

Theme session K

Making marine sediment extraction sustainable by mitigation of related processes with potential negative impacts.

Conveners:

Ad Stolk (the Netherlands) ad.stolk@rws.nl

Keith Cooper (UK) keith.cooper@cefas.co.uk

Michel Desprez (France) despzmike@wanadoo.fr

Introduction

Marine sediment extraction in the North Atlantic, including the Baltic and North Sea, has shown a spectacular increase from a few hundred thousand m³ per year in the early 1970s to millions in the 1990s and hundreds of millions m³ in recent years (fig.1). Of all the ICES countries most marine sediment extraction takes place in the Netherlands, The United Kingdom, Denmark, Belgium, France and Germany.

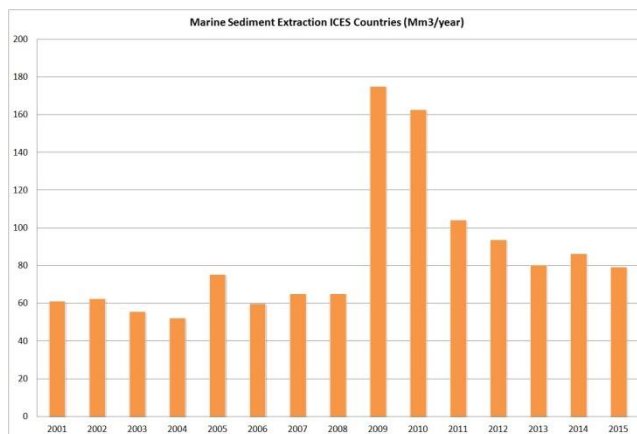


Fig. 1 Marine sediment extraction in ICES countries (2001 - 2015)(Stolk, 2016)

In the strict sense, marine mineral extraction is not sustainable as the extracted minerals are lost for the marine system. Extraction of marine sediments can also cause negative effects on the marine environment. Accompanied processes, such as the removal of sediments including benthic fauna, can introduce a sand blanket in the vicinity of the extraction and high concentrations of suspended matter in the surrounding area, as well as increase the level of underwater sound.

Nevertheless, the mineral extraction process can be sustainable in the sense that negative effects on the ecosystem can be minimized by mitigation measures that are beneficial for the recolonisation of the benthic fauna, leading to recovery within an acceptable period of time.

To ensure the goals of mitigation are reached, extensive monitoring programmes are executed on suspended matter, recolonisation, underwater noise, effects on other users of the sea, and coastal defence amongst others.

Within ICES, the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) has the objective to provide a summary of data on marine sediment extraction, marine resource and habitat mapping, changes to the legal regime, and research projects relevant to the assessment of environmental effects. Terms of reference have also been defined on databases and harmonization of data, Marine Strategy Framework Directive, publishing, deep sea mining, archaeological and cultural heritage values, Environmental Impact Assessments, cumulative assessment, mitigation, marine spatial planning and effects on fish and fisheries.

In theme session K, 14 oral presentations were given and 2 posters were presented during the conference. Several presentations were given by members of WGEXT (see Annex).

The session was divided into the following themes:

- 1) Identification of resources and sensitive habitats
- 2) Lessons from case studies (impacts/monitoring/recovery)
- 3) Improvement of monitoring and Marine Strategy Framework Directive

Identification of resources and sensitive habitats

An understanding of the location of aggregate resources, and the habitats which are sensitive to the effects of marine extraction is vital when deciding how and where to undertake aggregate extraction.

Research into marine sediments resources of sand, gravel and shells has, for a long time, been done through seismic investigations and sampling followed by a geological interpretation. In the last few years, several projects have started to improve the knowledge of aggregate resources by modelling. The lithological and geological information is used as input in voxel models of the sea bed sediments. Interpretation of these geostatistical models is not straightforward. Expert knowledge is needed to choose among model results and to combine them. Also inclusion of uncertainty is of added value, especially when it is related to the presence of fines, which often are the cause of negative effects on benthic fauna or primary production.

These aspects were addressed by the poster of Sytze van Heteren and the presentation of Vasileios Hademenos. In the presentation, the results were shown of a 3D voxel model of the Belgian Continental Shelf (fig.2). It gives a detailed image of the distribution of different sediment types. The model is an excellent tool to efficiently target suitable areas for extraction, estimate resource volume and quality and easily identify areas with poor data coverage. It gives information that is critical to assess potential habitat changes in depth and time in case the marine sediment will be extracted.

