GPMD has responsibility for the Bancs des Flandres Natura 2000 site, designated for "Sandbanks which are slightly covered by sea water all the time", the port authority has also used MBES to specifically to detect and monitor movement and change within the sandbanks and ridges.

This report presents two case studies where multibeam has been used in relation to Marine Protected Area. The first, on the Dorset coast, covers the use of multibeam in identifying and designating MPAs, the second, off the coast of Dunkirk, considers how multibeam can be used to monitor changes in the designated features of a MPA – sandbanks.

2. Case study – Use of MBES data in relation to MPA site selection and management in England

MBES produces detailed seabed topographic information of swathes of seabed with co-registered backscatter (reflectivity). It has become the tool of preference for hydrographic survey, which means that a lot of data is becoming available through programmes such as the Civil Hydrography Programme mentioned above. Such data may prove useful for MPA managers even though that was not the reason for collection (but see earlier caveats).

2.1 Habitat/feature mapping for MPA selection/designation

MBES data has been used in two MPA site selection processes in the UK Channel:

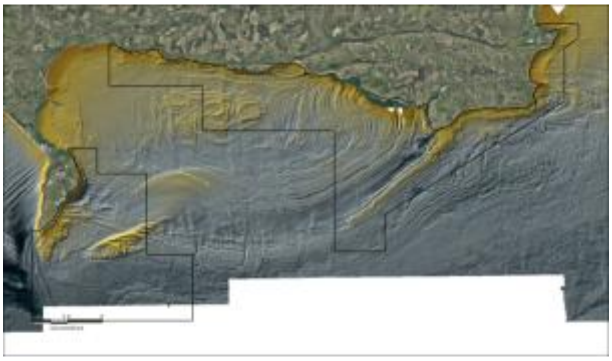
- Completion of UK complement of European Marine Sites for Annex 1 reefs
- Selection of network of Marine Conservation Zones

2.1.1 Example 1 – The search for additional Annex 1 reef SACs

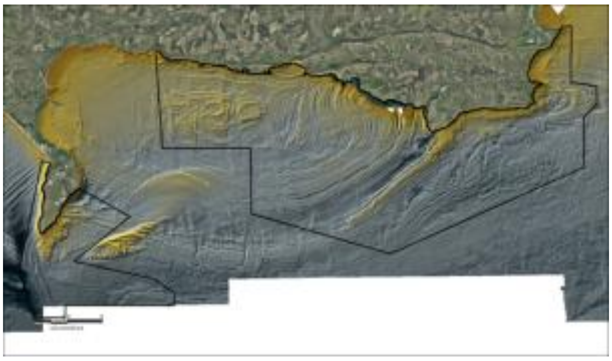
The search for additional examples of Annex 1 reef habitat in UK waters began in 2006 on the basis of existing information. Very little of this included multibeam data as it was just beginning to be used routinely by the Maritime and Coastguard Agency. Natural England and JNCC commissioned a small amount of additional survey work to improve the available evidence, but did not include any extensive multibeam surveys, on cost grounds.

The result of the data collation and additional survey work was the proposal of the Studland to Lyme Bay SAC in 2007. During the period of statutory public consultation on this proposal, Dorset Wildlife Trust submitted evidence, including full coverage multibeam and backscatter data collected during DORIS. This was used to justify the substantial re-drawing of the proposed SAC boundary between Studland and Portland to better follow the distribution of reef habitat (see maps) and to bolster the existing evidence.

The area covered by the proposed Lyme Bay and Torbay reefs SAC fell within the Civil Hydrography Programme's Shallow survey programme. This area was surveyed in 2010 to IHO order 1a, funded by Natural England and the data shared under the pan-government agreement.



a – outline of original proposed SAC boundary, based on desktop study
©GetMapping 2009



b – Revised SAC boundary following submission of new data, including multibeam
©GetMapping 2009

Figure 10: Changes in boundary of Studland to Portland SAC following provision of MBES data

2.1.2 Example 2 – Marine Conservation Zone site selection

In 2010 a number of regional projects around England began the process of identifying potential Marine Conservation Zones - a new national MPA designation. The process was stakeholder-led and involved socio-economic as well as ecological information in site selection. There was little supporting survey work carried out during the selection process, the aim being to rely on the "best available evidence" though some interested parties did carry out or commission some new studies.

Site selection principles were provided in the "ecological network guidance" document - in the absence of widespread, detailed data, much of the selection was based on UK-wide maps of broad habitat types, themselves based on modelled data. The projects recommended a number (127) of sites for designation but quickly ran into problems over evidence – many sites were suggested for features from the modelled habitat maps and there was little supporting evidence to show that many of these target features were present in the proposed sites.

The designation process was then put on hold while some additional evidence gathering was undertaken. Both Natural England and JNCC commissioned a number of multibeam surveys of recommended MCZs – mostly the offshore sites where there was little previous information. With the support of this extra information, 27 out of 31 sites proposed in the first tranche of designation were conformed in 2013 and a further 37 sites will be considered in the next tranche.

Alongside these processes, the Civil Hydrography Programme continued with its short term survey plans, including survey HI1366 in Poole Bay. The data arrived too late to support the designation of the Poole Rocks MCZ (designated 2013) but strongly corroborates the evidence used in the designation. It is likely that the boundary would have been slightly larger had this dataset been available at the time as the distribution of reefs clearly extends beyond the site boundaries.

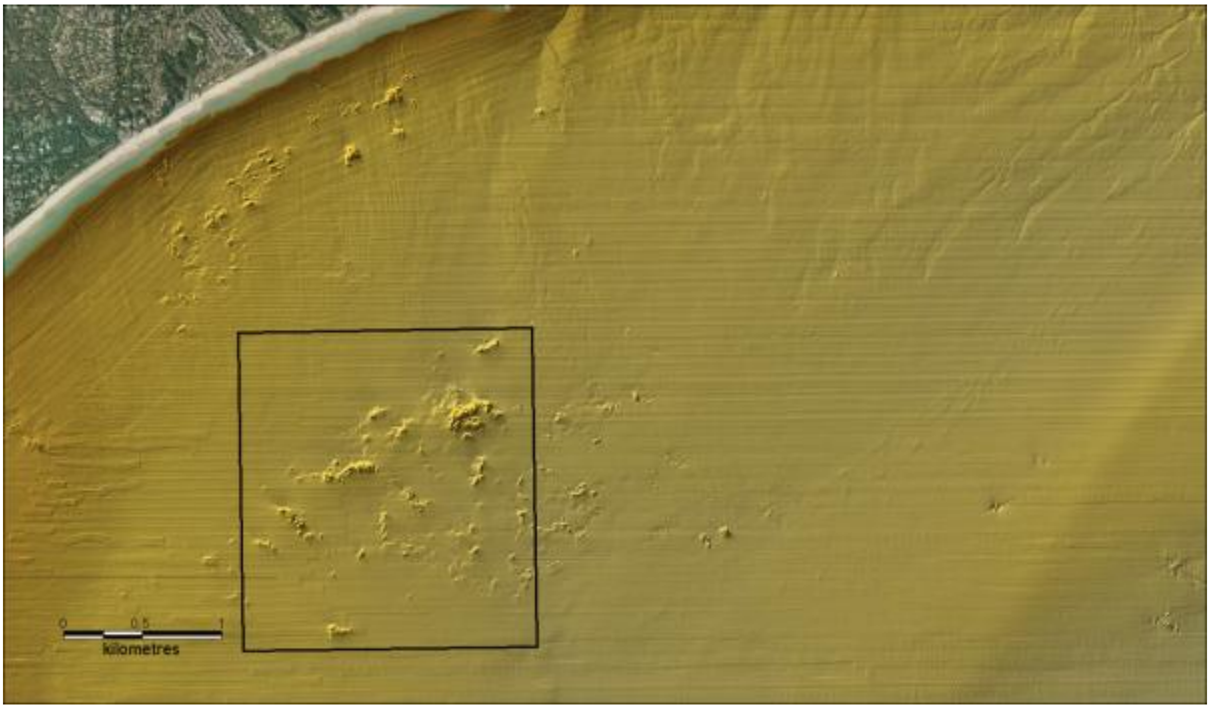
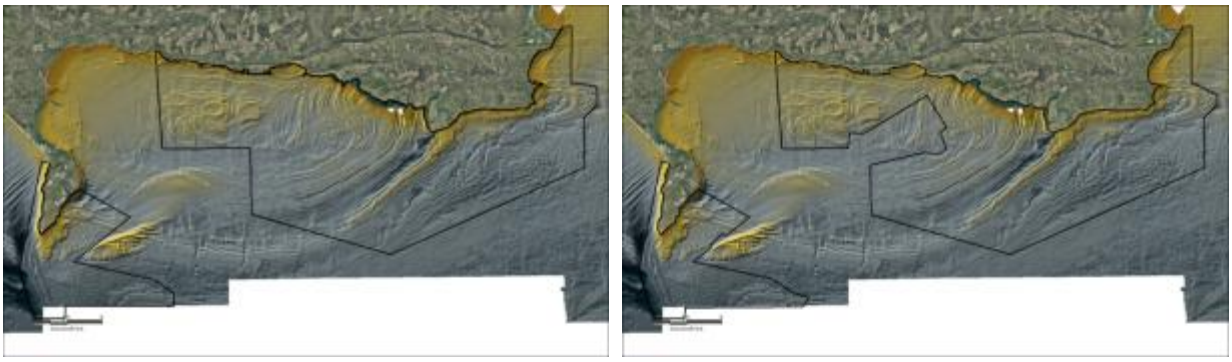


Figure 11: Boundary of Poole Rocks Marine Conservation Zone. Additional rock outcrops are clearly visible on the adjacent seabed.©GetMapping 2009

2.1.3 Support of management measures

In 2013, England changed its approach to managing fishing activities in European Marine Sites which led to a number of the most damaging gear types (heavy mobile gear) being restricted within EMSs. Rather than blanket bans across entire sites, the regulators preferred to restrict mobile gear only where there is strong evidence of the presence of the vulnerable site features. For Annex 1 reef habitat in SACs, much of that evidence came from multibeam data, supported by drop video evidence. In the Studland to Portland SAC, for example, the same data used to draw the site boundary was used in drawing up a local fisheries byelaw to restrict mobile fishing gear – though the two boundaries do not quite coincide and there is some argument over what constitutes “reef” habitat, especially where there may be a thin veneer of sediment over the seabed. This highlights the fact that multibeam alone is not always sufficient to recognise habitats.



a – Boundary of Studland to Portland SAC ©GetMapping 2009

b – area closed to mobile bottom gear ©GetMapping 2009

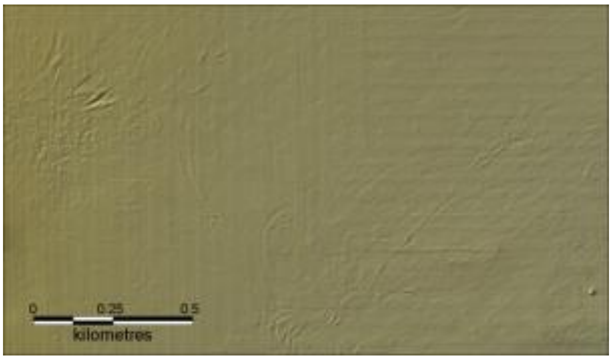
Figure 12: Differences between MPA boundary and management measures

2.1.4 Direct evidence of physical impact

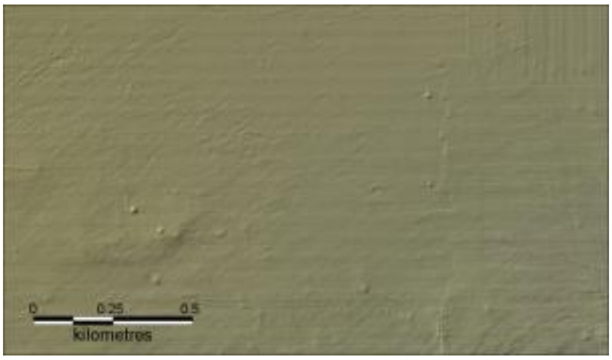
The DORIS multibeam dataset was not collected with the aim of documenting any physical impacts on the seabed but there are a number of medium to long-term impacts that are visible from the detailed data. This opens up the possibility of using multibeam as a condition monitoring or compliance monitoring tool

Scars on the seabed. Large vessels anchoring in sheltered waters can leave relatively long-lived anchor-scars on the seabed, clearly visible in the bathymetry data. Dredged areas in sheltered water also show up very well, see the examples below from Portland Harbour.

