WORKING GROUP ON THE EFFECTS OF EXTRACTION OF MARINE SEDIMENTS ON THE MARINE ECOSYSTEM (WGEXT)

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WORKING GROUP ON THE EFFECTS OF EXTRACTION OF MARINE SEDIMENTS ON THE MARINE ECOSYSTEM (WGEXT)

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Contents

i Executive summary ii
ii Expert group information iii
1 Introduction 1
2 ToR A1: Review data on marine extraction activities and provide a summary of data on marine sediment extraction for the OSPAR region to OSPAR 3
3 ToR A2: Review of development in marine resource mapping, legal regime and policy, environmental impact assessment, research and monitoring and the use of the ICES Guidelines on Marine Aggregate Extraction 8
4 ToR B: Create an ICES aggregate database comprising all aggregate related data, including scientific research and EIA licensing and monitoring data 9
5 ToR C: Incorporate the MSFD into WGEXT 10
6 ToR D: Ensure outputs of the WGEXT are accessible by publishing as a group and creating a webpage on the ICES website 11
7 ToR E: Discuss the mitigation that takes place across ICES countries and where lessons can be learned or recommendations taken forward 12
8 ToR F: Study the implications of the growing interest in deep sea mining for the WGEXT (legislation/environmental/geological) 14
9 ToR I: Cumulative assessment guidance and framework for assessment should be developed. 16
10 ToR K: Impacts of marine aggregate extraction on fish and fisheries 21
11 ToR L: Implications of Marine Spatial Planning on marine sediment extraction 22
Annex 1: List of participants 23
Annex 2: WGEXT Resolutions 25
Annex 3: Reporting format from 2020 onwards 29
Annex 4: ToR A1. Review of National Marine Aggregate Extraction Activities 31
Annex 5: ToR A2. Review of development in marine resource mapping, legal regime and policy, environmental impact assessment, research and monitoring and the use of ICES Guidelines on marine aggregate extraction 45
Annex 6: ToR C. Incorporating MSFD into WGEXT 60
Annex 7: ToR D. Ensure outputs of the WGEXT are accessible by publishing as a group and creating a webpage on the ICES web-site 99
Annex 8: ToR I. Cumulative assessment guidance and framework for assessment should be developed 109
Annex 9: ToR K. Impact of marine aggregate extraction on fish and fisheries 125
Annex 10: OSPAR National Contact Points for Sand and Gravel Extraction 132

i Executive summary

Marine sediment extraction in the North Atlantic, including Baltic and North Sea has shown a spectacular increase from a few hundred thousand m³ per year in early 1970s to millions in the 1990s and tens of millions m³ in recent years.

In the strict sense, marine mineral extraction is not sustainable because the extracted minerals are lost for the marine system. In fact, the extraction of marine sediments can even cause negative effects on the marine environment by accompanied processes like the removal of sediments including benthic fauna, introducing a sand blanket in the vicinity of the extraction, introducing high concentrations of suspended matter in the surrounding area and increasing the level of underwater sound.

Nevertheless, the way the minerals are extracted can be sustainable in the sense that the negative effects on the ecosystem are minimized by mitigation measures that are beneficial for the recolonization of the benthic fauna and recovery is fulfilled in an acceptable timeframe after extraction.

The Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) is mainly focused on the exchange and dissipation of information. This is reflected in the composition of the group. Not only scientists, but also representatives from governmental bodies, NGO's and industry are participating in the WGEXT.

The objective of the WGEXT is 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. The data on marine sediment extraction is reported to OSPAR on a yearly basis.

The data on amounts and areas of marine extraction are given for the ICES countries, both in an overview as well in detail. In 2018, a total of 73.2 million m³ was extracted in these countries.

This report includes extensive reviews on the relation between marine sediment extraction and the Marine Strategy Framework Directive, Cumulative Assessments, and the definition and calculation of intensity of dredging to define a footprint. An overview of the regulation of the impact of extraction on fish and fisheries in different ICES countries is available in the report.

ii Expert group information

Expert group name	Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT)
Expert group cycle	multiannual
Year cycle started	2017
Reporting year in cycle	3/3
Chair(s)	Ad Stolk , the Netherlands

Meeting venue(s) and dates	24-27 April 2017, Norwich, UK (18 participants)
	16-19 April 2018, Copenhagen, Denmark (12 participants)
	6-9 May 2019, Funchal, Portugal (13 participants)

1 Introduction

The main objective of WGEXT is to provide a summary of data on marine sediment extraction (Term of Reference (ToR) A1), marine resource and habitat mapping, changes to the legal regime and policy, and research projects relevant to the assessment of environmental effects (ToR A2). The data on marine sediment extraction will be reported on a yearly basis for OSPAR in an Interim Report. The other items will be addressed in the Final Report.

WGEXT had eight Terms of Reference (ToRs) in the current 3-year term. Most of them are intended for more than 3 years. These ToRs are: B (ICES aggregate database); C (Marine Strategy Framework Directive); D (Publications); E (Mitigation); F (Deep sea mining); I (Cumulative assessment); K (Effects on fish and fishery) and L (Spatial planning).

During and between the Annual Meetings of 2017, 2018 and 2019 these ToRs were discussed and results were formulated. Contributions were provided by correspondence from members who could not attend.

During the Annual Meetings presentations are given by members of WGEXT and local participants.

Yearly, data on marine sediment extraction, including amounts of extraction, spatial extent of licensed areas, spatial extent of extracted areas, geospatial shapefile information for all ICES-countries is published in the Annual Reports and delivered to OSPAR. This input is necessary for the Quality State Reports and for the Marine Strategy Framework Directive of the European Union. WGEXT developed a format for the request of these data. The new format is used from 2019 onwards.

The ICES database will be used for uploading the WGEXT information. As a result, of an intensive contact with the ICES Database Group a template was developed for the incorporation of the data in the ICES database.

The inventory on the relation between the Marine Strategy Framework Directive and marine sediment extraction has resulted in an extensive review. This review will be condensed to a journal paper for the ICES Journal of Marine Science and a presentation on the ICES Annual Science Conference in 2020. Another result is an intense discussion and collaboration with the ICES Workshop on Scoping of Physical Pressure Layers Causing Loss of Benthic Habitat (BEDLOSS) and participation in the ICES Workshop BEDPRES2. The recovery of benthos after sediment extraction should be acknowledged by incorporate it in the criteria and by taken it into account with the assessment of the Good Environmental Status. ToR C is completed.

The extensive review on Cumulative Assessment is finished, but will be rewritten as a journal paper for the *ICES Journal of Marine Science*. A publication on "Environmental impact Assessment and environmental monitoring on marine aggregate extraction site" based on a questionnaire is nearly finished. A proposal for a theme session at the ICES Annual Science Conference in 2020 has been accepted.

On mitigation as separate issue, not much progress has been made. A questionnaire on mitigation will be included in the questionnaire for ToR A2. ToR E is completed.

During the last years, it became clear that deep sea mining is a growing industry and its effects are an important issue. Nevertheless, WGEXT has decided to close this topic as a ToR, because there is a lot of attention for it elsewhere. Information on this topic will be incorporated in ToR A2. ToR F is completed.