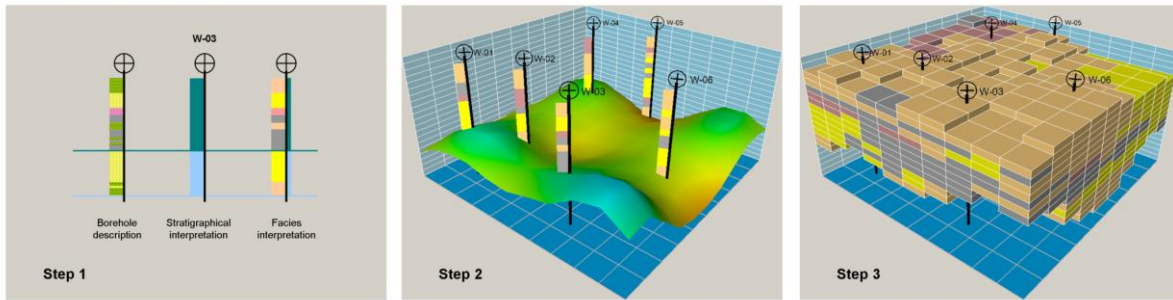


Fig. 2 Voxel model (Hademenos, 2016)

That the research for the identification of marine sediment resources can be very useful for the designation of Marine Protected areas is shown by Ian Reach. Data from the marine aggregate sector were used to differentiate the toe of sandbanks from the surrounding sand wave fields. This led to a better definition for the boundary of Natura 2000 areas and prevents unnecessary restriction of extraction activities. When necessary, e.g. in the case of Marine Conservation Zones for Black Bream nests, research leads to a restriction for sediment extraction. But also in this case, good research can limit the area and period of restriction for the location and volume of extraction.

In another presentation, Ian Reach showed that detailed knowledge of effects of extraction proved to be very important in the case of extraction versus spawning habitat of herring. A rather rigid advice to exclude extraction from all spawning areas could be converted to advice to exclude extraction, unless the effect have been assessed and shown not to be detrimental.

Lessons from case studies (impacts/monitoring/recovery)

Monitoring the effects of extraction is necessary to mitigate negative impacts on other uses of the sea and ecosystem, including benthic fauna and fish. The results of monitoring can lead to improved regulation of extraction resulting in better protection of the ecosystem and less restrictions on extraction activities.

In ICES countries, marine sediments are extracted in very different geological settings, ecological habitats and at a range of different dredging intensities. As a consequence, monitoring is often executed in different ways. For example, the long term extraction in gravelly areas in the English Channel calls for a different monitoring approach than the short but intensive extraction for the Rotterdam harbour.

Jyrki Hämäläinen and Ad Stolk both give presentations on the monitoring of the impact of the extraction activities for enlarging of the harbours of Helsinki and Rotterdam respectively. For the harbor of Helsinki, over 6 million m³ of sand and gravel was extracted. The monitoring was undertaken before, during and after the dredging occurred and were focused largely on fish and fisheries. At the Helsinki site the area proved problematic for trailing suction dredging. Therefore stationary suction dredgers were used. This caused isolated depressions in the seabed that were very consistent. Recent multibeam investigations showed that these features hardly changed in 10 years. Older extraction pits were still seen after 25 years. This highlights the need to reconsider future extraction methods in this area.

The largest marine sand extraction in Europe was executed for the enlargement of the harbour of Rotterdam, the Maasvlakte 2 project. In a period of 3 years, about 200 million m³ were extracted. The weekly amount quite often exceeded 2.5 million m³ (fig.3).