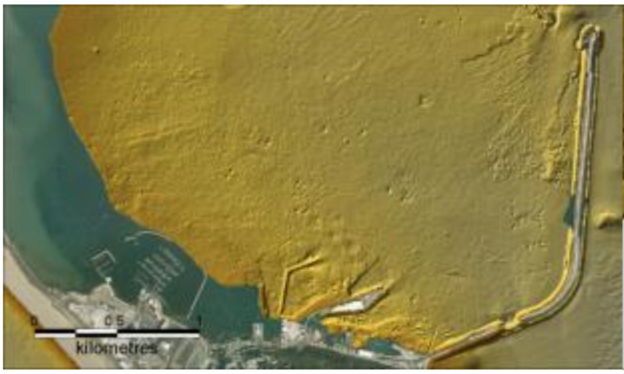
Objects on the seabed. This could include anything from wrecks to dredge spoil. Figure 13b shows some examples of objects either deliberately of accidentally placed on the seabed, identifiable from multibeam data



a – Anchor scars from large vessels in soft sediment

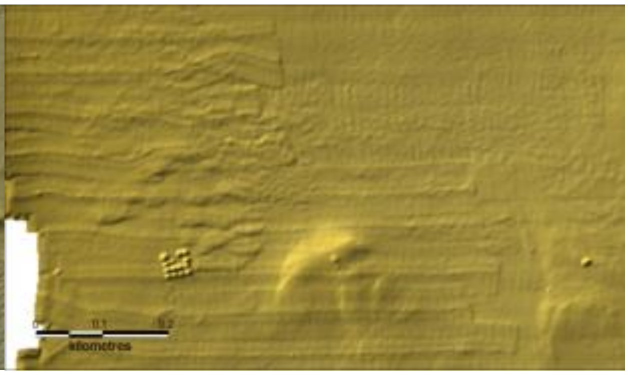


b – objects deposited on the seabed in Weymouth Bay

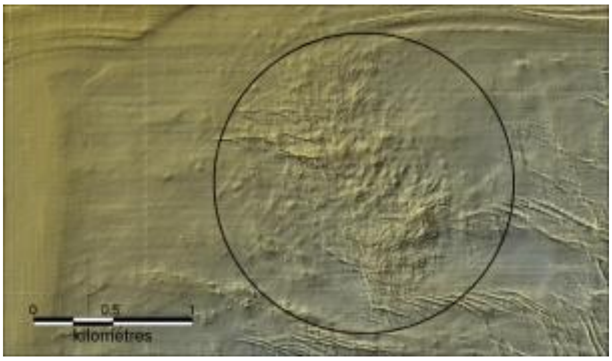


c – variety of impacts on seabed of Portland Harbour

©GetMapping 2009



d – artificial reef and nearby wreck of "Valentine" tank in Poole Bay



e – Swanage dumping ground

Figure 13: Examples of physical impacts on the seabed detectable by MBES

2.1.5 Awareness raising

It can be difficult to remember how little we knew about the seabed and how hard it was to visualise it before the widespread introduction of detailed, large area surveys by multibeam. The ability to create stunning, detailed visulisations of the seabed in a variety of formats brings the seabed to life in a way that was not possible before, a boon for those trying to win support for protection of the marine environment. As well as posters and interactive maps., multibeam data can be used to create « fly-through » animations or virtual worlds for gaming. In 2012 DWT created a 360° animation to be displayed by 5 projectors on a 6m high, 20m diameter dome screen, based on multibeam data – some sample stills are shown below.

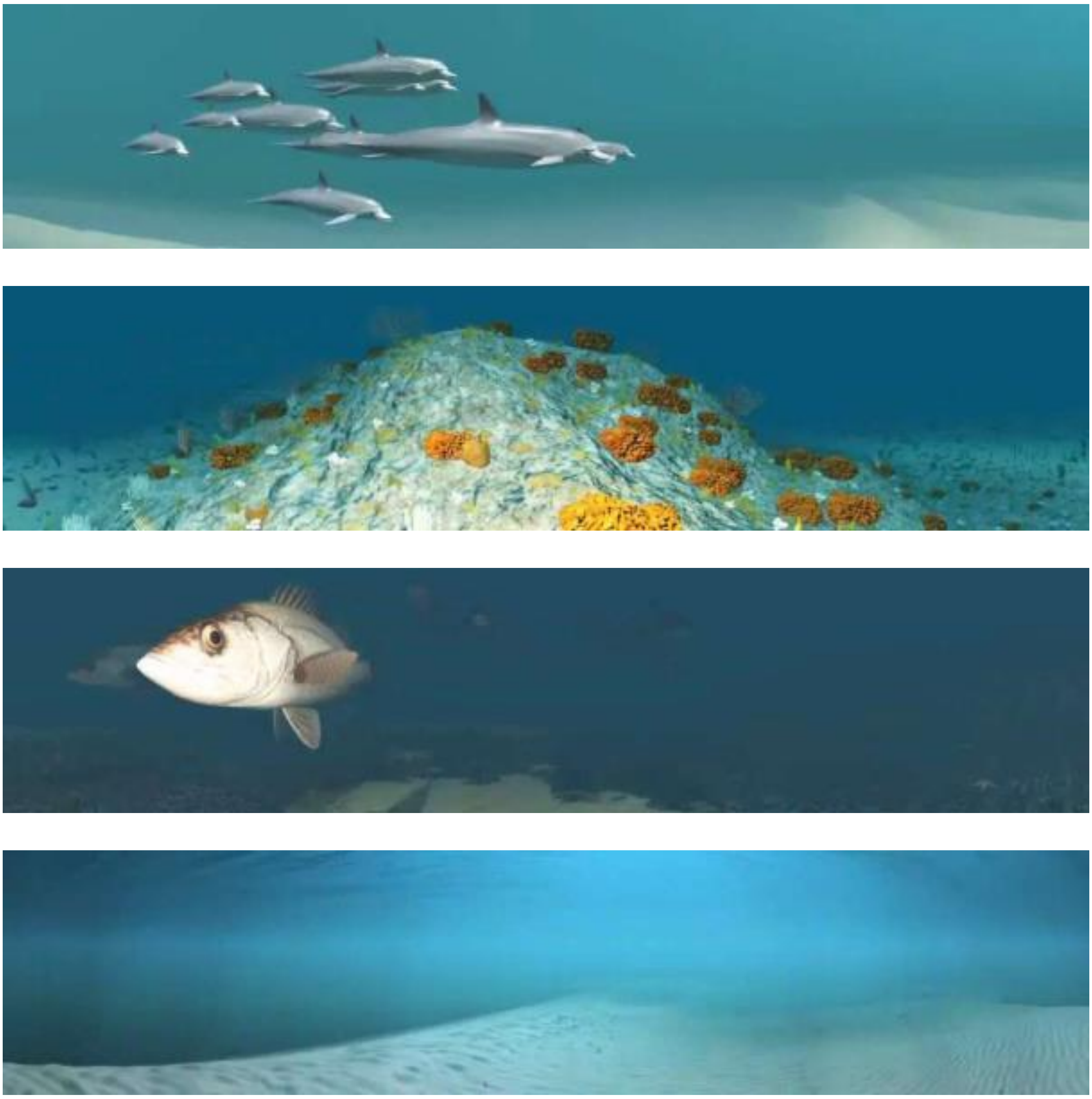


Figure 14: Example stills from 360° animation based on multibeam data

3. Case Study 2 – Use of MBES for monitoring sedimentary habitats in the Bancs des Fladres Natura 2000 site

This mission aims to bring to light practices that have already been tested by certain partners and which could be used by all MPAs in the area.

In recent years, the Grand Port Maritime de Dunkerque (Port of Dunkirk - GPMD), France's third largest port, has become aware of the environmental impacts of its activities and has made commitments and developed action to improve its environmental management. The stakes are indeed considerable: stretching along 17km of seafront, the port area covers 7,500 hectares and its district covers 38,000 hectares. It is also an operator of the Bancs des Flandres Natura 2000 marine site which is located opposite. The management and conservation of marine ecosystems that are subject to significant human-induced pressure, such as coastal and port zones, demand tools to assess and monitor the quality of the environment on a large scale.

To monitor dredging and disposal operations, the GPMD uses a multibeam sonar to detect the bathymetric variations of the sea bed. This equipment, which the GPMD acquired in 2001, provides the port services with information about the growth status of its docks and the various traffic lanes that ships take to reach the GPMD's quays. Knowledge of this phenomenon allows it to trigger the dredging operations required for the navigability of the areas concerned.

In addition to measuring bathymetric variations within the port district, the multibeam sonar can be used for another purpose. The Bancs des Flandres Natura 2000 site is justified by the presence of a submarine habitat protected under the European Habitats Directive: sandbanks with little permanent water coverage (pSIC FR3102002). These banks are home to a multitude of associated species and form an excellent resting area for certain species of marine mammal. A good understanding of their dynamics and their location is therefore necessary for effective management. Furthermore, in intertidal position, these sandbanks attract avifauna and particularly breeding birds, which justifies the site's classification under the European Birds Directive (SPA FR3112006).

Therefore, the multibeam sonar can be an appropriate tool for detecting any variations in the sandbanks and ridges present in the Bancs des Flandres Natura 2000 site. It allows both the nature and dynamics of the sea bed to be assessed.

3.1 Presentation of the Study Area

3.1.1 Geographical context

The coast of Dunkirk, which is rectilinear and facing WSW-ENE is, like all French, Belgian and Dutch coastlines in the southern part of the North Sea, mainly lined with recently formed coastal dunes and extensive sandy beaches. These beaches extend out at sea by a gradually sloping sandy foreshore, then by sandbanks belonging to the group called "Bancs des Flandres" for the French part and "Bancs de Flandre" for the Belgian part (VICAIRE, 1991).

From the open sea to the coast, four clearly isolated banks are identified: the *Out Ruytingen* and *In Ruytingen,* the *Dyck occidental* and the *Dyck central*. Then come nine banks more or less arranged parallel in 4 alignments, which form the Bancs des Flandres. There is the *In Ratel*, the *Buitten Ratten*, the *Breedt*, the *Haut-Fond de Gravelines*, the *Smal*, the *Snouw*, the *banc de Mardyck,* the *Break* and the *Hills*. These sedimentary structures are coalescent and their tops are very close to the lowest water levels, so the most coastal banks are awash (Figure 15).