The work on cumulative assessment concentrated on the intensity of extraction. An important progress is made by research on the intensity of extraction. Methods are developed to calculate the footprint of extraction on the environment. Complication is that the necessary data are not available for all ICES countries. But for the countries with the largest amounts of extraction these data are available. Results will be shared with the ICES Workshop WKBEDPRES2 on their next meeting.

Reports on the regulation of the impact of extraction of fish and fisheries are lately delivered by several countries. ToR K is completed.

On the topic of spatial planning no progress is made. There should be more contact with other groups in this field. Nevertheless spatial planning more and more influences the extraction and the way it effects other use of the sea and nature areas. This topic will be continued under another title.

Terms of Reference C, E, F, K are completed. The remaining Terms of Reference will be included in the new resolution 2020–2022.

2 ToR A1: Review data on marine extraction activities and provide a summary of data on marine sediment extraction for the OSPAR region to OSPAR

WGEXT have again attempted to provide information for all ICES countries on the annual amounts of sand and gravel extracted but have still found difficulty in obtaining information from countries not regularly represented in person at ICES WGEXT meetings. WGEXT members again attempted to contact those countries who were unable to submit data for inclusion in the annual report. A summary of available information is included in Table 1.

Table 1. Summary Table of National Marine-sediment Extraction Activities in 2018.

Country	A) Construction/ industrial aggregates (m³)	B) Beach replenishment (m³)	C) Construction fill/ land reclamation (m³)	D) Nonaggregate (m³)	E) Total Extracted (m3)	F) Aggregate exported (m³)
Belgium (OSPAR)	2 801 000	988 000	0	0	3 795 000	1 075 000
Canada	N/d	N/d	N/d	N/d	N/d	N/d
Denmark (HELCOM)	2 369 405	276 713	2 772 840	0	5 418 958	160 720
Denmark (OSPAR)	1 894 887	3 731 213	116 476	0	5 742 576	317 826
Denmark1 (total)	3 990 662	3 901 291	2 249 040	0	10 140 993	478 546
Estonia (HELCOM)	0	0	0	0	0	0
Finland (HELCOM)	0	0	0	0	0	0
France (OSPAR)	3 476 303	N/d 2	N/d	200 400 3	3 676 703 4	0
France (Med)	0	N/d 2	N/d	0	N/d	0
Germany (HELCOM)	N/d	N/d	N/d	N/d	N/d	N/d
Germany (OSPAR)	20 560	1 148 682	0	0	1 169 242	0
Greenland (OSPAR)	63 50010	0	0	0	63 500	0
Faroes (OSPAR)	N/d	N/d	N/d	N/d	23 000	N/d
Iceland (OSPAR)	316 7775	0	0	105 043	421 820	06
Ireland (OSPAR)	0	0	0	0	0	0
Latvia (HELCOM)	N/d	N/d	N/d	N/d	N/d	N/d
Lithuania (HELCOM)	0	0	0	0	0	0
Netherlands (OSPAR)	0	12 374 401	8 947 131	135 3117	24 583 921	3 262 389

Norway (OSPAR)	N/d	N/d	N/d	N/d	N/d	N/d
Poland (HEL-COM)	459 682	970 411	0	0	1 430 093	91.936
Portugal (OSPAR)	137 951	0	0	0	137 951	0
Spain (OSPAR)	0	3000	0	0	3000	0
Spain (MED)	0	994 397	0	0	994 397	0
Spain (Canary Islands)	0	0	0	0	0	0
Sweden (OSPAR)	0	0	0	0	0	0
Sweden (HEL-COM)	0	0	0	0	0	0
United King-dom8 (OSPAR)	8 080 127	493 355	779 572	0	9 353 054	2 375 805
United States9	0	16 928 253	525 782	0	17 454 035	0

Table Definitions and notes:

A. Construction/industrial aggregates - marine sand and/or gravel used as a raw material for the construction industry for building purposes, primarily for use in the manufacture of concrete but also for more general construction products.

B. Beach replenishment/coastal protection – marine sand and/or gravel used to support large-scale soft engineering projects to prevent coastal erosion and to protect coastal communities and infrastructure.

C. Construction fill/land reclamation – marine sediment used to support large scale civil engineering projects, where large volumes of bulk material are required to fill void spaces prior to construction commencing or to create new land surfaces.

D. Non-aggregates – comprising rock, shell or maerl.

E. Total Extracted – total marine sediment extracted by Member Countries

F. Aggregates Exported - the proportion of the total extracted which has been exported i.e. landed out-side of the country where it was extracted. This value is not included in the total.

[1] The OSPAR area and the HELCOM area are overlapping in Denmark. The Kattegat area from Skagen to north of Fyn-Sjælland is included in both Conventions. Therefore the figures from the two Convention-areas cannot be added. The total for Denmark has been reported separately.

[2] No information is available for extraction quantities used for beach nourishment in France although sand extraction for beach replenishment is likely to have occurred.

[3] Licensed data (maximum permitted) because extracted data is subject to statistical confidentiality.

[4] Included licensed data (maximum permitted) for non-aggregate because extracted data is subject to statistical confidentiality.

[5] The fraction of total extraction attributed to "construction aggregate" and that to "construction fill/reclamation" has been estimated. Most construction aggregate was used in concrete, and most of the aggregates used for fill and reclamation were are used in harbour construction.

[6] Although marine aggregates are not exported from Iceland, maerl (non-aggregate) is commercially extracted in Bíldudalur, Arnarfjörður and exported.

[7] Total shell extraction including Western Scheldt and Wadden Sea, Voordelta of the North Sea and the North Sea. Total sand-extraction figures exclude 135,311 m3 of shell as non-aggregate material.

[8] Conversion from reported tonnes to m³ achieved using density / specific gravity conversion factor of 1.66 tonnes/m3 although the Mineral Products Association generally uses 1.73 tonnes/m3 (Per. Com. 2018).

[9] Figures reported for USA pertain to northern areas of the eastern seaboard only (North of Cape Hatteras)

[10] Average amount extracted every year from 2013.

A new reporting format (Annex 3) is developed that is partially used this year and will be generally used next year at the beginning of our next three-year cycle. OSPAR may have been considering developing a standard reporting format, but we have no news.

Table 2. Specific matters highlighted in response to OSPAR request for ICES WGEXT to supply national data.

DATA ADJUSTMENTS FOR SPECIFIC COUNTRIES NECESSARY TO DISTINGUISH DATA FOR THE OSPAR REGION	
SPAIN	Atlantic coast activities only (note separation of Mediterranean data).
FRANCE	Atlantic and Channel coast activities only (note separation of Mediterranean data)
GERMANY	North Sea activities only (exclude Baltic)
SWEDEN	Delineate activities in the Baltic area (Kattegat) which fall within the boundaries of the OSPAR
DENMARK	Delineate activities in the Baltic area (Kattegat) which fall within the boundaries of the OSPAR

Table 3 summarizes information on spatial extent of areas licensed for extraction where available, for ICES WGEXT member countries. Although the data are incomplete at this time, it is important to note that the areas in which extraction occurred were much smaller than the areas licensed and the actual spatial footprint should be used to assess impacts.

Table 3a. Spatial extent of areas licensed for extraction.