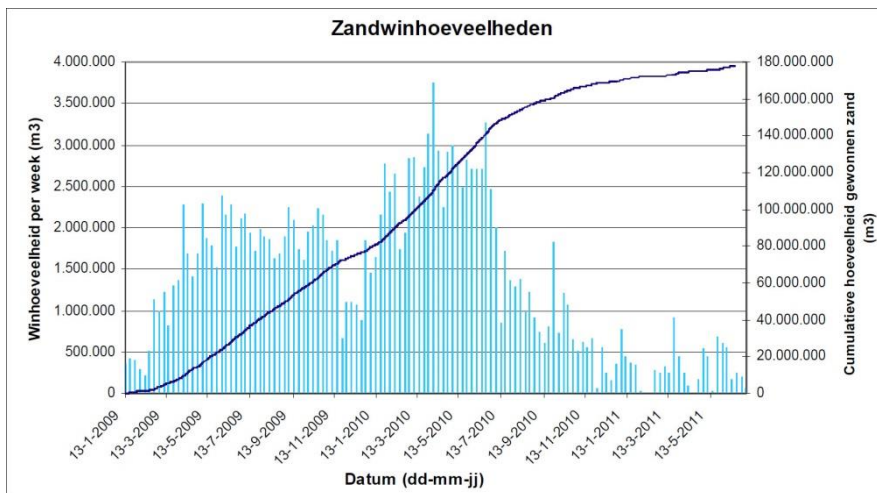


Fig.3 Marine sand extraction for Rotterdam harbour. In light blue (left scale) weekly amounts. In dark blue (right scale) total amount (Stolk, 2016)

The area of the extraction pit was minimised to 16 km² by increasing the depth of extraction to 20 m below the sea floor. In a general water depth of 22 m, this was nevertheless a large scale operation. A comprehensive monitoring programme was executed focusing on the effects of suspended matter on benthos and N2000 areas, under water noise and recolonisation of benthic fauna. The monitoring showed that the effects of this very large and deep extraction are within the expectation of the EIA and limits accepted in the license.

The sand extraction pit of the Maasvlakte 2 was used by Maarten de Jong to study the recolonisation of benthos and the presence of fish in this deep pit compared to shallower extractions. In his presentation he showed that in the deep pit the biomass of macrozoobenthos and demersal fish increased 10 to 20-fold in the first two years after the extraction. His study leads to the formulation of ecosystem-based design rules which can be used for the future design of extraction pits. The bed shear stress proved to be a useful steering parameter and ecological output can be designed via extraction depth. In this way it is possible to maximize the sand extraction volume and decrease the surface area of direct negative impacts.

An important parameter for the impact of extraction on the ecosystem is the intensity and frequency of dredging (fig.4). Annelies De Backer showed how the benthic sandy habitat of the Belgian Continental Shelf is impacted by different values of these parameters.

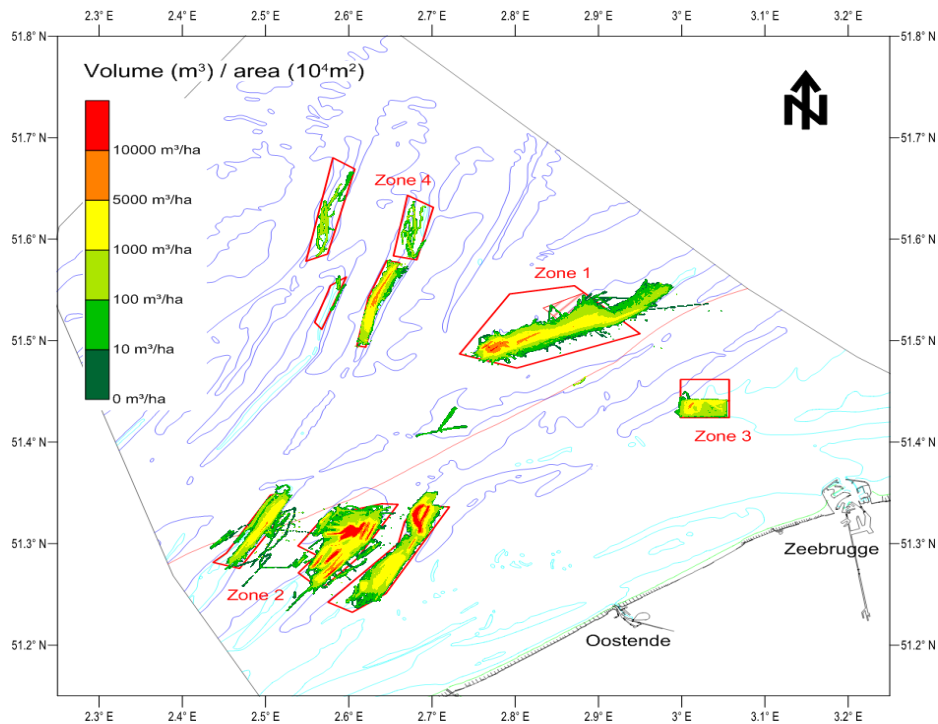


Fig.4 Extraction zones on the Belgium Continental Shelf with frequency of dredging (De Backer, 2016)

The conclusion is that these sandy benthic habitats are resilient enough to buffer aggregate extraction when performed at low intensities or at high but infrequent intensities. One of the reasons for this is that the area is a very dynamic system with high natural disturbance and a high pressure from e.g. fishing activity. However, when dredging is performed at high and frequent intensities or at high intensities, changes in sediment composition do result in structural changes in the benthic ecosystem.