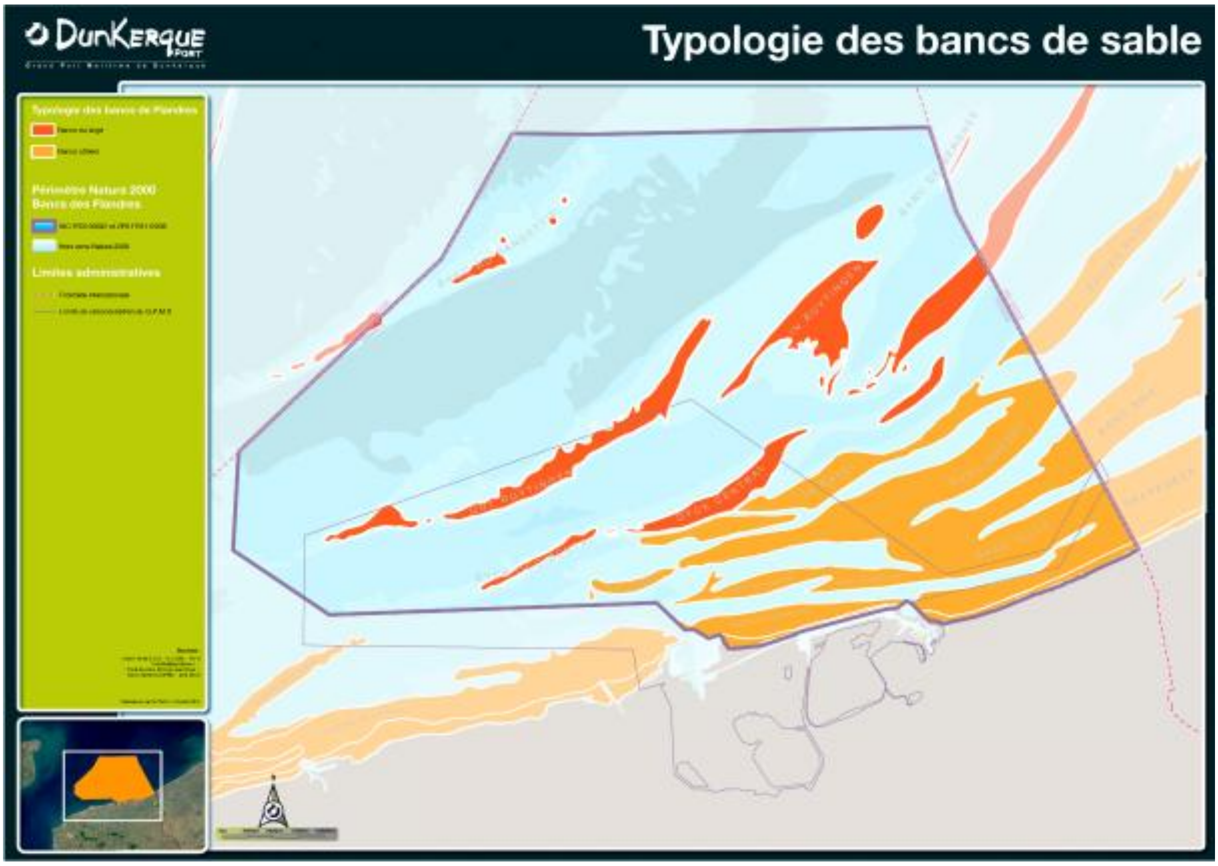


Figure 15: Perimeter and geomorphology of the Bancs des Flandres site

3.1.2 Sediment dynamics

The Nord-Pas-de-Calais coastal front is the site of major transport of sediments, resulting from the combined effect of hydrodynamic agents (tidal currents and swells) (e.g. Augris, et al., 1990; Corbau, 1995; Hemdane, 2006; Aernouts, 2005).

Offshore, the action of strong tidal currents practically parallel to the shore causes a migration of the sand parallel to the coast. The direction of this migration depends on the resulting transit which is in the same direction as the dominant tidal current. Thus, the macrotidal regime dominated by the flood stream and the offshore dominant swells coming from the West, lead to resulting sediment transport in the direction of Belgium.

The movement, parallel to the coast, occurs primarily on the sandbanks where there is a large amount of transportable sediment. This transport by thrust only affects a thin layer measuring a few centimetres on the banks' surface. Consequently, the offshore banks can be considered to be stable structures on a decennial or even a centennial scale, but with constant renewal of their surface layer.

Thus, the Bancs des Flandres sandbanks that are old offshore banks are considered stable. A comparison of cartographic documents from the archives of the SHOM, drawn up between 1836 and the 1990s, shows that most of the banks on the Northern front of the Nord-Pas-de-Calais region have undergone little or no spatial change (Aernouts, 2005).

Furthermore, this result tallies with those of Belgian work which has shown a low variation in the position and volume of the Bancs des Flandres around a mean position (De moor, 2002).

However, this stability is not found on a larger scale. The Ridens banks, located opposite the port of Calais, are gradually moving North-East under the effect of the tidal currents (Garlan, 1990; Aernouts, 2005) dominated by the flood stream in this zone. The same studies near Calais have also shown that the changes in the seabed morphology near the coast are affecting the sediment balance of the coastal zone and the profile of the beaches.

In the coastal zone, the tidal currents are attenuated and the effect of swells on sediments prevails over that of tidal currents. The combined action of these two hydrodynamic agents generates complex phenomena and significant coastal transit, causing the differential trend in terms of erosion and accretion of the Nord-Pas-de-Calais coastline.

The Channel-North Sea front is by far the most exposed to coastal erosion on a national scale. The Plan Littoral d'Actions pour la Gestion de l'Erosion (Coastal Erosion Management Action Plan - Smco, 2003) highlights zones with risks of erosion and marine submergence in the medium and long term on the shoreline of the Opal Coast (Côte d'Opale). The Bancs des Flandres Natura 2000 site thus comprises the hydrosedimentary management units (MU) no. 3, 4 and 5. They all feature coastal areas under erosion and others undergoing accretion (Figure 16). To specify the sediment dynamics, management unit no. 4 (MU4) is monitored by the Université du Littoral Côte d'Opale for GPMD. The results are referred to within the framework of work packages WP2 and WP3 of PANACHE which focus on knowledge and management of the "terns" platform, an emblematic site for remarkable avifauna. As it provides a propitious habitat, this site has swiftly been colonised by the Little Tern (Sternula albifrons), a species that justifies the designation of the Bancs des Flandres Natura 2000 site under the Birds Directive. Now, within the framework of the PANACHE programme, specific monitoring of this species is carried out (WP2 and WP3). Therefore, to understand the changes affecting this habitat and plan work to be done to ensure the colony's durability, the GPMD realised the need to learn more about the hydrosedimentary dynamics of the area, particularly the exchanges of sediment between the foreshore and the beach. But Bertier (2009) and Tresca (2013) have already shown that within this sedimentary unit, sediments are redistributed from the centre outwards to the limits.

Furthermore, it is acknowledged that the shores are changed by sea levels reached during storms which cause major erosion or extensive immersion (CHAVEROT, 2006; MASPATAUD, 2011). However, the dynamics of the offshore sandbanks must be taken into account as it appears to play a key role in the coastal morpho-sedimentary dynamics. The variation in the coast line would appear to be very much correlated to changes in the sediment balance of the shallow sand banks (AERNOUTS, 2003; HÉQUETTE & AERNOUTS, 2010). The dynamic agents shape the inshore banks and thus influence the sediment movements of the coastal area. Conversely, these inshore geomorphological changes have effects on the morphodynamic agents.

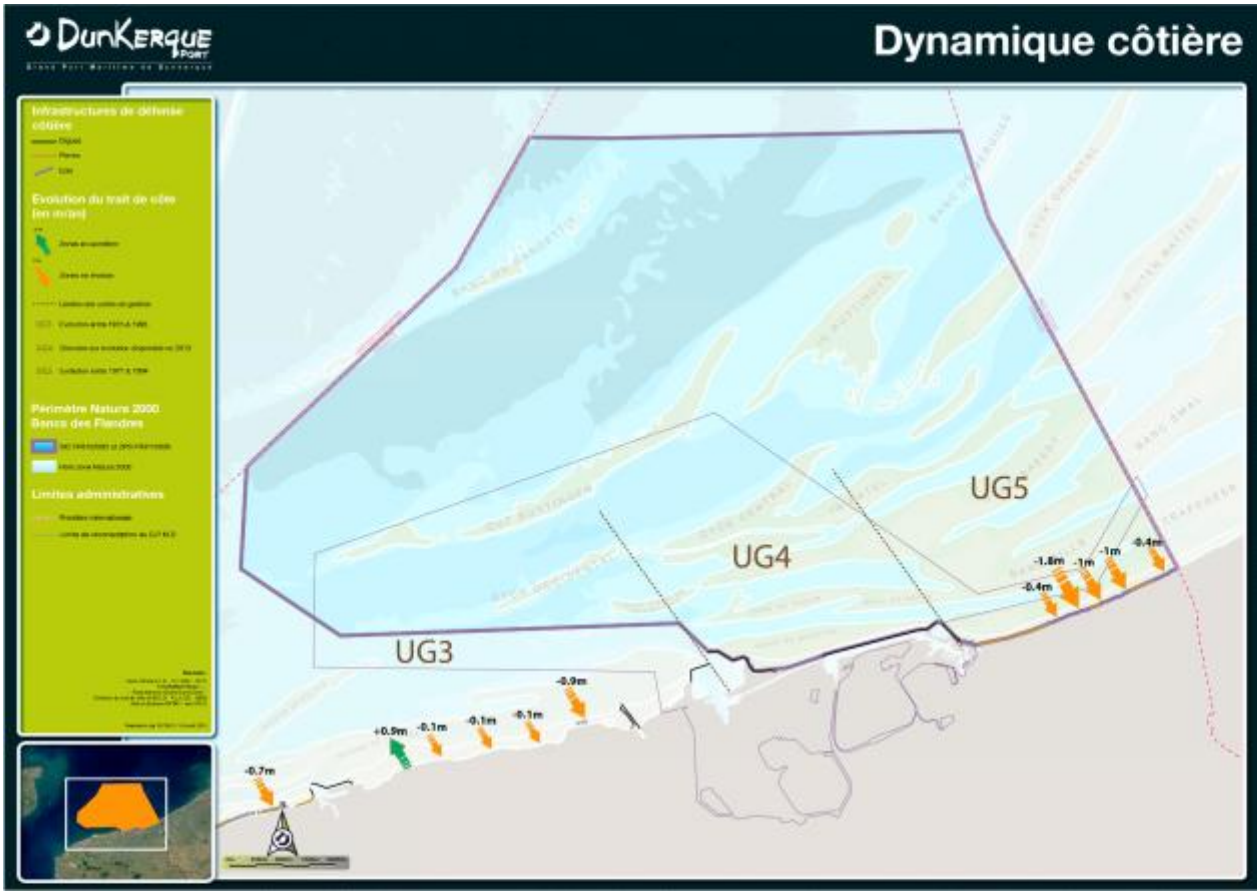


Figure 16: Location of the hydrosedimentary management units along the Bancs des Flandres site (according to SMCO, 2003)

3.2 Areas monitored within the framework of PANACHE

Several spatial scales have been analysed to assess whether or not it is appropriate to use the multibeam echosounder to confirm the mobility of the banks.

3.2.1 Analysis on the scale of the site

The Bancs des Flandres Natura 2000 site designated under the European Habitats Directive covers a surface area of 113,223 ha. Given the site's extensive surface area and marine constraints, there is currently no single bathymetric survey of all of the Bancs des Flandres, but a series of surveys carried out by various players, particularly the GPMD and the SHOM, at different periods.
For this study, given the availability and accessibility of data, it will not be possible to obtain a difference. However, pairing between sounding and sedimentary facies will be proposed.

3.2.2 Mesoscale analysis, inshore area

In its archives, the GPMD has a series of bathymetric maps of the shallow waters of the Natura 2000 site. They cover the *Mardyck, Braek* and *Snouw* banks. Only the most recent maps have been created using a multibeam echosounder. They are the result of several measuring campaigns carried out at different periods. The analysis follows on from work initiated by BERTIER (2009) which particularly sought to establish the relationship between port development and sandbank migration.

3.2.3 Microscale analysis, inter-bank area

Within the Bancs des Flandres Natura 2000 site perimeter, the GPMD has four disposal areas for dredged port sediment: one West-South zone (ISO: 140ha), a West-North zone (ION: 120ha), a Centre zone (IC: 80ha) and an East zone (IEST: 100ha). Bathymetric monitoring is regularly conducted on these zones by multibeam echosounder to analyse variations (Figure 17).