Country	2006	2007/08	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Licensed Area Km²											
Belgium	273	273	273	273	319	319	319	203.2	203.20	203.20	203.2	203.2
Denmark	N/d	429	430	789	650	700	N/d	N/d	N/d	686		
Estonia	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	51.02[8]		
Finland	6	10/10	10	10	10	10	12	12	12.1	12.1	10.1	10.1
France[1]	73.08	72.97/74.97	74.87	67.87	67.87	135.34	168.54	165.4	169.4	170.17	171.54	190.74
Iceland	N/d	N/d	20.55	20.50	20.57	20.57	20.55	20.57	20.62	20.58		
Netherlands[2]	453	456/585	564	490	456	439	462	470	480	524	524	548
Poland	51.10	51.10	51.10	51.10	25.66	25.66	25.66	25.66	25.33	25.33	44.54	44.54
Portugal	N/d This is not controlled in Portugal.											
Sweden	0	0	0	0	9.70	0	0	9.70	9.70	9.70		9
UK[3]	1316	1278	1286	1291	1274	711	739	726	912	930.2	1057	1102
USA[4]											2.3	179

Table 3b. Actual areas over which extraction occurs.

Country	2006	2007/08	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Area in which extraction activities occur km²											
Belgium	N/d	N/d	N/d	N/d	105.7	106.2	113.7	61.5	61.5	24	67	
Denmark	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d		
Estonia	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	0	0	0
Finland	N/d	0	0	0	0	0	0	0	0	0	0	0
France[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iceland	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d
Netherlands	47	383/ 35.3	86	86	71	64	86[3]	90	88	90		95
Poland	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d	N/d
Portugal	N/d This is not controlled in Portugal.											
Sweden	0	0	0	0	9.70	0	0	9.70	0	0		3
UK	141	138	124	105	114	97	99	86		87.5	90.94	96
USA[4]											0	N/d

Notes to Tables 3a. and 3b:

[1] 38.18 sand and gravel extraction area and 2.48 non aggregate area in 2014; 162.96 sand and gravel extraction area and 6.48 non aggregate area in 2015; 162.96 sand and gravel extraction area and 7,209 non aggregate area in 2016; 162.96 sand and gravel extraction area and 2.48 non aggregate area in 2014; 162.96 sand and gravel extraction area and 7.209 non aggregate area in 2016, 163.96 sand and gravel extraction area and 7.58 non aggregate area in 2017, and 183.16 sand and gravel extraction area and 7.58 non aggregate extraction area in 2018

[2] 90 of material extracted in the Netherlands is taken from 7.5 km2 (2006) and 9.2 km2 (2007) and 8.3km2 (2008), and 23 km2 (2009), 38 km2 (2010), 23 km² (2011) and 45 km² (2013).

[3] 90% of material extracted in UK is taken from 46 km2 (2003) and 43 km2 (2004), 49.2 km2 (2006) 49.95 km2 (2007), and 39.2 km2 (2013).

[4] leases north on latitude 36.55 and in Federal waters only (beyond three n.miles from shore)

[5] French dredging vessels are fitted with EMS but the information is not treated to make area in which extraction activity occur available.

WGEXT again noted that this type of information has to be taken from an analysis of electronic monitoring data and this is not a straightforward task to achieve and therefore not possible for all WGEXT members to provide.

The last part of the ToR A1 concerns the collection of geospatial data on licensed and extraction locations in the form of shape files. WGEXT requests that shapefiles be provided on the WGEXT SharePoint site annually, even if values have not changed, from all ICES countries including those which are not in OSPAR, and reported to both < Johan.nyberg@sgu.se >. In addition, OSPAR countries are asked to provide available shapefiles for 2018 to OSPAR at < Chris.moulton@ospar.org > or <Lucy. ritchie@ospar.org >. Spatial data files (e.g. shapefiles) would be required for the pressure index analysis. Countries that have shapefiles are listed in Table 4.

Table 4. Geospatial Shapefile information

COUNTRY	Shape-files li-censed	Shape-files ex-tracted	Deliv-ered to ICES	Deliv-ered to OSPAR
Belgium	Yes	Yes	Yes	Yes
Canada	No	No	No	No
Denmark	Yes	No	Yes	Yes
Estonia	N/d	N/d	No	No
Finland	Yes	No	Yes	No
France	Yes	No	Yes	Yes
Germany	Yes	Yes	No	No
Greenland and Fa-roes	No	No	No	No
Iceland	Yes	No	Yes	Yes
Ireland	N/d	N/d	No	No
Latvia	N/d	N/d	No	No
Lithuania	N/d	N/d	No	No
Netherlands	Yes	Yes	Yes	Yes
Norway	No	No	No	No
Poland	Yes	No	Yes	No
Portugal	N/d	N/d	No	No
Spain	N/d	N/d	No	No
Sweden	Yes	Yes	Yes	Yes
United Kingdom	Yes	Yes	Yes	Yes

More national details on Term of Reference A1 are given in Annex 4.

Data on marine sediment extraction for 2016 and 2017 can be found in WGEXT report 2017 and 2018 (available in the ICES on-line library).

3 ToR A2: Review of development in marine resource mapping, legal regime and policy, environmental impact assessment, research and monitoring and the use of the ICES Guidelines on Marine Aggregate Extraction

A new table was developed (Annex 5) that is intended to provide a basis for further examination of the procedures involved in each country for managing the extraction of marine sand and gravel. Of course, procedures are different in each country and our purpose is not to suggest that they be harmonized, they are different for a reason, but rather to help each country search for solutions to their problems, perhaps, based on what works in other countries. Members are also encouraged to submit the form that Alexander Robert sent out earlier; he needs the results for an article in preparation (see ToR D6). Many of the relevant topics had been covered in previous WGEXT reports, like when EMS's are required or the use of black-boxes, but the information can be difficult to find. The intention of the form is to compile an overview. We will consider preparing a peer-reviewed publication (ToR D) to make the aggregate of this information more accessible.

4 ToR B: Create an ICES aggregate database comprising all aggregate related data, including scientific research and EIA licensing and monitoring data

Carlos Pinto and Signe Bagger from ICES Data Centre participated in the 2018 meeting during the Monday afternoon and informed the group of the progress with the database. They had had been able to start on the WGEXT database in 2018 with the help of Johan Nyberg and Laure Simplet. They presented the reporting format and revisions were suggested. A template and an associated guidance document were discussed. This had been developed and sent out to the members of the working group before the meeting, to be used by WGEXT members to provide data annually to the database. The template is based on the proposals from the group produced during earlier meetings and can be found at http://magg.ices.dk. The template, an Excel spreadsheet template, has three primary worksheet tabs (Header, Total Licensed Area and Licensed Area Level). Some entries, like "Reporting Organization" is entered as a numeric code; the reference codes are tabulated in the "Vocabulary". If the organization is not on the list, a code will have to be requested. The worksheets contain both mandatory data elements, indicated by red columns, and non-mandatory data (green columns). Some members had filled in the template and uploaded the resulting xml-document to the database.

In discussion, it was recommended that the number of cells be reduced. We deleted the "Legislative Authority", whether the permitting authority or the supervisor, because we do not collect that data and the question make replies more complicated. Historical data or revisions to data already submitted can be made as long as the appropriate "Year" is entered. It was concluded that some information in the Licensed area level, that is the area from which aggregate was actually extracted, would be difficult, if not impossible, for some countries to provide. It was also suggested that information provided in the new form be linked to attribute tables in shapefiles. Cooperation with the ICES Data will continue.