Intensity of extraction is also an important parameter affecting fish within and near extraction sites in the English Channel. Michel Desprez has studied benthos and fish and the trophic relationships between them (by stomach content analysis) in an area near Dieppe and in the Baie de Seine. The study was undertaken in the dredging areas themselves, in areas of deposition of fines from overspill and in reference areas. In an area with intensive dredging the benthos and fish abundances were strongly reduced, as expected. But in areas of extensive dredging the decrease in abundance of fish was moderate and the number of fish species was increased by 50% (fig.5), consequently as a result of an increased number of habitats (sediments and benthic prey species). This gives rise to methods to mitigate the effects of extraction and minimize the traditional competition for space between fishermen and mining companies.

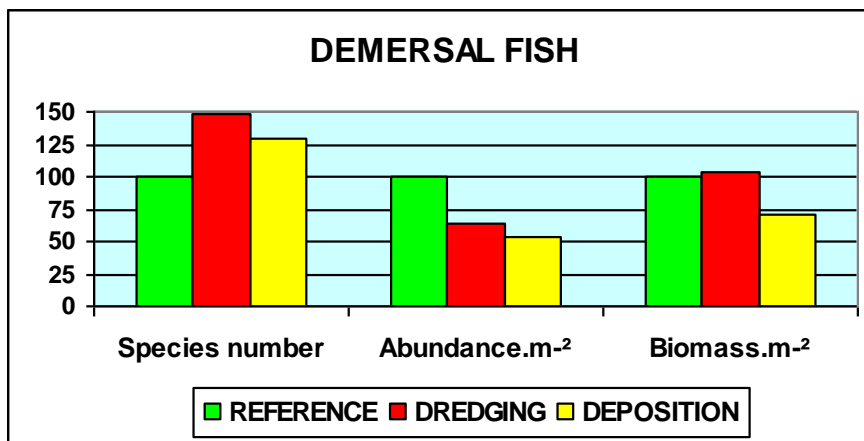


Fig.5 Effect of 10 years of extensive dredging on demersal fish in and near the Dieppe extraction site (Desprez, 2016)

Improvement of monitoring and Marine Strategy Framework Directive

Marine sediment extraction can influence several descriptors of the Marine Strategy Framework Directive (MSFD) of the EU, like D1 (biodiversity), D3 (commercially exploited fish and shellfish), D4 (food webs), D6 (sea-floor integrity), D7 (hydrographical conditions) and D11 (underwater noise).

In a presentation on the role of extraction strategy on the recovery of biological communities in two French extraction sites in the eastern channel, Michel Desprez showed from intensive monitoring of benthos and fish that extraction of marine sediment can fit in with the goals of the Marine Strategy Framework Directive if a good extraction strategy is followed: in an environment with moderate to high energy avoiding vulnerable habitats, a low extraction intensity and/or a limited duration of extraction can minimise negative effects and promote recovery.

In a poster Vera Van Lancker described an investigative monitoring study with a focus on MSFD descriptors D6 and D7.. Sand extraction on a tidal sandbank can influence the colonization and growth of epifauna in nearby gravel beds due to the distribution of fines by turbidity plumes by overspill.

The MSFD is also an important factor for the monitoring of marine aggregate dredging in the UK. Keith Cooper outlined a new monitoring approach characterised by the goal to ensure that sea bed conditions are left in a state that will allow for the return of the original faunal community after dredging. This is achieved through reference to the range of environmental conditions that are naturally found in association with different faunal communities in the wider region. To reach this goal the marine aggregate industry adopted Regional Seabed Monitoring Plans that are expected to offer better environmental protection, whilst at the same time significantly reducing the costs of monitoring. The location of samples used in this study are shown in fig.6.