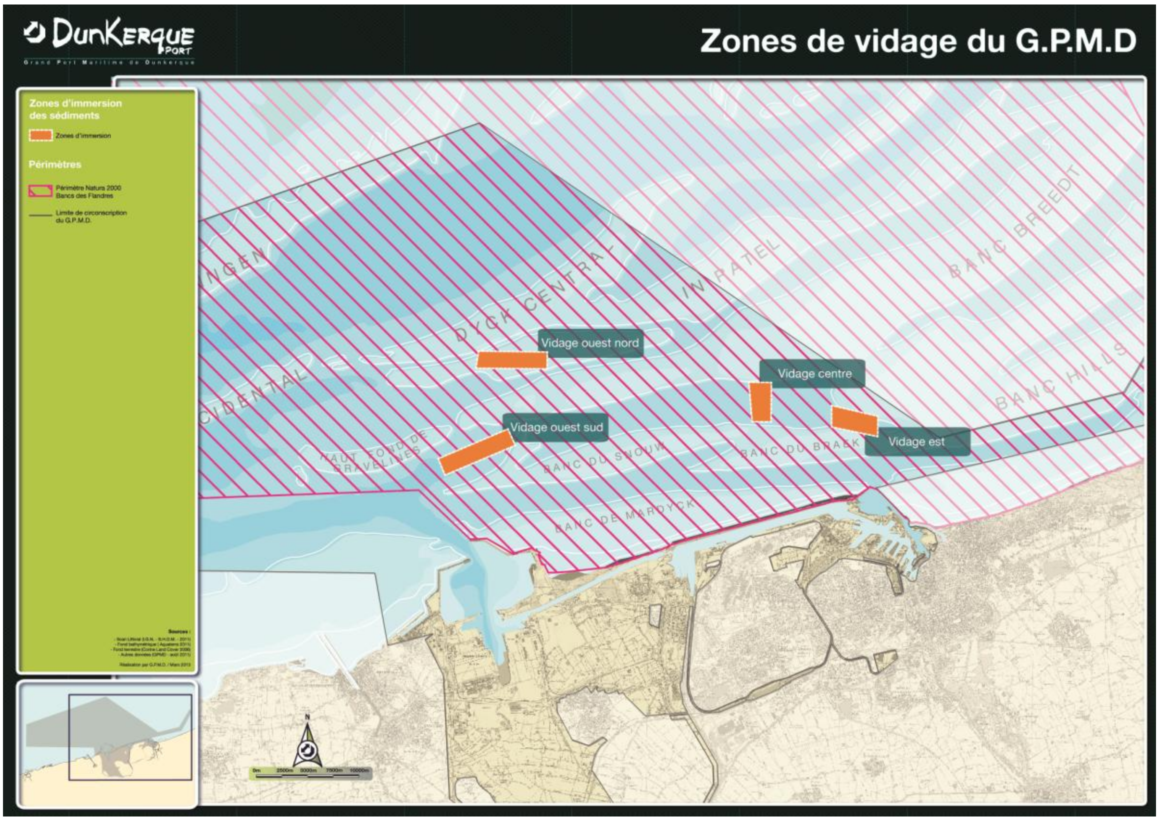


Figure 17: Location of the GPMD disposal areas monitored by bathymetric survey

3.3 Data management and processing methodology

3.3.1 Bathymetric data acquisition

The GPMD conducts its bathymetric surveys itself, from a ship (16m frigate) equipped with an ATLAS FANSWEEP 20® multibeam echosounder, at a frequency of 210 kHz and an echosounder beam aperture of the order of 600%. The precision of planimetric measurements is inframetric and the precision of altimetric measurements will be ± 5cm.

The bathymetric data is then processed by the CARIS® software program to model the sea bed. For more efficient processing, the precision of the raw data is reduced to one metre. Similarly, the range of data collected is reduced. Data that is outside a beam aperture of 400% is not taken into account. Beyond this aperture, the risk of disturbance is too high and increases data inaccuracy.

3.3.2 Mesoscale analysis, inshore area

Using the methodology proposed by BERTIER (2009) for shallow water monitoring, PANACHE updates the analysis of the dynamics of banks near the coast. The GPMD has bathymetric data covering a large part of MU4 for the years 1962, 1986 and then 2000, 2007, 2011 and 2013 as well as solely in front of the Braek breakwater for 1988. One of the limits of this study is that the data is not homogeneous and does not cover exactly the same area. An analysis of variations in the bathymetric surveys simply provides an idea of changes in the morphology of the shallow water areas caused by the movement and migration of the banks over the century, but not the short-term variations which can only be assessed on a smaller scale.

3.3.3 Microscale analysis, inter-bank area

Within the framework of PANACHE, several campaigns on the various areas were conducted between 2012 and 2014. Some of them could not be used (two campaigns in 2012 and two campaigns in 2013), as several bathymetric campaigns on the same area and with the same precision and the same surface area were needed in order to implement identical and thus comparable methods. They were subsequently redone, to obtain a panel of useable data.

All of the bathymetric files used for this study are presented in Table 1. To determine a probable evolution of the submarine banks and megaripples, the GPMD used previous campaigns available, which had the same technical characteristics. They are also compiled in Table 1.

IC	IEST	ION	ISO
16/11/2010	15/12/2009	22/03/2010	23/03/2010
14/03/2012	01/08/2012	02/04/2012	26/03/2012
09/09/2013	04/09/2013	06/03/2014	10/03/2014

Table 1: Bathymetric surveys used by the GPMD

3.3.4.Bathymetric data analysis

The data obtained from the surveys carried out by the multibeam echosounder and following application of the various corrections required by the numerous parameters to be taken into account (roll, pitch, beam velocity in the water column, etc.) gives rise to geographic coordinates, i.e. longitude (X), latitude (Y) and height (Z). The data is presented as a points file with the X, Y and Z coordinates in Lambert 93 CC50 projection, the elevation reference being the hydrographic zero of the SHOM of the port of Dunkirk (Figure 18).

The points files of the bathymetric surveys are then processed using the SURFER 9.0 software program by GOLDEN SOFTWARE, which enables Digital Terrain Models (DTM) to be processed and represented in 2D or 3D. Linear interpolation between each chosen point is the extrapolation method used, as it would appear to provide the most accurate view of the reality (Figure 19). It consists in using the weighted average of the three nodes of the triangle containing the point of interpolation. In addition to modelling the DTM, this phase in the approach defines its resolution by choosing the appropriate grid. For this study, a grid of 1m x 1m prevailed for the required use and given the computing capabilities of the available hardware. Once the DTM generated, the last step consists in creating classes of colours according to the altitude of the pixels generated, to appropriately highlight the depth of the sea bed. A common scale for the four areas studied was chosen.

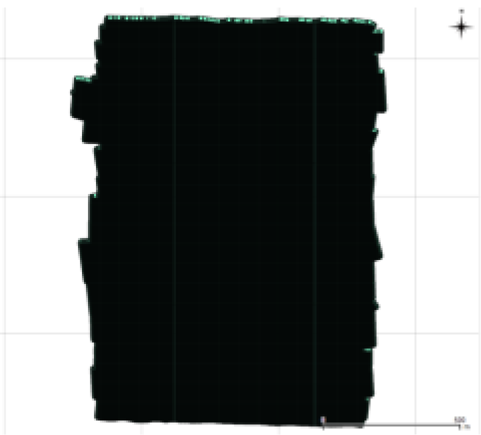


Figure 18: Scatter diagram – example of the IC area

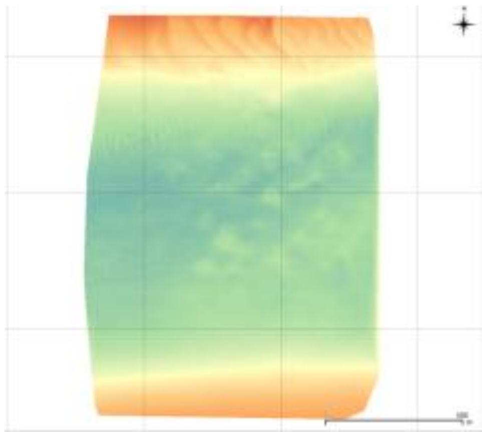


Figure 19: DTM generated – example of the IC area

3.3.5.Comparison between two bathymetric surveys

To be able to make comparisons and to calculate valid volumes between two dates on strictly identical surface areas, the spatial coverage of each file had to be reworked in order to have an equal surface area for each zone. Each bathymetric survey is then broken down according to the common coverage defined (Figure 20).

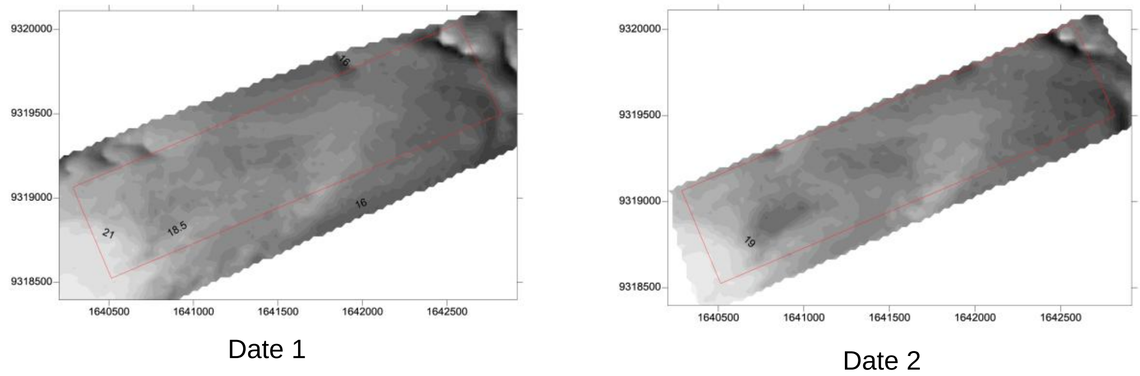


Figure 20: Delimitation of a common coverage – example of the ISO zone

Then, for each zone, minimum and maximum limits along X and Y, common to all the DTMs of each zone, were calculated to be able to compare the DTM and thus be able to subtract the grids from one another and calculate the volume differences between two DTMs of two different dates (Figure 21). The differential map thus generated will therefore allow sectors of erosion and accretion to be spatially assessed. For greater visibility, it will be laid on the most recent 3D bathymetric block.

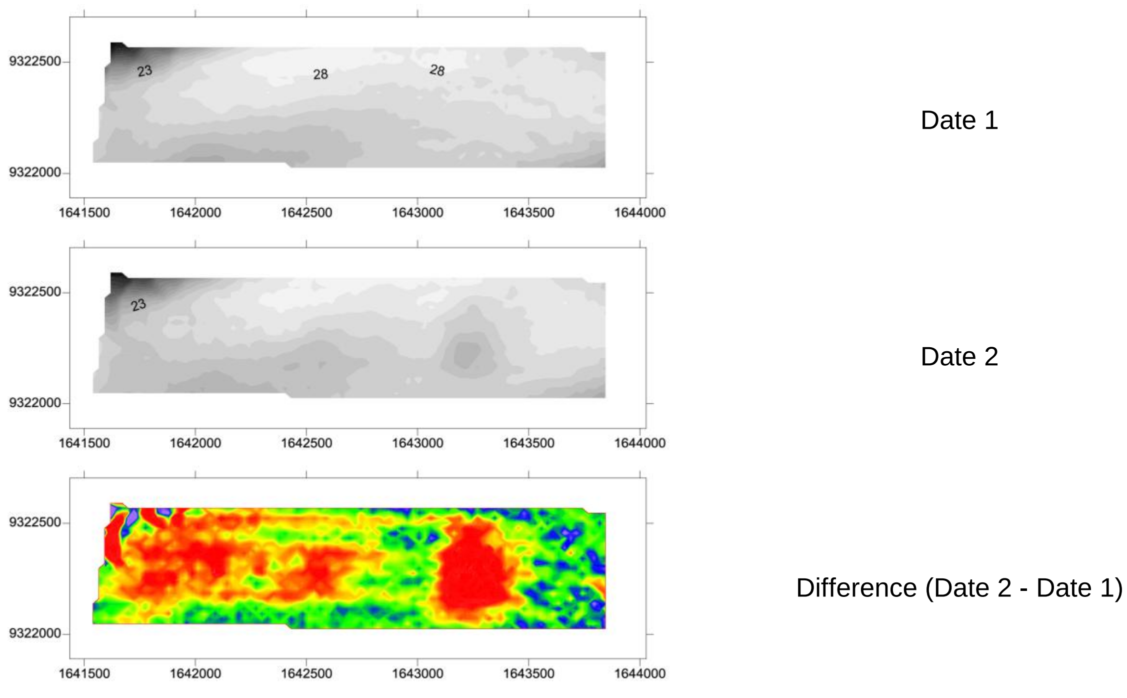


Figure 21: Comparison of 2 DTM – example of the ION zone

3.3.6. Sedimentary facies characterisation methodology

As we have just shown, the processing of the multibeam echosounder data leads to computing a digital terrain model resulting from the bathymetry measurements. It can also allow the type of sea bed to be assessed by using the degree of reflectivity (coded in shades of grey) of the sedimentary facies. Once the data corrected, a mosaic of images is formed, with each pixel corresponding to a patch on the bed, associated with a level of back-scatter expressed in decibels.

The mosaics obtained are compared with seabed sampling or observation data (video or *in situ* diving) and are then calibrated and interpreted in the form of sedimentary facies.

The proposed methodology thus consists in mapping the habitats with the acoustic method combined with the "ground truth". Each of the systems taken separately cannot provide all of the information required to obtain an appropriate map of the habitats. Only a combination of these two means provides a sufficient degree of confidence to ultimately define the delimitations of the sedimentary facies.