5 ToR C: Incorporate the MSFD into WGEXT

"Pressure" is defined as "the mechanism through which an activity has an effect on any part of the ecosystem" and is determined by activity type, intensity and distribution (Robinson *et al.* 2008). Within the UK, methods have been developed to produce pressure maps of habitat structural changes removal of substratum) and/or disturbance of the substrate below the surface of the seabed. The published methods outline the data types available to map pressures caused by fishing as well as by aggregate extraction. Areas of two, high priority pressures occurring within UK waters are discriminated. They are being used within the OSPAR common indicator 'BH3 – Extent of Physical damage to predominant and special habitats' which aims to assess the current spatial extent and level of disturbance that pressures on the seafloor at the sub-regional scale. This will be used to inform the assessment of GES for Descriptor 6.

MSFD have been incorporated into the ongoing deliberations of WGEXT as embodied in our draft review article on Marine Aggregate Extraction and Marine Strategy Framework Directive: A review of existing research (Annex 6). In addition we note that HELCOM is preparing a report on MSFD as a holistic assessment of the ecosystem health of the Baltic Sea (HOLAS II).

ToR C is discontinued. The topic is included in the article being prepared in ToR D (Annex 6). It is also included in our discussion in 2019 with ICES Workshop on "Scoping of Physical Pressure Layers Causing Loss of Benthic Habitat".

Annex 6 contains an extensive paper on MSFD and marine sediment extraction by Michel Desprez.

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6 ToR D: Ensure outputs of the WGEXT are accessible by publishing as a group and creating a webpage on the ICES website

This ToR will continue with an updated wording: “Ensure outputs of the WGEXT are accessible by publishing as a group”.

The Final report for each 3-year period gives the results of that period. A new cooperative report will not be written.

“Marine Aggregate Extraction and Marine Strategy Framework Directive: A review of existing research” by Michel Desprez (ToR C, Annex 6). This paper will be finalized and then condensed for publication.

“Marine Aggregate Extraction and Marine Strategy Framework Directive: A review of existing research” by Jan van Dalfsen (ToR I, Annex 8). This paper will be finalized and then condensed for publication.

Annelies de Backer is preparing an article on definition and quantification of dredging intensity (ToR I).

Alexandre Robert is preparing a publication on “Environmental Impact assessment and environmental monitoring on marine aggregate extraction sites”. The co-authors are K. Cooper, A. De Backer, J. Hämäläinen, B. G. Róbertsdóttir, M. Russel, R. Quartau, N. Desroy, C. Vogel, and L. Simplet.

Ad Stolk, Keith Cooper, and Michel Desprez convened the WGEXT session entitled “Making marine sediment extraction sustainable by mitigation of related processes with potential negative impacts” at the ICES Annual Science Conference (Theme Session K) in Latvia in September 2016 (Annex 7).

WGEXT submitted a theme session proposal for the 2020 ICES Annual Science Conference: “Marine sediment extraction: footprint, sustainability and effects.” The theme session was approved and will take place in Copenhagen, Denmark, during 7–10 September 2020.

7 ToR E: Discuss the mitigation that takes place across ICES countries and where lessons can be learned or recommendations taken forward

A questionnaire on mitigation was prepared and distributed in 2014. Responses were provided by the Netherlands, France and the UK. Because of the low number of responses, questions on mitigation will be included in a new questionnaire being prepared for ToR A2. ToR E will be closed.

In the UK, mitigation is embedded in a document on good practice: "Good Practice Guidance: Extraction by dredging of marine aggregates from England's seabed". Marine Minerals Guidance 1 (MMG1) was published by the Office of the Deputy Prime Minister (subsequently replaced by the Department for Communities and Local Government) in July 2002. This, in turn, mirrored the guidelines produced by ICES WGEXT. The guidance provided '...a statement of the Government's policies on the extraction of marine sand and gravel and other minerals from the English seabed'. This included high level policy objectives around supporting the sustainable use of marine aggregate resources and the need for a long-term view to support this, balanced against the importance of ensuring that fisheries and the marine environment in general was not significantly harmed and other legitimate marine users were not unacceptably affected.

To deliver these outcomes, MMG1 formalized a number of best practice principles which remain valid today, including minimizing the area of seabed licensed/dredged, the careful location of new dredging areas, the scope of EIA studies, and the adoption of dredging practices that minimize the impacts of dredging. At the time of introduction, the British marine aggregate industry was regulated through a non-statutory Government View arrangement which mirrored the requirements of the EIA and Habitats Directives. An accompanying document (MMG2) provided procedural guidance on the Government View process.

MMG2 was superseded with new procedural guidance once the statutory Marine Mineral Regulations were introduced in 2006, but MMG1 remained the only statement of Government's policies on marine aggregate extraction until the publication of the UK Marine Policy Statement (MPS) in March 2011. While the MPS provides a high-level summary of the key policy expectations regarding various activities and uses that take place in the marine environment (including marine aggregates), it is understood that the MPS was never intended to replace the detailed content of existing policy guidance.

Rather, the MPS provides the framework for preparing statutory Marine Plans. Paragraph 1.1.3 of the MPS notes that 'The MPS does not provide specific guidance on every activity which will take place in, or otherwise affect, UK waters. The MPS provides a framework for development of Marine Plans to ensure necessary consistency in policy goals, principles and considerations that must be taken into account, including in decision making'.

English Government is embarking on a process of 'Better Regulation', a central component of which is a substantial reduction in centrally provided guidance. Consequently, there was no provision for MMG1 to be formally updated – indeed there was growing pressure for it to be removed entirely.

From a marine aggregate industry perspective, there was considerable concern that many of the principles and general guidance MMG1 contains are not replicated in any other policy or guidance documents. Therefore, if MMG1 was withdrawn without a suitable replacement, these guiding principles and the reasoning behind them would also potentially be lost. This potential loss has implications not only to the aggregates industry and a vast number of associated interests, but also to Government policy makers, planners, regulators, statutory advisors – particularly given the rate of personnel change and the challenges of retaining corporate memory.

Recent experience had shown that retaining a touch point for best practice principles associated with the management of marine aggregate extraction activities remains critically important. This ensures that the industry can be regulated and managed in a consistent and proportionate manner, which recognizes the considerable and significant developments that have taken place over the last decade. Maintaining clarity about these best practice principles continues to professionalize the sector and promote and maintain the quality of proposals put forward by industry in the development process.

Recognizing that there was still a need for a key reference document to help inform not only industry, but also policy makers, regulators and advisors, the marine aggregate industry (BMAPA) and the marine mineral owner (The Crown Estate) have produced a new Good Practice Guidance document that takes the original content of MMG1, but substantially updates it to reflect modern practice in English waters. This includes EIA, management, mitigation, monitoring and stakeholder liaison.

The process of doing this has involved extensive consultation with Defra, MMO, Natural England, JNCC and Historic England, and while it is not formally endorsed by these agencies their participation in its production has been acknowledged. This is crucial, as without buy-in from Government agencies the value of the new document would be substantially reduced.

The new Good Practice Guidance will be formally launched as a replacement for MMG1 and will be available at: http://www.bmapa.org/

8 ToR F: Study the implications of the growing interest in deep sea mining for the WGEXT (legislation/environmental/geological)

Given the significant time, effort and investment that has taken place over the last forty years to better understand the nature and significance of environmental impacts arising from marine sand and gravel extraction and how these impacts can be assessed, mitigated, and monitored, principles associated with the management of marine sand and gravel extraction may equally apply to the emerging deep-sea mining activities.