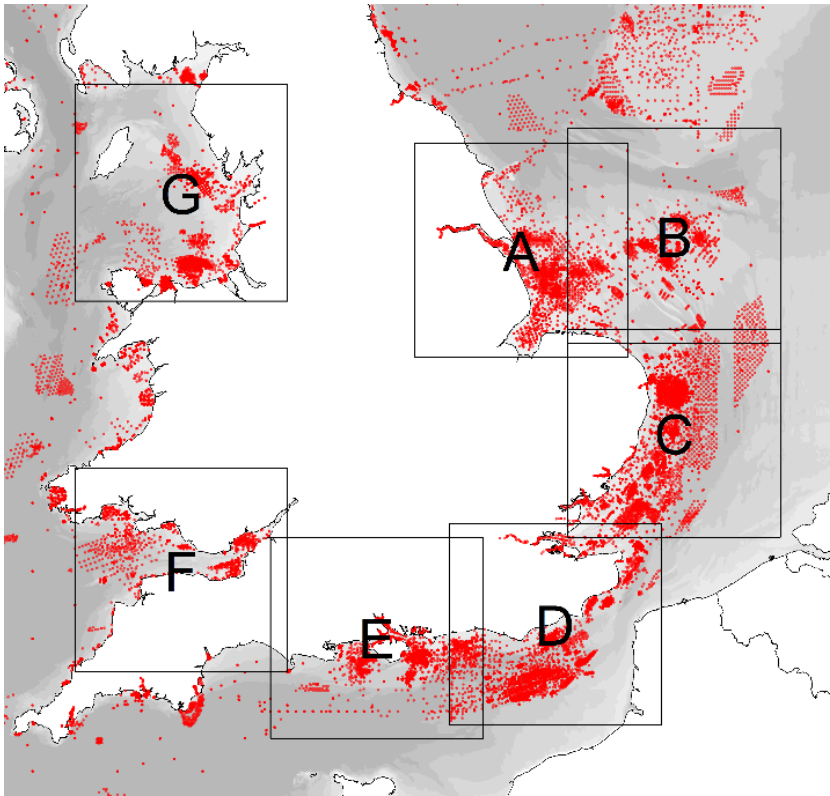


Fig.6 Regional Seabed Monitoring Plans in the UK (Cooper, 2016)

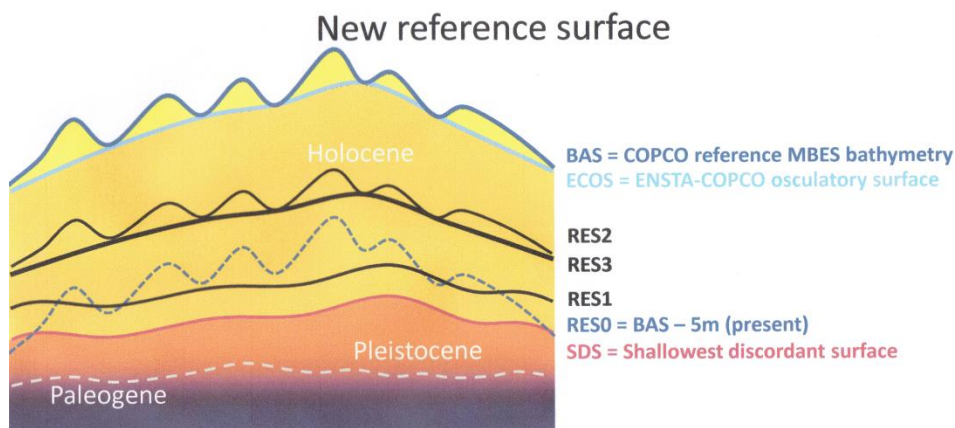
In Belgium several studies have been undertaken on the monitoring of sand extraction to improve the location and the extraction depth in order to meet the goals of the MSFD.

The Belgian, legislation limits extraction to a depth of 5 meters below a global reference surface in the extraction area. Koen Degrendele presented a project to define a new depth limitation surface based on the nature of the seabed, the geological structure and the differences in marine ecology (fig.7). This new approach is focused on the principles to avoid the most vulnerable areas, allow no changes in surface sediments, conservation of sand bank morphology and to be economically sustainable

Both monitoring and modelling are necessary to enable the mitigation of the impact of extraction as Nathan Terseleer emphasized in his presentation. High resolution bathymetric surveys showed that dune morphology and migration are coupled and lead to a general flattening of the seabed in and around the extraction area.