As the GPMD does not have the software programs developed in particular by IFREMER to facilitate reflectivity processing, implementing the methodology on the scale of the Bancs des Flandres proved tricky.

With the aim of defining the major sedimentary groups that characterise the study area, the acoustic data was calibrated using particle size data from sampling campaigns Figure 22and Figure 23) on the IC, IEST, ION and ISO zones as well as data from CARTHAM (AAMP, 2012).

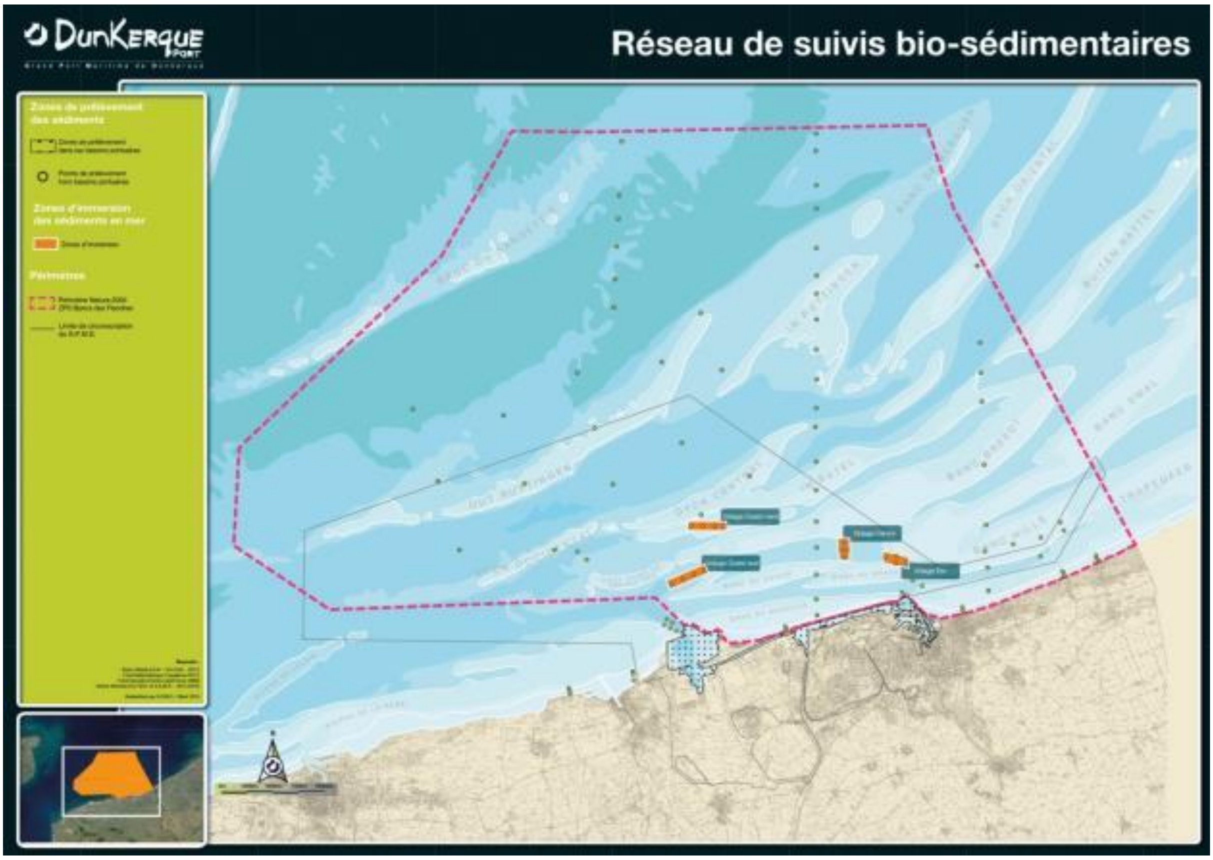


Figure 22: Sediment and benthic sampling points

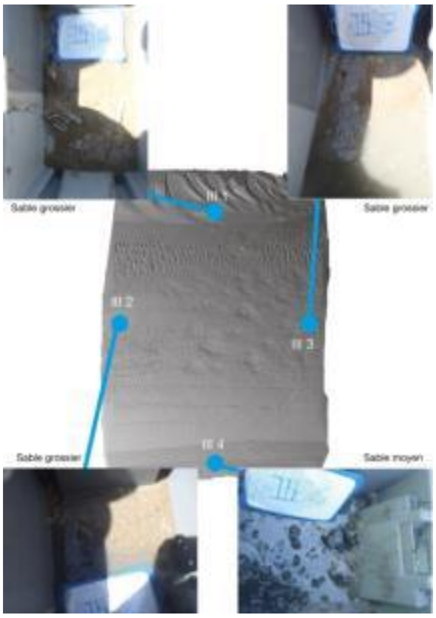


Figure 23: Characterisation of the seabed substrata – example of the IC zone

3.4 Resultats

3.4.1 Bathymetry of the Bancs des Flandres Natura 2000 site

All of the bathymetric data that the GPMD was able to collect is presented inFigure 24. The marks detected indeed indicate a high-energy hydrodynamic context (Figure 25for the CARTHAM study (AAMP, 2012), a previous interpolation of the data had been done, but with a lower resolution (Figure 26).

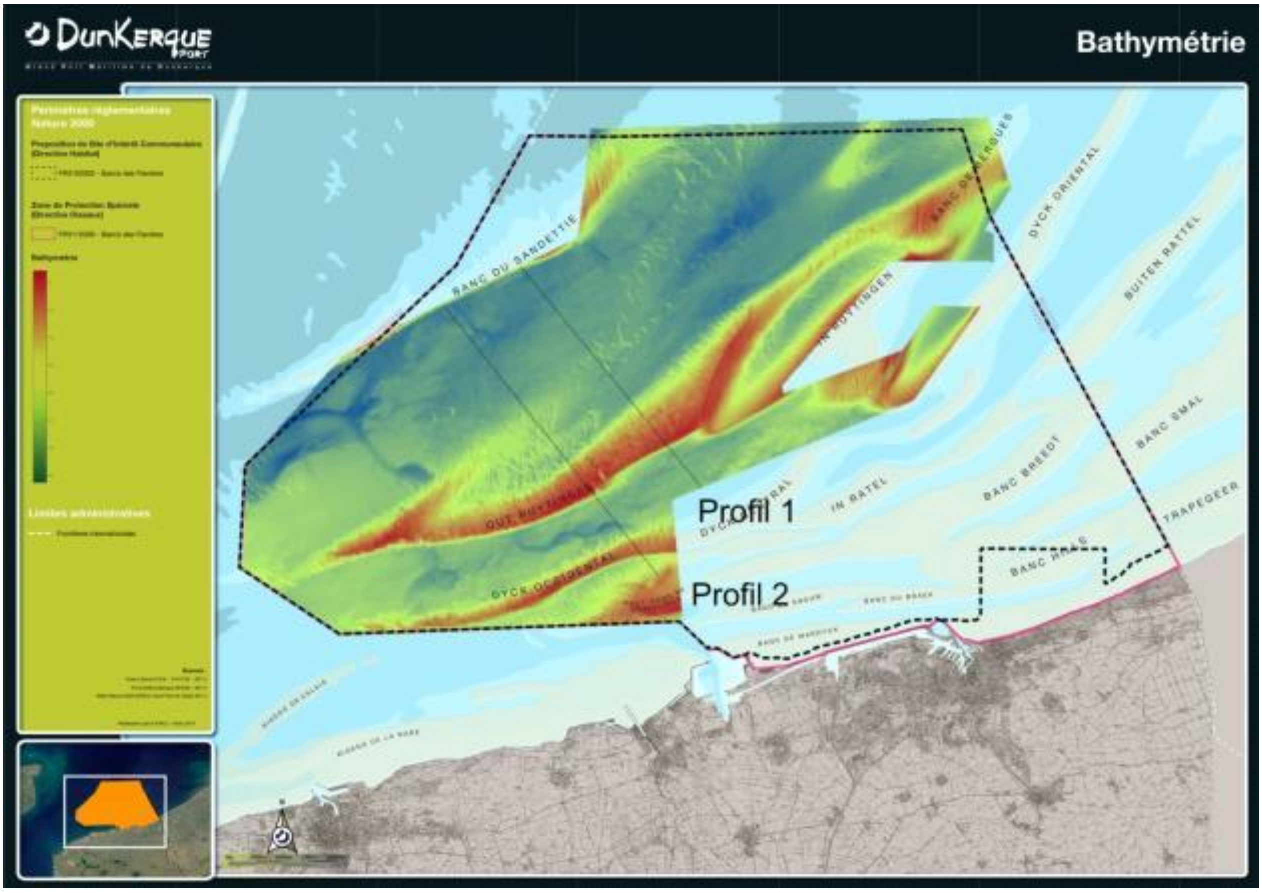


Figure 24: Interpolation of the bathymetry using data available at the Bancs des Flandres site