The early stages of development appear to be taking place for various locations around the globe. For example, a Norwegian report on progress in deep sea mining can be found at:

http://www.miljodirektoratet.no/Documents/publikasjoner/M532/M532.pdf

However, there remains a considerable amount of uncertainty around the precise nature of the extraction activities that are being proposed in terms of their geographical setting and scale (particularly the wide variability in water depths that are being considered), the associated physical and environmental conditions that will be present, the potential pressures that may arise from the extraction operations that are being proposed and the potential sensitivity of the physical and biological receptors that may be exposed. Except for differences in water depth and in the stability and sensitivity of the environments, the general nature of the deep-sea mining operations being proposed are broadly comparable to those associated with marine sand and gravel extraction. Both activities involve the removal of seabed sediments resulting in physical disturbance to the environment. In turn, this can be expected to result in a combination of primary, direct or near-field, pressures arising from the removal of the seabed sediments themselves which will tend to be localized to the point of extraction, and secondary, indirect or far-field, pressures resulting from the suspension of seabed sediments into the water column, which can either be from the extraction process itself or from subsequent processing, and their subsequent settlement outside of the point of extraction.

The official term in ISA International Sea Bed Authority is "deep-sea mining", however ISA's jurisdiction is the high seas and not defined by depth. In addition, some deep-sea mining occurs in national waters, outside of ISA's jurisdiction, in the Azores, for example, close to a marine protected area, and in Iceland and other places mining for metals (rare earth elements) and industrial minerals as well as for aggregates occurs in shallow coastal waters. Any commercial industry applying for a license from ISA must be sponsored by an ISA member country (Annex 7). Because the US is the only ICES country not a member of ISA, a US company is being sponsored by the UK. A legal foundation must be established in each country before they can sponsor an industry.

Exploration of Ilmenite sands for recovery of titanium has been done by Blue Jay Mining in Dundas, Greenland and reported at the 11th Fennoscandia Exploration and Mining meeting in 2017. It is estimated that the total resource amounts to 7.9 million tonnes with 350 000 tonnes. Recovery is intended to begin in 2019.

Deep-sea mining was discussed on the OSPAR EIHA Meeting in April 2018. Documents on deep-sea mining were provided by the UK ('Draft OSPAR background document on the management of deep seabed mining') and by Central Dredging Association-CEDA ('CEDA deep-sea mining information portal'). This portal can be found on the CEDA website. There are still open questions concerning how monitoring should occur and how operations should be regulated.

It was noted that The UK is preparing a draft scoping document for regulation of potential activity in the northeast Atlantic. A Belgium company has a license to conduct test of a 20-m long robotic device to collect Mn nodules in 4000m of water in the Clarion-Clipperton Fracture Zone in May 2019. The test will be monitored by an international team of scientists. A Dutch company is expected to get an exploitation license next year. One company considered deep-sea mining on the MidAtlantic ridge near the Azores, but that had been discontinued. Investigations are underway in Iceland for geothermal heating on the shallow part of the ridge.

ToR F will be discontinued. The topic is being addressed in more detail in other groups. However, it can be reopened when (deep)sea mineral extraction is executed in the ICES area.

9 ToR I: Cumulative assessment guidance and framework for assessment should be developed.

ToR I comprises two items. An overview of cumulative effects related to marine sediment extraction and a study to define and quantify dredging intensity.

An overview has been prepared by Jan van Dalfsen (Annex 8). A journal article is planned to be written on this subject.

The study on dredging intensity is summarized below. Annelies de Backer is preparing a journal article on this subject.

Following the 2018 request to provide shapefiles on licensed dredging areas and Automatic Identification System (AIS)/Electronic Monitoring System (EMS) data of actual dredging for the year 2017, 9 countries replied. France and Portugal (only dredging on the islands Madeira and Azores, not on the mainland) provided shapefiles from the licensed areas, but were not able to provide detailed AIS/EMS information. In Finland, no dredging took place in 2017, but information on the permitted areas was provided. US could not provide any data.

Sweden (data from 2014), the Netherlands, UK, Denmark and Belgium provided both shapefiles of licensed areas and shapefiles with AIS or EMS data.

The data came in different formats and differed in processing steps. Some data was already quality checked and contained only dredged points (UK, Belgium and Sweden), while Dutch EMS data still needed some quality checks and processing, and Danish AIS data contained all tracks (polylines) from dredging vessels (both when dredging and non-dredging). All data was processed to present a standardized map showing dredging footprint as total time dredged (in classes of <5min, 5–15min, 15–30min, 30–60min, 60–120min and >120min) at a resolution of 50 x 50 m grid cells over the course of the year 2017.

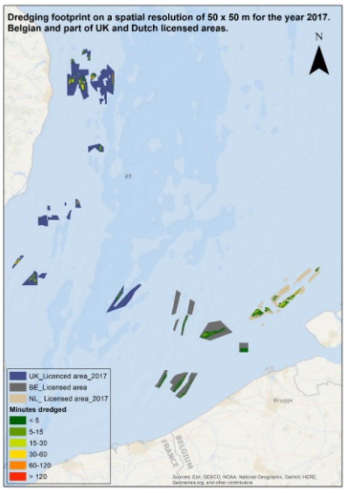
Data processing done in order to be able to harmonize and standardize.

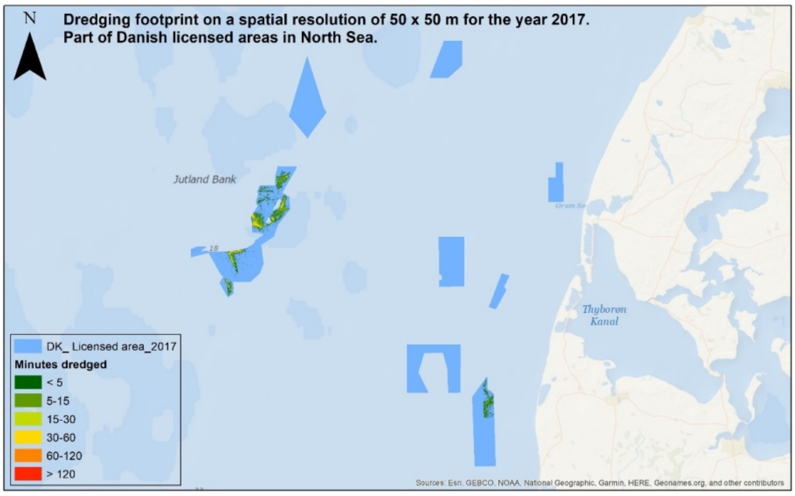
UK EMS data was provided by Kevin O'Shea (Royal Haskoning DHV, Managing Agents for The Crown Estate) and was already quality checked and processed on a grid of 50 x 50 m cell size with total time dredged (in minutes) in 2017 for each 50 x 50m grid cell.