The modelling of this behaviour of the seabed, combined with the 3D geological voxel model and a model of the hydrodynamics and sediment transport, leads to a better performance of scenario's over time to simulate parameters related to the descriptors 6 and 7 of the MSFD.

A main parameter is the bottom shear stress, which determines the sediment resuspension and erosion, deposition and bottom morphology. Dries Van den Eynde shoes how a model for the bottom shear stress was validated with measurements from different extraction zones of the Belgium Continental Shelf. Although measurements of bottom shear stresses are difficult, the model gives good results. Bottom shear stress will be used as an indicator in the Belgium implementation of the MSFD to evaluate changes linked to human activities, including marine sediment extraction.



Reference surface scenarios:

| | Definition | Volume = economic reserve | Criteria |
|------|-----------------------------------|---------------------------|--|
| RES1 | SDS + 1m | maximum | No changes in sediment |
| RES2 | SDS+BAS / 2 with minimum SDS +1m | minimum | No changes in sediment Preservation of sandbank morphology |
| RES3 | SDS+ECOS / 2 with minimum SDS +1m | medium | No changes in sediment Preservation of sandbank morphology Use of mobile sand volume |

Fig.7 New reference surface for marine extraction in Belgium (Degrendele, 2016)

Concluding remarks

The session was the opportunity to show the progress of research in the marine sediment extraction process through 14 presentations and 2 posters (see Annex).

The presentations and posters can be classified in relation to the extraction activity. Several presentations address more than one issue.

Before extraction

- resource mapping; progress in modelling for sustainability: 3 presentations
- protection of sensitive habitats of high ecological (biological reefs) and /or economical value (spawning areas) : 2 presentations

During extraction

- impact monitoring : 5 presentations
- progress in monitoring for sustainability : 6 presentations
- mitigation : 7 presentations
- MSFD : 6 presentations

After extraction

- recovery : 1 presentation

The attendance was minimal during the session in spite of efforts of the conveners and the vice-president of ICES. The reasons for that can be that it was scheduled on the last day of the conference or that the issue was not directly related to fisheries.

Although 6 presentations mentioned the link between extraction and fish/fishery, the subject of marine sediment extraction appeared to be of marginal interest to the wider ICES community. Nevertheless, it is an important issue within ICES in relation to OSPAR and MSFD.

For future Annual Science Conferences we suggest that theme sessions that are not directly related to fisheries, but which are never-the-less important for ICES, should not be scheduled on the first or last day of the conference.

Progress on several items was emphasised during the session. The main points that came forward during the presentations and the discussions were:

- Impact and recovery of benthos
- Mitigation and sustainability of marine sediment extraction
- Prime role of bottom shear stress in different environments
- The use of modelling
- MSFD descriptors relevant to marine sediment extraction
- New data on impact and recovery (of) for fish and fishing activity

During the session it became clear that it is indeed possible to make marine sediment extraction sustainable by mitigation of related processes with potential impacts.

To reach that goal, efforts must be made to monitor the resources and the effects of extraction, and implement the results in policy and legislation.

Annex: Theme session K

Making marine sediment extraction sustainable by mitigation of related processes with potential negative impacts

Conveners: Ad Stolk (the Netherlands) Keith Cooper (UK) Michel Desprez (France)

Friday 23 September 2016

Title: Introduction session

Make marine sediment extraction sustainable by mitigation of related processes with potential negative impacts

Author: Ad Stolk

Keywords: marine sediment extraction, effect monitoring, resource mapping

Presentation type: Oral

Title: Robust Marine Protected Area designation through the use of marine aggregate sector environmental data

Authors: Ian Reach, Stuart Lowe, Mark Russell, Andrew Bellamy, Joseph Hopcroft, Louise Mann, Defied Lloyd Jones, Rob Langman

Keywords: Marine Protected Areas, nature conservation, aggregate dredging, North Sea, data, knowledge, information, designation, palaeochannel, sandbanks, Ross worm, Sabellaria spinulosa reef, black bream, Spondyliosoma cantharus

Presentation type: Oral

Title: Quantifying the resource potential of Quaternary sands on the Belgian Continental Shelf: a 3D voxel modelling approach