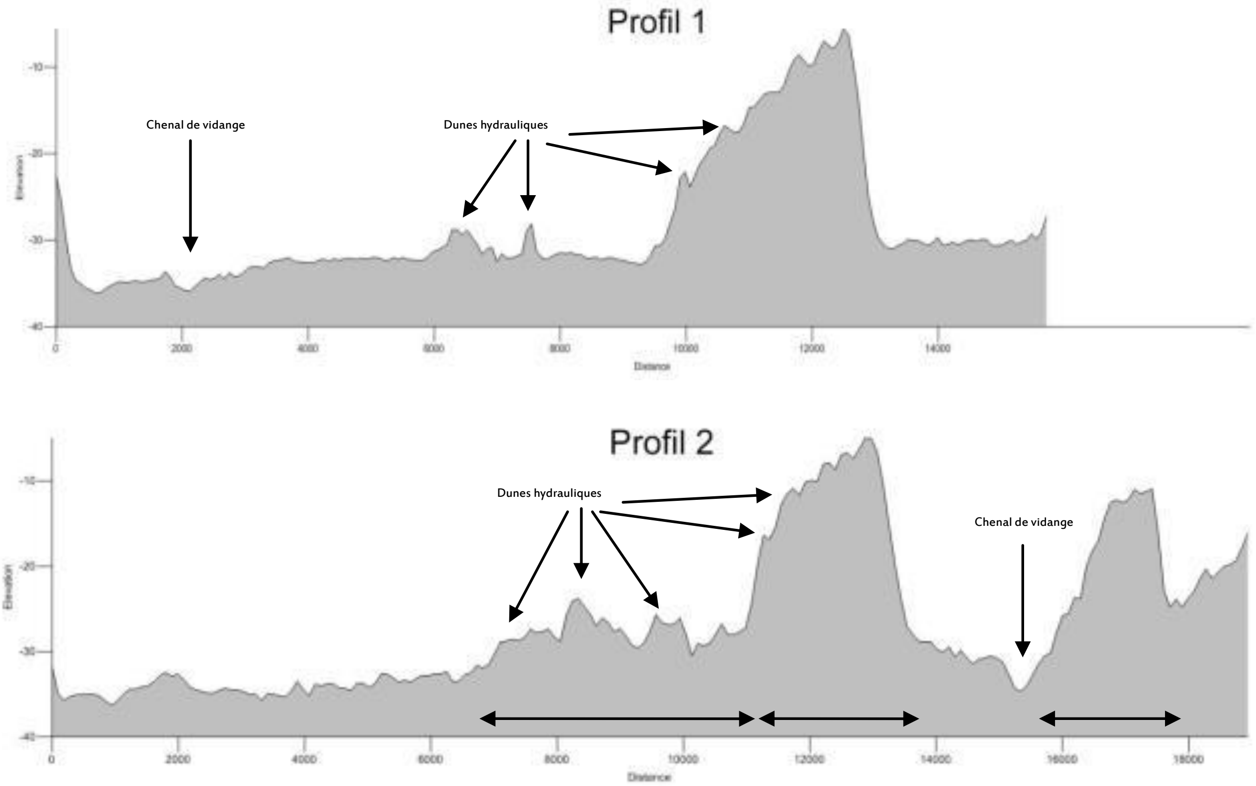


Figure 25: Profile sections

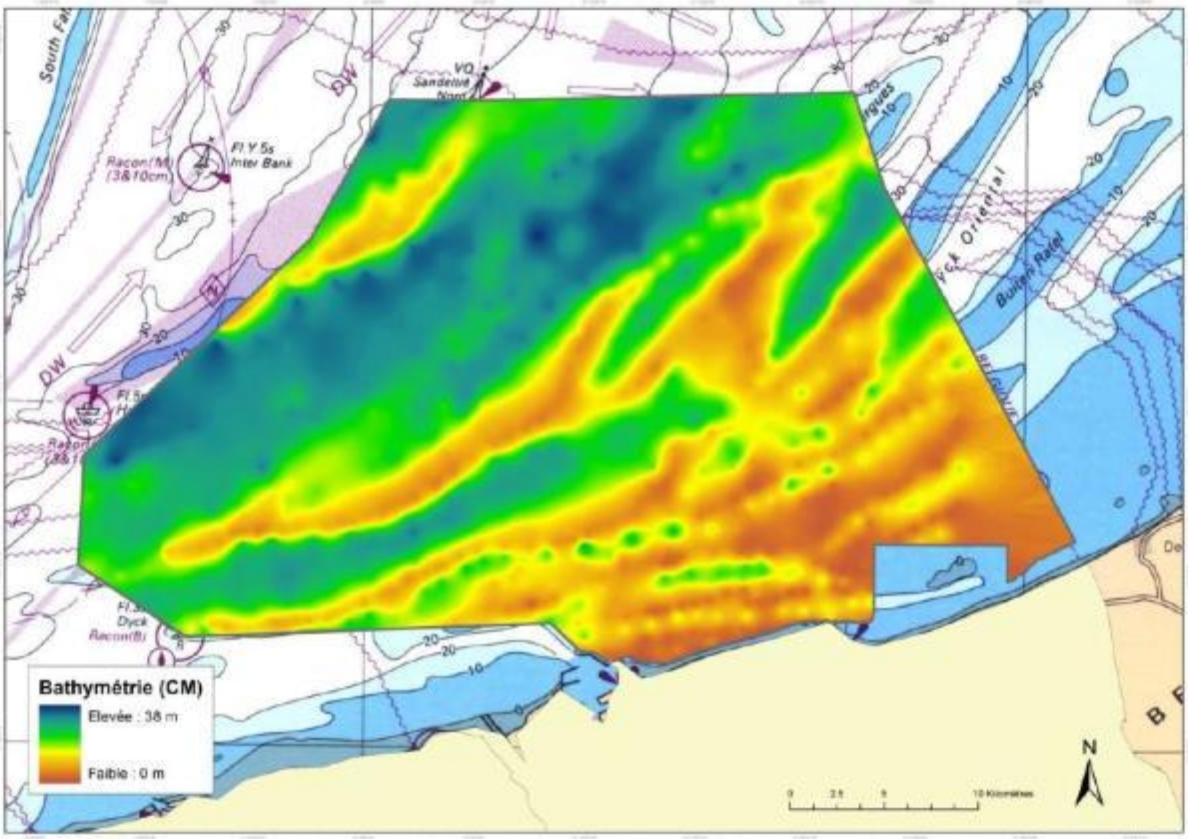


Figure 26: Interpolation of the Bancs des Flandres site bathymetry for the CARTHAM study (AAMP, 2012)

The analysis of the sedimentary facies based on the acoustic data from the multibeam echosounder was tricky and not representative of the entire site or the scale of MU4. When setting the sonar's parameters, the GPMD indeed gave priority to the quality of bathymetry acquisition rather than reflectivity.

However, three sedimentary facies appear to stand out and are greatly correlated to the bathymetry.

- The course sand facies: Without any sedimentary body, it corresponds to the homogenous or rough reflective acoustic facies. It occupies almost the entire western part of the site particularly between the *Out Ruytingen* and *Dyck occidental* banks. It tends to reflect the inter-bank sedimentary facies.
- The medium sand facies: It corresponds to the reflective acoustic facies shaped by hydraulic dunes. It is preponderant and occupies mainly the eastern part of the site.
- The fine sand facies: It corresponds to the acoustic facies with very low reflectivity. It is found close to the Belgian border.

The results obtained are consistent with the results from CARTHAM (AAMP, 2012), but given the poor quality of the initial data, they cannot be described as conclusive in this report (Figure 27).

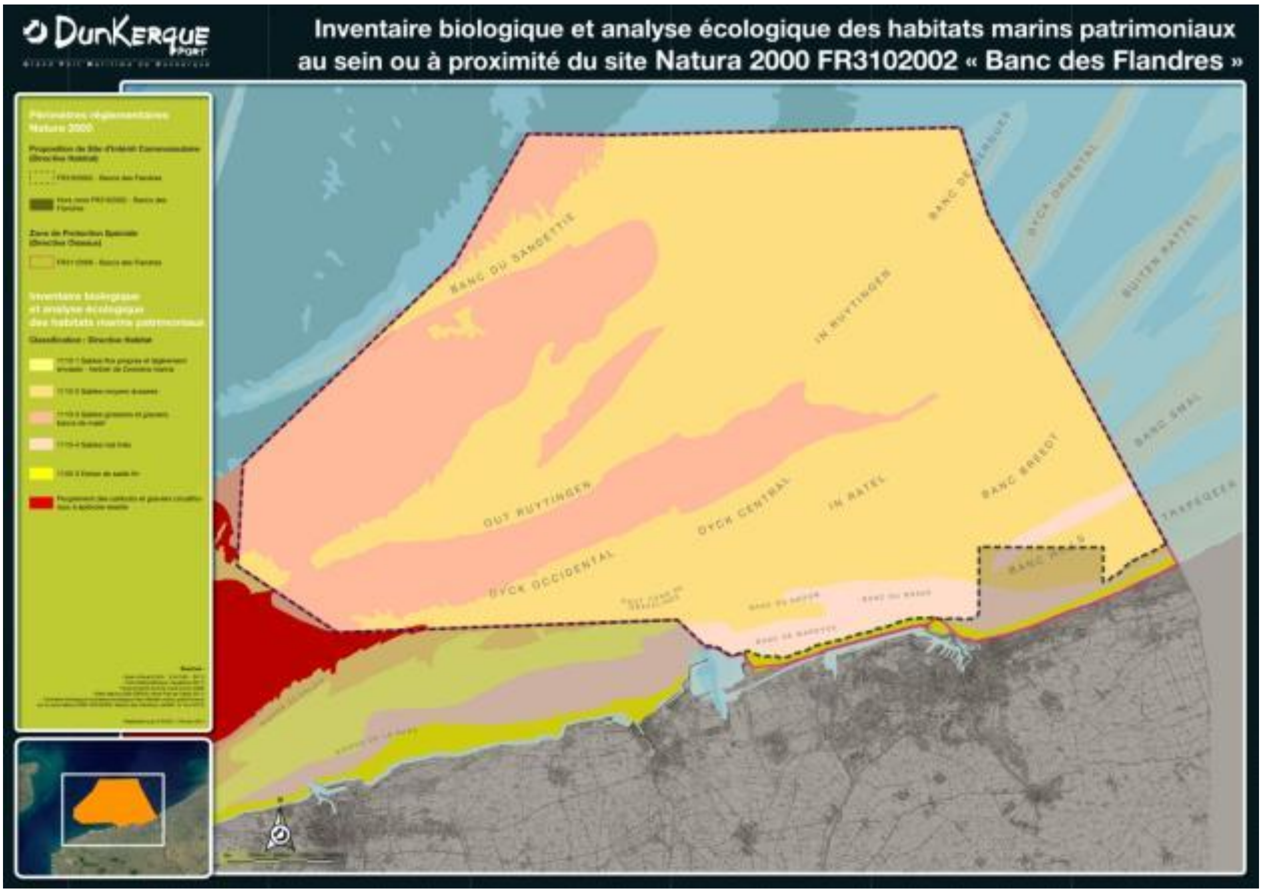


Figure 27: Mapping of habitats of Community interest in the Bancs des Flandres site for the CARTHAM study (AAMP, 2012)

3.4.2 Bathymetry of the MU4 inshore area

An analysis of changes in the bathymetric depths of MU4 was conducted based on the surveys carried out (Figure 28). The bathymetric maps from 1962 and 2000 show considerable differences in the morphology of the inshore area (BERTIER, 2009). These changes are linked to the major works undertaken during this period to make various extensions to the port, particularly the complete construction of the Braek breakwater, the West outport and the creation of the Dunes canal. These port developments greatly influenced the morphology of shallow water beds.

Between 1962 and 2000, in addition to the area of major erosion in front of the entrance to the West outport caused by its creation and the construction of a navigation channel, a slight deepening of the channel can be noted at several points, as well as a widening of the channel in the west part. These changes in the channel's morphology, which can no doubt be partly explained by the dredging work done to create the west outport of Dunkirk, can be seen on the map of bathymetric variations by an area of erosion parallel to the coast.

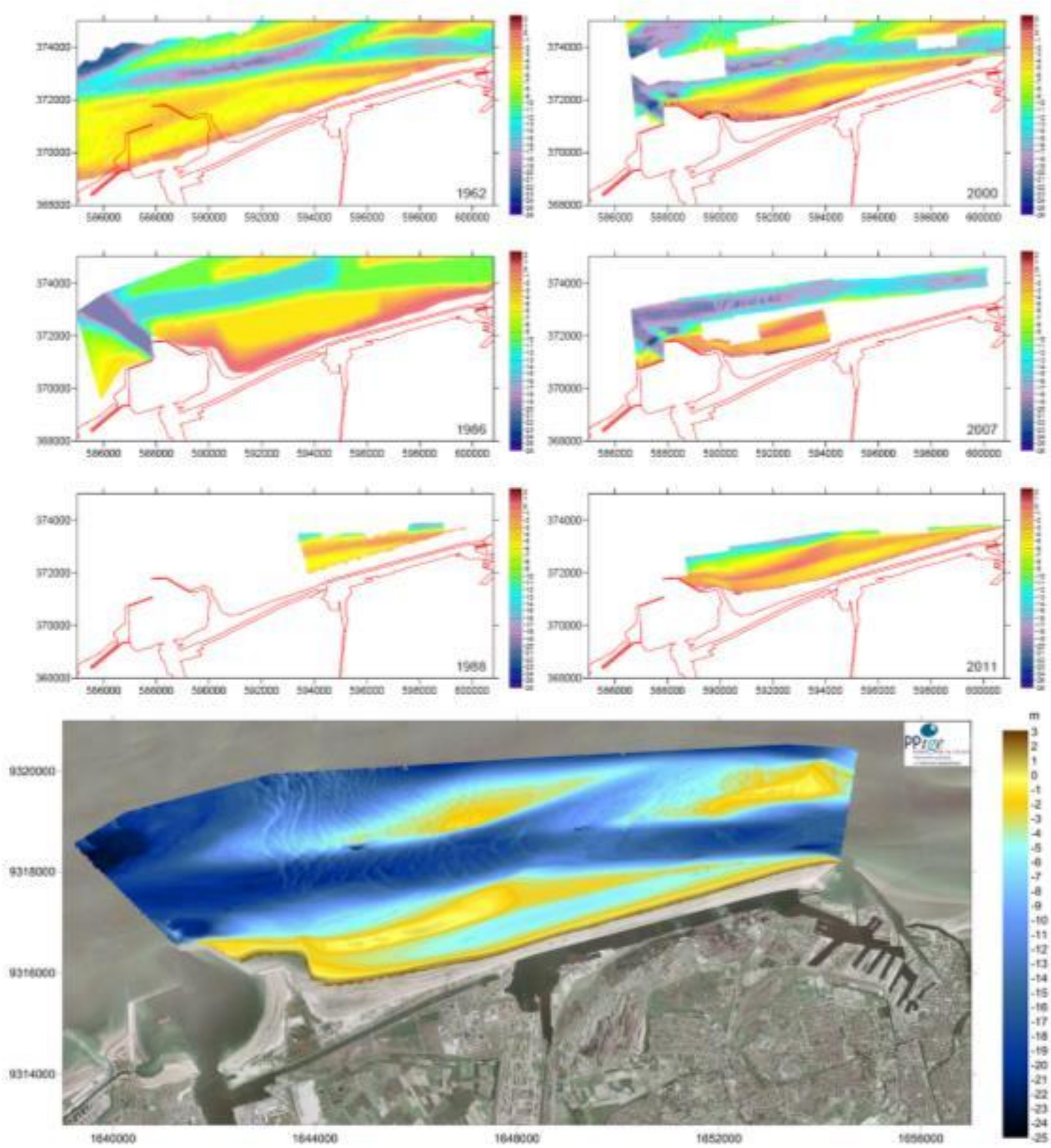


Figure 28: Bathymetric lines of the MU4 inshore area in 1962, 1986, 1988, 2000, 2007, 2011 and 2013. (HEQUETTE& al, 2012 and 2014)

Over the same period, areas of uplift are fewer and smaller than the areas of subsidence. However, an accumulation can be seen to the north-east of MU4, directly related to the installation of the Jetée du Clipon (jetty) and the Ruytingen, and which gave rise to the sandy "Terns" platform monitored within the framework of Work Packages 2 and 3 of PANACHE. Lastly, uplifts can be seen to the East in front of the Braek breakwater, which correspond to an accumulation in the inter-bank zone and the spill-over of the *Mardyck* bank. This phenomenon confirms the hypothesis of a longitudinal transfer of sediments in this area causing an increase in this bank both towards the open sea and the coast.