Belgian EMS data was processed and quality checked by OD Nature and FPS Economy, and provided as XY data with extracted volume (m^3), date and time per XY coordinate. In order to harmonize with the other countries, time between XY locations for each trip was calculated and data was further processed to present total time dredged (in minutes) in 2017 at a resolution of 50 x 50 m. Dutch data came as two datasets one with EMS data of commercial dredging and one with EMS data of dredging for beach replenishment. Both datasets, although filtered for status 'dredging', still contained non-dredging records and records outside Dutch waters, so both datasets were clipped on Dutch licensed area. Furthermore, standard EMS time interval for commercial dredging is 60 secs and for beach replenishment 5 sec, but deviations are possible. However, time intervals longer than 5 mins, were excluded from the datasets since these are most likely anomalies. After quality control, both datasets were merged and further processed to present total time dredged (in minutes) in 2017 at a resolution of 50 x 50 m.

Denmark is the only one using AIS to monitor and control dredging. So, Danish data were derived from AIS and have a totally different format. The dataset contained all sailing tracks from all dredging vessels for 2017, so both dredging and non-dredging activity was combined. Tracks consisted of several separate polylines, including start/stop date and time and sailing speed. The dataset was first filtered on sailing speed to make the distinction between dredging (< 3 knots) and non-dredging (> 3 knots) polylines. Polylines with 0 knot speeds were also excluded unless within a licensed area, since static dredging is allowed in Denmark. Secondly, polylines were filtered on licensed areas to exclude the abnormalities. Afterwards based on start and stop times, minutes dredged per polyline was calculated. In order to be able to standardise dredging footprint on a 50 x 50m area, lines were split into start, mid and end XY coordinates and each point was assigned a time value equal to the dredged time of the polyline divided by 3 making it possible to process the AIS data as total time dredged (in minutes) in 2017 at a resolution of 50 x 50 m.

Output maps showing examples of the standardized dredging footprint generated from national dredge monitoring data.





Results

Table 5. Overview for the year 2017 of total volume extracted (based on WGEXT report 2018), total dredging time and average dredging time in a 50 x 50 m grid cell per country.

Country	Total volume extracted (m³)	Total time dredged (h)	Avg time dredged (min) in a 50 x 50 m grid cell
UK	11 448 528	15 400	25.4
Belgium	4 196 860	2 128	3
Netherlands	19 707 522	8 255	7.5
Denmark	8 676 254	21 631	21
Sweden	80 304	72	1.8

Table 6. Number of grid cells dredged for each country in 2017 and relative occurrence of the different time classes over the dredged grid cells.

	UK	BE	NL	DK	SE
# Dredged grid cells (50x50m)	36373	43757	66176	63892	2309
< 5 min (% grid cells)	39	84	64	46	96
5 - 15 min (% grid cells)	22	16	22	31	4
15 - 30 min (% grid cells)	14	1	9	12	0
30 - 60 min (% grid cells)	13	0	3	6	0
60 – 120 min (% grid cells)	8	0	1	3	0
>120 min (% grid cells)	4	0	0	3	0

This analysis revealed different 'dredging time prints' for different countries in 2017. The UK has the highest average dredging time of 25.4 minutes at grid cell level, closely followed by Denmark with an average dredging time of 21 minutes (Table 5). For both UK and Denmark, also higher percentages of over 30 minutes of dredging in 2017 at grid cell level was observed (Table 6 and more yellow, orange and red colours on the maps), and also total dredging time is highest for UK and Denmark (Table 5). However, the Netherlands had the highest extracted volume of 19.7 million m³, while average dredging time per grid cell was 7.5 minutes (Table 5), and much higher percentages of the smaller time classes occur (Table 6 and mainly greener colours on the map), but also highest number of dredged grid cells and highest dredged footprint of 165 km². Whilst UK has the lowest number of dredged grid cells and thus the lowest dredged footprint of 91 km² (except for Sweden where extraction is minimal); (Table 6). Belgium with an extracted volume of 4.2 million m³ in 2017 (lower than UK), has a higher dredged footprint of 109 km² and thus a higher number of dredged grid cells, and a very high percentage of these (84%) is dredged for less than 5 minutes in 2017, and none are dredged for over 30 minutes in 2017 (Table 6).

The monitoring data helps to illustrate the differences that exist between the dredging operations that are taking place in the different national waters. The differences that are observed are considered to be the result of a combination of three very distinct variables.

i. National regulation/policy

In the UK, national policy requires operators to minimize the area of seabed dredged. This is to limit the impacts on the environment, and also to reduce the potential for impacts on other marine users (principally fisheries), and is enforced through the licensing system that permits the removal of sand and gravel resources. There is also a policy requirement for operators to work zoned areas to economic exhaustion before moving on to a new part of the license, to allow the benthic recovery of previously worked areas to occur without further disturbance.

By contrast, in the Netherlands dredging activities are required to be undertaken over a wider spatial area to ensure changes in seabed depths are minimized. This results in a larger dredge footprint. As both these examples demonstrate, national policy and regulatory requirements can actively influence the footprint of operations.

ii. Nature of the geological resources that are being dredged
Some dredging operations will extract relict (fossil) sand and gravel resources. Such geological deposits are typically more spatially constrained, being associated with paleo-channel systems or similar. This requires dredging activities to be directed more carefully to obtain the resources required – occasionally requiring static dredging (rather than trailing). As a consequence, the overall dredging footprint will be more limited, such is the case in the UK and Denmark.

Sand resources, such as those extracted on the Belgian and Netherlands continental shelves, are generally more widely distributed on the seabed. As a consequence, dredging operations are able to occur over a larger area.

iii. Dredging practices employed
The capacity and production rate of dredging vessels can be expected to have an influence on the intensity of dredging operations that are observed. However, dredging intensity may also be influenced by the dredging practices that are employed. For example, many of the dredging operations in the UK will use on-board screening to modify the ratio of sand to gravel that is retained in the vessels cargo hopper compared to what may be present naturally on the seabed. This is required to obtain a commercially viable cargo, with the right balance of coarse and fine material for the required end-use, often concrete aggregate, which typically requires a 50:50 mix of sand to gravel but alternatively, vessels may be required to dredge sand cargoes from a sand and gravel deposit. Screening will affect the efficiency of the dredging process, so while it may take a vessel 2 hours to load a cargo 'all-in' with no screening, when screening is employed it can significantly increase the loading times and therefore the time recorded by monitoring systems on licensed areas. This will be reflected in a higher average time recorded in 50m x 50m grid cells.

Where the seabed resources are more homogenous, such as sand deposits, screening is unlikely to be necessary meaning that the loading times will be faster. This is likely to be reflected in lower average time recorded in 50m x 50m grid cells.

Conclusions

Different countries have different formats to control aggregate extraction. It is possible to process all these formats in order to come to a standardized output as is shown for aggregate extraction data of 2017 for UK, Belgium, the Netherlands, Denmark and Sweden. However, the different provided data formats make the data processing quite time consuming. In addition, computing time in ArcGIS is very demanding, since it is a huge amount of data for most countries.

A standardized delivery format in which countries provide quality checked and processed data on an agreed temporal and spatial scale would simplify the exercise, but this means that countries will have to do the processing themselves, and as said this takes time, and might not be feasible for some countries for different reasons e.g. budget, time constraints, skilled persons, confidentiality of the data.

In cooperation with WKBEDPRES, WGEXT will examine whether a data flow could be agreed upon in order to be able to deliver standardized reporting formats for shapefiles for countries able and willing to deliver AIS/EMS data. Furthermore, it might be easier and faster to work with the open source software program post-GIS (https://postgis.net/), but this option has to be explored by people with knowledge and expertise in working with this type of spatial databases.