Authors: Vasileios Hademenos, Lars Kint, Tine Missiaen, Jan Stafleu, Vera Van Lancker

Keywords: resource estimation, 3D voxel model, North Sea, sand extraction, sustainability

Presentation type: Oral

Title: Identifying, assessment and adaptive environmental management of environmental effects between UK dredging areas and herring Clupea harengus spawning habitat

Authors: Ian Reach, Phil Latto, Dafydd Lloyd Jones, Rob Langman, Caroline Chambers, Iain Warner, Mark Russell

Keywords: herring, Clupea harengus, North Sea, spawning area, aggregate dredging, gravel beds, geography, data, knowledge, information, environmental impact, adaptive management

Presentation type: Oral

Title: Marine sand and gravel extraction for Helsinki harbor - monitoring the impact of the extraction works

Author: Jyrki Hämäläinen

Keywords: Helsinki, marine aggregate, sand, gravel, extraction, monitoring

Presentation type: Oral

Title: Large scale sand extraction. Monitoring effects on morphology and ecosystem

Author: Ad Stolk

Keywords: large scale sand extraction, effect monitoring, suspended matter, recolonization, underwater noise

Presentation type: Oral

Title: Combining measured and visually observed granulometric characteristics in updatable voxel models of seabed sediment

Author: Sytze van Heteren

Keywords: seabed-sediment maps

Presentation type: pitch and Poster

Title: MSFD-compliant investigative monitoring of the effects of intensive aggregate extraction on a far offshore sandbank, Belgian part of the North Sea

Authors: V.R.M. Van Lancker, M. Baeye, D. Evangelinos, G. Montereale-Gavazzi, N. Terseleer, D. Van den Eynde

Keywords: Marine Strategy Framework Directive, sediment plumes, gravel beds, North Sea

Presentation type: pitch and Poster

Title: Impact of dredging activity on the distribution and diet of demersal fish species in a commercial marine aggregate extraction site of the eastern Channel (Dieppe, France)

Author: Michel Desprez

Keywords: marine aggregate extraction, demersal fish, habitat diversity, trophic relationships

Presentation type: Oral

Title: Ecosystem based design rules for sand extraction sites

Authors: Maarten de Jong, Martin Baptist, Bas Borsje, Daan Rijks

Keywords: deep sand extraction, macrozoobenthos, hydrodynamics, ecosystem

Presentation type: Oral

Title: Relation between dredging intensity and frequency and its impact on a benthic sandy habitat

Authors: Annelies De Backer, Kris Hostens

Keywords: macrobenthos, dredging intensity, structural and functional characteristics, Belgian part of the North Sea

Presentation type: Oral

Title: The role of extraction strategy on the recovery of biological communities in two French sites of marine aggregate extraction in the eastern Channel. Management implications for sustainability

Author: Michel Desprez

Keywords: marine aggregate extraction, benthos and fish recovery, eastern Channel, sustainability

Presentation type: Oral

Title: Marine aggregate dredging: a new monitoring approach to meet the needs of the Marine Strategy Framework Directive

Authors: Keith Cooper, Jon Barry, Claire Mason

Keywords: aggregate, dredging, benthos, macrofauna, sediments, recovery, monitoring, sea-floor integrity

Presentation type: Oral

Title: Optimization of monitoring and modelling frameworks to mitigate negative effects of aggregate extraction, Belgian part of the North Sea

Authors: Nathan Terseleer, M. Roche, K. Degrendele, D. Van den Eynde, V.R.M. Van Lancker

Keywords: monitoring, modelling, resource mapping, management plan, sustainable extraction, Marine Strategy Framework Directive

Presentation type: Oral

Title: Minimisation of the impact of sand extraction on the Belgian part of the North Sea by the introduction of a newly defined reference surface.

Authors: Koen Degrendele, Marc Roche

Keywords: sand extraction, sustainable, reference surface, minimization of impact

Presentation type: Oral

Title: Changes in bottom shear stress, due to aggregate extraction, in the area of the Hinder Banks (Belgian Continental Shelf)

Authors: Dries Van den Eynde, Matthias Baeye, Michael Fettweis, Frederic Francken, Vera R.M. Van Lancker

Keywords: bottom shear stress, Marine Strategy Framework Directive, modelling, sustainable extraction

Presentation type: Oral