Although the 1988 data only covers a small area close to the coast, it also attests to the migration of the banks near the coast. Thereafter, changes are again more natural and the shallow water beds tend to recover the morphology they had in 1962 (BERTIER, 2009).

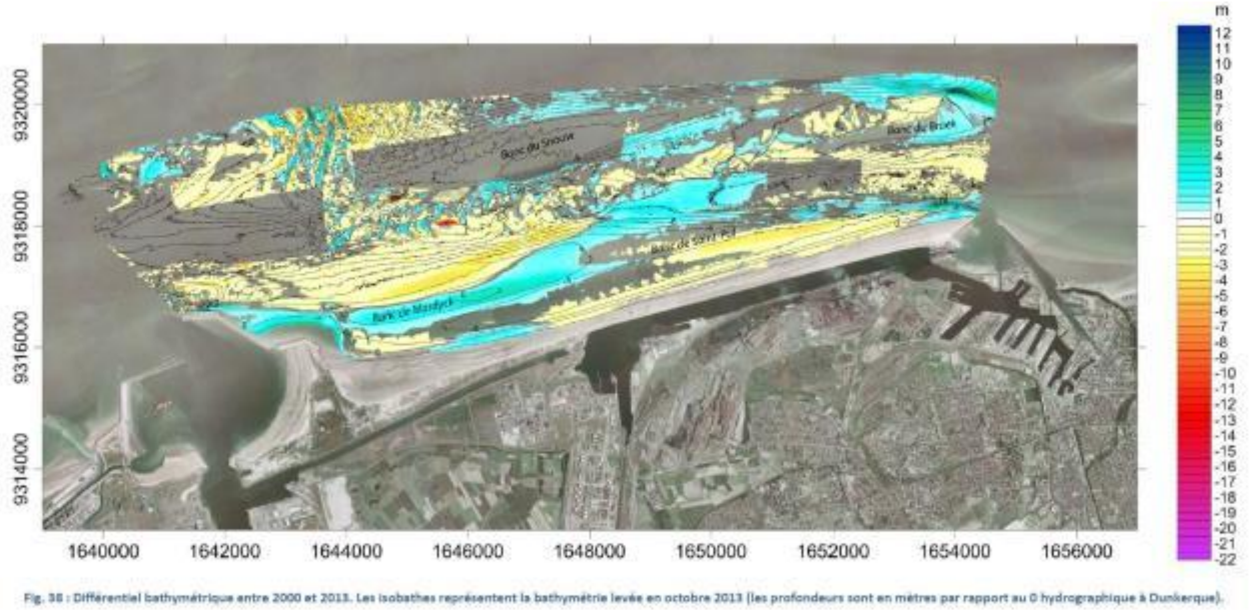


Figure 29: Bathymetric difference of the MU4 inshore area between 2000 and 2013 (HEQUETTE& al, 2014)

Between 2000 and 2013 (Figure 29), the shoreface underwent major morphological change. The western part of the intermediate channel features erosion of one metre on average and reaching -5m in places. This erosion is combined with growth of the outer side of the *Mardyck* bank, the uplift of which can reach +3.5m. These changes reflect a widening and deepening of the channel together with storage of sediment on the *Mardyck* bank and its progression to the east (HEQUETTE *& al*, 2014).

3.4.3 Discussion

The mesoscale analysis of changes in shallow waters provides several indications about the general trends of seabed evolution, but does not provide evidence of the impact of events occurring over short timescales.

3.4.4 Bathymetry of the inter-bank zones

Centre zone – IC

This inter-bank zone is located to the north of the *Braek* bank and south of the *Breedt* bank, at a maximum depth of 22m (Figure 30).

The difference between March 2012 and September 2013 reveals an accretion in the bowl, to the south of the zone, i.e. at the foot of the slope formed by the north side of the *Braek* bank. This confirms the mobility of the sand banks with agitating conditions from the south, which enables this deposit north of the *Braek* bank, in a relatively sheltered location.

Over a broader timescale, the volumetric balance between November 2010 and September 2013 shows a practically stable zone.

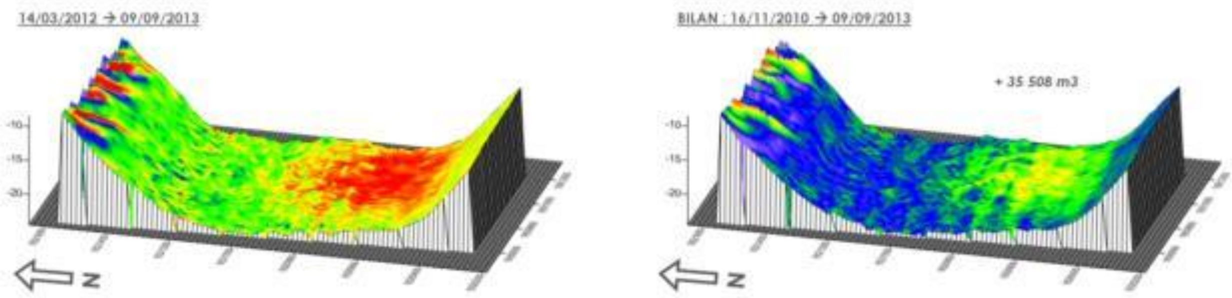


Figure 30: Bathymetric differences of the IC zone (IDRA, 2014)

East Zone - IEST

Continuing on from the IC zone, this IEST zone is also located in a bowl at the foot of the north side of the *Break* bank at a maximum depth of 19m (Figure 31).

Between August 2012 and September 2013, the volumetric variation is low. Only a slight accretion occurs on the central part of the north side of the Braek bank, and slight erosion at the top of the bank.

The assessment over the entire period studied shows a clear sedimentation over almost the entire zone. Sediments have primarily deposited at the bottom, and on the slope corresponding to the north side of the *Braek* bank. This confirms the mobility of the bank, like the IC zone, particularly as the erosion of the top of this same bank also suggests a slight displacement of its crest northwards.

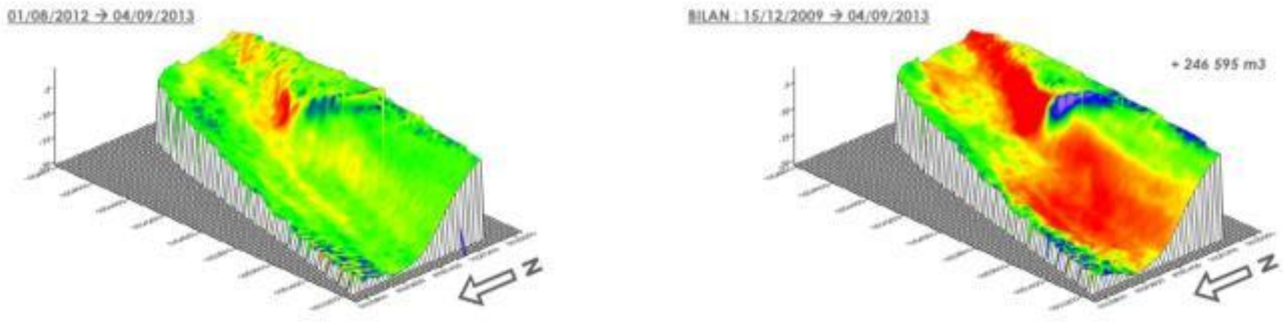


Figure 31: Bathymetric differences of the IEST zone (IDRA, 2014)

West-North Zone - ION

Located on the *Buitten Ratten* bank, this relatively flat area reaches a depth of 27m (Figure 32).

Sedimentation occurred between April 2012 and March 2014, at the foot of the North-West slope where the depths are shallower (down to -10m), and in an area located between the central part and the east of the zone, creating a "bump".

In the end, over the entire study period, sedimentation clearly predominates over almost the whole zone studied, probably following the sediment input.

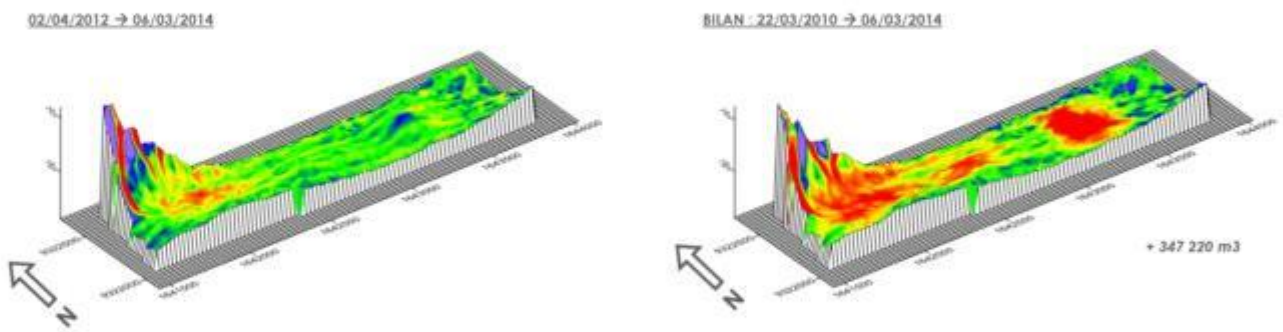


Figure 32: Bathymetric differences of the ION zone (IDRA, 2014)

West-South Zone - ISO

At a depth of approximately 20m, this is a disposal zone frequently used by the GPMD for its dredging (Figure 33).

Between March 2012 and March 2014, a measurement period that is two times longer than for the other sites, erosion can be seen over the entire zone. This seems quite logical since erosion occurs primarily on recent sedimentation zones which form obstacles more exposed to the currents, and where the sediments are less compressed and less cohesive.

Over the entire period considered, the volumetric balance shows widespread erosion occurring essentially in the south-east part, whereas a deposit of sediments can also be seen localized in the south-west.

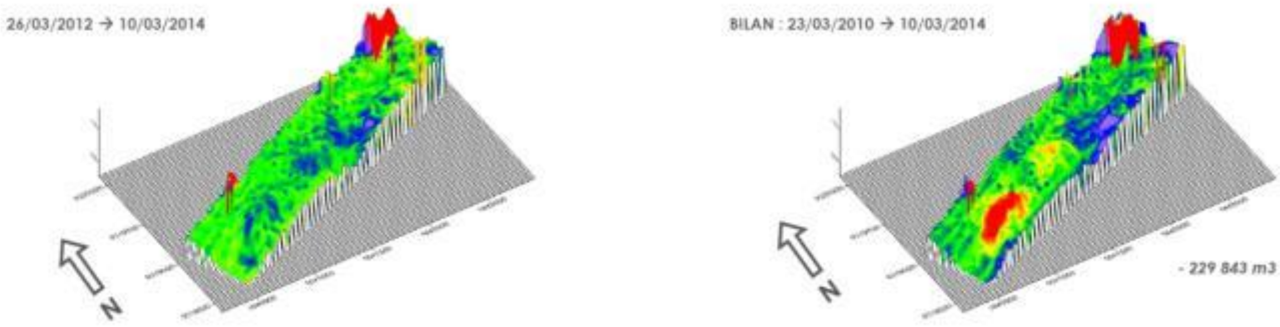


Figure 33: Bathymetric differences of the ISO zone (IDRA, 2014)

3.4.5 Discussion

The results of the bathymetric surveys by multibeam echosounder carried out on the Bancs des Flandres site suggest a migration of the hydraulic dunes but indicate that the sand displacements above all affect the top parts of the banks. DE MOOR (2002) had come to a similar conclusion concerning the Belgian part of the Bancs des Flandres.

The volumetric variations found are the result both of disposal operations and natural sediment movements due to the dynamic hydrodynamic conditions of the North Sea. It would appear that sediments disposed of can be handled and dispersed more rapidly than the sediments in place, due to the fact that they form a pile of sediments more exposed to erosion phenomena, but also because the sediments are less compressed and more easily scattered (IDRA, 2014).

A more detailed analysis, particularly of the profiles, should clarify the analysis concerning the banks' displacement. However, a rapid analysis of a few bathymetric profiles of the sedimentary shapes (Figure 34) shows that on an annual scale, the dunes have systematically moved East. This trend is particularly visible for the hydraulic dunes in the IEST zone. These displacements result in migrations of the entire dune core, and not solely the top part. However, in the Channel, FERRET (2011) pointed out that the forms of these displacements can vary from one dune to another. And that over short timescales, dune migrations were often the consequence of the morphodynamics of the small dunes superimposed on them. In the end, it would seem appropriate to monitor dune crests to assess the dynamics of the bottom, provided that the scale is at least annual.

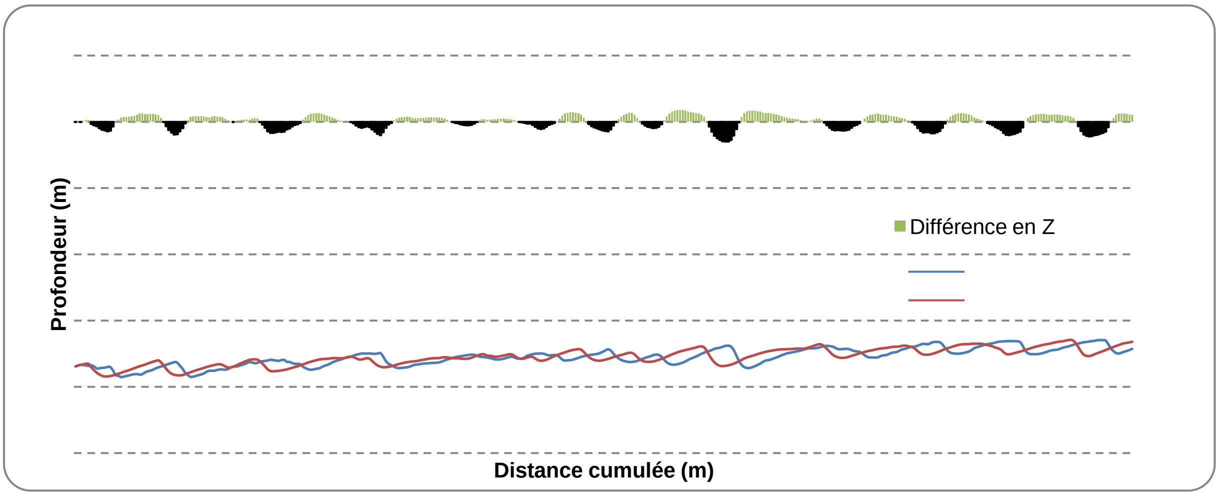


Figure 34: Comparison of two profiles in the dune field – example north-west of the IEST zone

Another conclusion drawn from the observations highlights the influence of hydrodynamic conditions and particularly seasonality on the sediment dynamics. The summer surveys indeed show depositing trends due to the usually calmer summer conditions. The winter surveys, on the other hand, reveal a lowering of the topographic surface as winter conditions are generally rougher and propitious to erosion and suspension of sediment (IDRA, 2014). To confirm this observation, swell and current data measured during the bathymetric study period could be collected and analysed. A study that meets this need was conducted in the western part of the Bancs des Flandres at the "Terns" platform in order to respond to the management issue of PANACHE WP3.

IV. Conclusions

Just like aerial photography or satellite images that revolutionized mapping of the earth's surface, multibeam echosounders have profoundly changed perception of the ocean depths. Once processed, the data acquired during the missions allows the morphology and quality of the sea bed to be viewed in 2D or 3D.

Though multibeam data are expensive to collect, there are many opportunities to collaborate between agencies and data can be and should be shared to maximise its use. Different users have different needs as regards data quality – coverage and positional accuracy are important for navigational surveys and backscatter is important for habitat mapping. As most surveys are undertaken for navigational purposes, backscatter quality is often a lesser priority and can range from adequate to poor or useless.

Even without good quality backscatter, much information can be gleaned from high resolution multibeam data, aided by the use of various terrain analysis tools. Many features, such as rock ledges and sediment waves/dunes can be identified from the digital terrain model derived from the multibeam data and this has been used, with and without additional ground-truthing data, to provide evidence for the presence and extent of potential conservation features during MPA site selection.

The resolution of the data (can be less than 1m) is such that physical impacts of some human activities on the seabed can be identified – anchor scars, dredge marks, dumped material etc. This means that the sea can no longer be relied upon to hide such impacts, which has always been a problem when managing activities in the sea. Repeat surveys are able to detect change over time – this could be human-induced (disposal of dredge spoil, for example) or natural – migration of sandbanks or storm-related movement. IDIER (2002) and FERRET (2011) confirmed the legitimacy of using this technology to assess the migration of sand banks in the Channel. The originality of this work done for PANACHE lies in the survey strategy which is based on interleaving several spatial scales (the bank, a sedimentary unit or the entire site) and time scales (one year, several decades). The multibeam method has proved to be appropriate. It has led to: 1) objectively confirming the migration of the sedimentary structures; 2) the identification of a multi-scale approach as an essential feature and lastly, 3) the beginnings of reflection on the importance of hydrodynamic characteristics (tidal currents, swell, weather conditions) in the dynamics of the environment. In Work Packages 2 and 3 of PANACHE, in order to optimally assess the hydro-morphosedimentary dynamics of the Bancs des Flandres on the littoral zone, use of the multibeam echosounder is coupled with high spatial resolution topographic surveys using a DGPS (Differential Global Positioning System) featuring altimetric precision of ± 3cm and centrimetric positioning precision. Once coupled and after correcting variations in the water level due to the tide, the two bathymetric and topographic surveys conducted at the same period allow Digital Terrain Models (DTM) to be produced, thus providing a global view of the hydrosedimentary system. The two technologies prove to be complementary in this case.

Finally, the echosounder has shown that it can help to optimise sediment facies and habitat recognition strategies, by minimising sediment and biological sampling, and thus the time-consuming laboratory analyses. The implementation of acoustic systems thus saves on resources without compromising the quality of results.

A significant by-product of the widespread use of multibeam is public engagement – the enhanced ability to visualise the seabed makes it much easier for people to relate to underwater landscapes as many features are intuitively recognisable – reefs and dunes, for example. This is of great help in winning wide support for designating and managing marine protected areas. The widespread availability of detailed seabed data has been of great interest to recreational divers – in return, they are providing much needed ground-truthing information.

Advantages	Drawbacks
▪ Bathymetric survey ▪ Co-located seabed reflectivity data enabling rapid mapping of the facies ▪ repeated surveys allows calculation of physical changes ▪ Once collected, can be used for many purposes – increased cost-effectiveness ▪ High acquisition rate ▪ High boat speed ▪ Accurate information ▪ Adaptable to a small boat ▪ Data integratable to GIS ▪ Visualisation	▪ High cost ▪ Very significant volume of digital data acquired and post-processing difficulties ▪ Recording of external parameters (velocity, salinity, roll) requiring post-processing ▪ Need for experienced technicians ▪ Tricky maintenance conditions ▪ Backscatter/reflectivity data lower quality than sidescan ▪ Backscatter/reflectivity data important for habitat definition but quality often compromised in hydrographic surveys

Table 2: Advantages and drawbacks of the multibeam echosounder

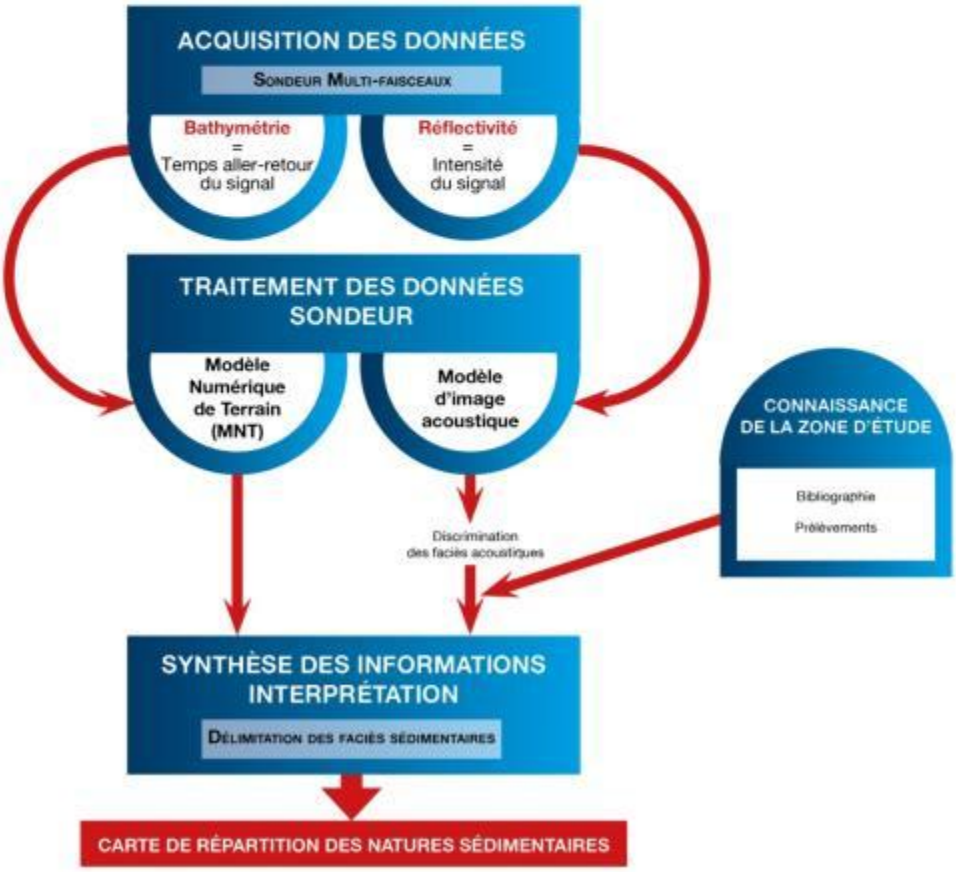


Figure 35: Possibility of using the multibeam echosounder.

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PANACHE

Protected Area Network Across the Channel Ecosystem

PANACHE is a project in collaboration between France and Britain. It aims at a **better protection** of the Channel marine environment through the **networking** of existing marine protected areas.

The project's five objectives:

- **Assess** the existing marine protected areas network for its ecological coherence.
- **Mutualise** knowledge on monitoring techniques, share positive experiences.
- **Build** greater coherence and foster dialogue for a better management of marine protected areas.
- **Increase** general awareness of marine protected areas: build common ownership and stewardship, through engagement in joint citizen science programmes.
- **Develop** a public GIS database.

France and Great Britain are facing similar challenges to protect the marine biodiversity in their shared marine territory: PANACHE aims at providing **a common, coherent and efficient reaction**.

PANACHE est un projet franco-britannique, visant à une **meilleure protection** de l'environnement marin de la Manche par la **mise en réseau** des aires marines protégées existantes.

Les cinq objectifs du projet :

- **Étudier** la cohérence écologique du réseau des aires marines protégées.
- **Mutualiser** les acquis en matière de suivi de ces espaces, partager les expériences positives.
- **Consolider** la cohérence et encourager la concertation pour une meilleure gestion des aires marines protégées.
- **Accroître** la sensibilisation générale aux aires marines protégées : instaurer un sentiment d'appartenance et des attentes communes en développant des programmes de sciences participatives.
- **Instaurer** une base de données SIG publique.

France et Royaume-Uni sont confrontés à des défis analogues pour protéger la biodiversité marine de l'espace marin qu'ils partagent : PANACHE vise à apporter **une réponse commune, cohérente et efficace**.

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