Important limitations of the current dredging footprint maps

The dredging footprint data presented here as total time dredged over an area for a given time period is the best way to standardize and compare extraction intensity between countries (see earlier WGEXT report 2016). The information presented here represents the most accurate aggregate dredging footprint for a wider sea region. This information can be very valuable to the work on seafloor integrity for MSFD (e.g. ICES WKBEDPRES and WKBEDLOSS), potential effects of aggregate extraction, and potential cumulative effects. However, it is important to realize that the representation of dredging footprint as time dredged per area per time-period will be the consequence of other variables, such as the policy or regulatory regime that is in place, the geological nature of the resources that are being extracted or the dredging practices that are being employed. In order to fully assess the direct (primary) effects of aggregate extraction, it is important to take into account these other factors, as more intense activity (time wise) will not necessarily mean larger or more significant effects. For this reason, the dredging footprint map does not represent an effect footprint of the activity. Furthermore, dredging footprint only presents the direct footprint of the activity. It does not reflect the potential indirect (secondary) effects related to aggregate dredging such as increased turbidity, sediment plumes, and changes in currents and so on.

Whilst polygons provide a record of the area of seabed dredged in any one year, it is important to recognize that the spatial extent of these areas, in so far as they represent areas of 'impact', will likely shrink over time as a result of recovery and recolonization. Given the range of factors affecting recovery (e.g. nature of local environment, faunal assemblage type, intensity of dredging, proximity of ongoing operations), it would be very difficult to show this, but caution must be applied, particularly when merging annual dredging footprints to create a cumulative footprint. Equally, it should be recognized that areas of seabed falling outside an annual footprint may have been subject to dredging in the past and may therefore still be recovering. In other words, annual dredge footprints don't necessarily show the full extent of impacted seabed at any one time.

10 ToR K: Impacts of marine aggregate extraction on fish and fisheries

WGEXT members were asked to complete a survey providing information on:

- existence of monitoring data
- existence of monitoring guidelines
- type of funding (public/private)
- scale of monitoring)
- frequency of monitoring
- type of monitoring
- fishing activity (logbook data)
- impact on fish and fisheries
- bibliographic references

Eight countries responded to the survey (Annex 9). Information was gathered from Belgium, Denmark, Finland, France, the Netherlands, Portugal, Sweden and the UK. Monitoring is locally done in France, but done on a regional basis in the UK. Annual monitoring is done in UK and monitoring is seasonal in Belgium and France. In France and Belgium, the whole demersal community is monitored, with specific fish resources being targeted in the UK as well as in France. Temporal and spatial restrictions of dredging activity are employed in the UK and in France as mitigation to protect vulnerable species and habitats.

Three countries could not provide information consequently to an absence of extraction (Sweden) or of monitoring (Finland, Portugal). In Denmark, no data of monitoring are presently available, but EIA has to include an impact assessment of the extraction on important fish habitats, spawning and nursery areas.

11 ToR L: Implications of Marine Spatial Planning on marine sediment extraction

No progress had been made but this ToR will be carried over to the WGEXT resolution 2020–2022 with an updating wording “Exchange information on changes in national policy and the implications on marine sediment extraction”.

Annex 1: List of participants

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Annex 2: WGEXT Resolutions

The **Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem** (WGEXT), chaired by Ad Stolk, The Netherlands, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	24–27 April	London, UK	Interim report by 30 June	
Year 2018	16–19 April	Copenhagen, Denmark	Interim report by 1 June	
Year 2019	6–9 May	Lisbon, Portugal	Final report by 15 June to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
A1	Review data on marine extraction activities. Provide a summary of data on marine sediment extraction for the OSPAR region to OSPAR.	a) OSPAR Requirements b) Advisory Requirements c) Inform other countries to optimize their policy and management	2.1; 6.4	yearly	Annual extracted volumes and areas as a chapter in all Interim and Final Reports
A2	Review of development in marine resource mapping, legal regime and policy, environmental impact assessment, research and monitoring and the use of the ICES Guidelines on Marine Aggregate Extraction.	a) Advisory Requirements b) Inform other countries to optimize their policy and management	2.1; 6.4	Year 3	chapter in Final Report
B	Create an ICES aggregate database comprising all aggregate related data, including scientific research, EIA, licensing and monitoring data.	a) Advisory Requirements b) Inform other countries to optimize their policy and management c) Cooperation with other WG's d) Link to ICES database	2.1; 6.4	Year 1,2,3	Year 1: review and validation historical data Year 2: finalise template for approval ICES Data Centre Year 3: template to ICES countires

C	Incorporate MSFD into WGEXT	a) Advisory Requirements b) Inform other countries to optimize their policy and management c) Tuning WGEXT and ICES guidelines with EU guidelines	2.4; 6.4	Year 2 and 3	Year 2and 3: participation in ICES workshops on MSFD D6 Year 3: review of ICES Guidelines on Marine Aggregate Extraction
D	Ensure outputs of the WGEXT are accessible by publishing as a group and creating a webpage on the ICES website.	a) Inform other countries to optimize their policy and management b) Contribute to the visibility and impact of ICES	2.1	Years 2,3	Year 2: submitting review manuscript on MSFD to a peer-reviewed journal Year 3: submitting manuscript on intensity of extraction to a peer-reviewed journal
E	Discuss the mitigation that takes place across ICES countries and where lessons can be learned or recommendations taken forward	a) Advisory Requirements b) Inform other countries to optimize their policy and management	2.4; 2.7; 6.4	Year 2 and 3	Year 2: specific inventory on mitigation in ICES countries Year 3: evaluation and assessment of mitigation measures
F	Study the implications of the growing interest in deep sea mining for the WGEXT (legislation, environmental, geological)	a) Initiate the incorporation of this coming issue within ICES b) Inform other countries to optimize their policy and management	2.1; 6.4	Year 1,3	Year 1: inventory of marine mineral mining by ICES countries Year 1: poll to ICES countries concerning policy and legislation on dep sea mining Year 3: report on the assessment of outcome of inventories
I	Cumulative assessment guidance and framework for assessment should be developed.	Contribute and working together with possible other ICES and OSPAR WG's that are involved in this subject	2.2	Year 1,3	Year 1: contacting OSPAR and ICES working groups on the incorporation of marine sediment extraction in cumulative assessments Year 3: finalise the definition of

					quantification of dredging intensity Year 3: report on examples and a general methodology to incorporate marine sediment extraction in Cumulative Impact Assesments
K	Impacts of marine aggregate extraction on fish and fisheries	Contribute and working together with possible other ICES WG's that are involved in this subject	2.7	Year 2,3	Year 2: report on the inventory of policy of ICES countries Year 3: review of research
L	Implications of Marine Spatial Planning on marine sediment extraction	a) Advisory Requirements b) Inform other countries to optimize their policy and management	2.7; 6.4	Year 2,3,	Year 2: report on the inventory of ICES countries policy development Year 3: review report on the incorporation of marine sediment extraction in Marine Spatial Planning in ICES member countries

Summary of the Work Plan

Year 1	A1, B, F, I
Year 2	A1, B, C, D, E, K, L
Year 3	A1, A2, B, C, D, E,F, I, K, L

Supporting information

Priority	The current activities of WGEXT will lead ICES into issues related to the ecosystem effects of marine aggregate extraction. Aggregate extraction is increasing in some countries and rather stable in others. This activity is connected to several Descriptors in the EU MSFD. The Report of WGEXT and the Guidelines are used in the management of this activity in the member countries. Consequently, these activities are considered to have a high priority.
Resource requirements	Notice that the activities of WGEXT are focussed on the use of existing research programmes (e.g. EIA monitoring) and data on extraction and management. The additional resource required to undertake additional activities in the framework of this group is negligible
Participants	The Group is normally attended by some 12–20 members and guests.

Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	There is a potentially working relationship with all the groups of SCICOM. The coming years a cooperation with other WG's is planned on the subjects of cumulation of effects, create and use a database and the effects on fisheries. On deep sea mining there is cooperation with WGMS.
Linkages to other organizations	Data on marine extraction are delivered to OSPAR

Annex 3: Reporting format from 2020 onwards

ICES WGEXT

REPORTING FORMAT FOR AGGREGATE EXTRACTION

COUNTRY:

YEAR:

A. AMOUNTS (m³)

Type of activity	OSPAR area	HELCOM area	ICES area i.e. USA
Construction/industrial			
Beach replenishment			
Construction fill/land reclamation			
Non-aggregate (shells)			
TOTAL extracted			
Aggregates exported			

B. SHAPE FILES of licensed areas available?

YES ☐ **NO** ☐

If yes, send the shape files to the contacts mentioned below:

1. WGEXT contacts:
   - henry.bokuniewicz@stonybrook.edu
   - Johan.nyberg@sgu.se
2. OSPAR contacts:
   - Lucy.ritchie@ospar.org
   - Chris.moulton@ospar.org
   -

C. SHAPE FILES of extracted areas available?

YES ☐ **NO** ☐

If yes, send the shape files to the contacts mentioned below:

1. WGEXT contacts:
   - henry.bokuniewicz@stonybrook.edu
   - Johan.nyberg@sgu.se

2. OSPAR contacts:

- Lucy.ritchie@ospar.org
- Chris.moulton@ospar.org

D. Spatial extent of areas licensed for extraction (km²) e.g. total of all licensed areas is 10 km²

E. Actual areas over which extraction occurs (km²) e.g. actual extraction took place in only 7 km²; this is important information for the real footprint of the activity

F. Is an EIA (environmental impact report) required in your country?

1. Always
2. Never
3. Conditional (e.g. for extractions more than x million m³)? If yes: define the x

G. Is monitoring carried out in your country?

YES ☐ **NO** ☐

If yes, can you give some examples?

H. Are mitigation measures applied in your country?

YES ☐ **NO** ☐

If yes, can you give some examples.

Annex 4: ToR A1. Review of National Marine Aggregate Extraction Activities

A detailed breakdown of each country's sediment extraction dredging activities

4.1 Belgium.

Due to the change to the marine sand and gravel legislation by the entry into force of the marine spatial plan (12 June 2014), the maximum amount which can be extracted from zone 2 – which is laying in a habitat area - during 2018 is 1.595.000 m3. This amount decreases every year (from 2014 till 2019 by 1%, i.e. 17.000m³ per year). In zone 2 it is also prohibited to extract gravel.

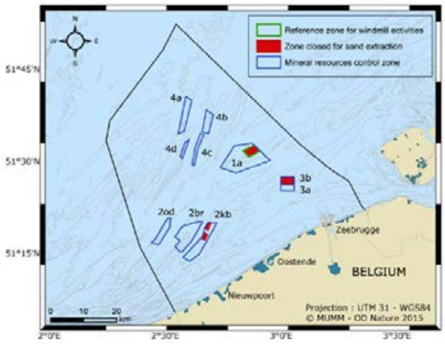


Figure 4.1.1: Extraction areas on the Belgian part of the North Sea, from 12th of June 2014 onwards.

In 2018, a total amount of 3.795.000 m³ sand and no gravel was extracted from the Belgian Continental Shelf both by the private sector and the Flemish Region, Coastal Division and Division Maritime Access.

The private sector extracted 2.807.000 m³ sand by 13 private license holders, which is mainly used for industrial purposes. Two licenses were also granted to the Flemish Region, Coastal Division and Division Maritime Access.

The licenses for the Flemish Region have the same conditions (reporting, black-boxes, etc.) as licenses for the private sector with the exception that they are exempted from the fee system. The Flemish Region-Coastal Division extracted 988 000 m³ sand, which was used solely for beach nourishment and originated from zones 1, 2 and 4. The decrease of the total amount extracted in 2018 compared to 2017 is mainly due to the decreased extraction by Flemish region for breach nourishment; there is only a small increase in the extraction total from industry (Table 1)

Table 4.1.1: Marine aggregate extraction figures for 2018 from FOD Economie, KMO, Middenstand en Energie. (Includes aggregate extraction for beach nourishment).

Dredging area	Amount (m³)
Thorntonbank (1a)	1,676,000
Gootebank (1b)	0,000

Kwintebank (2ab)	111,000
Buiten Ratel (2c)	145,000
Oostdyck (2c)	323,000
Sierra Ventana (3a)	457,000
Hinderbanken (4c)	1,083,000
TOTAL	**3,795,000**

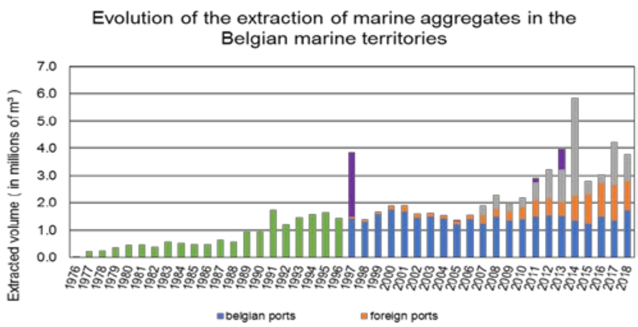
In 2018, 1,075,000 m³ of sand for industrial purposes was exported to our neighbouring countries France, UK and the Netherlands (Table 10.1.2). The other 1,248,000 m³ of industrial sand was landed in the Belgian coastal harbours.

Table 4.1.2: Export of marine aggregates in 2018 from FOD Economie, KMO, Middenstand en Energie.

Landing country	**Amount (m³)**
France	196,000
UK	205,000
Netherlands	674,000
TOTAL	**1,075,000**

It should be noted that the quantities exported to the Netherlands, are landed in Vlissingen, from which they turn back to Belgium.

Sand extraction on the Belgian Continental Shelf started in 1976 and data are available since then (Figure 4.1.2). From 2007 onwards the extra quantities extracted by the Flemish Region are included in the graph.



4.2 Canada. No report.

4.3 Denmark. No details.

4.4 Estonia. No details.

4.5 Finland.

There was no extraction in 2018.

Table 4.5.1. Historic pattern of marine aggregate extraction (m3).

YEAR	Amount
2003	0
2004	1,600,000
2005	2,388,000
2006	2,196,707
2007	0
2008	0
2009	0
2010	0
2011	0
2012	5,800
2013	0
2014	0
2015	0
2016	0
2017	0
2018	0
Total (2003-2018)	**6,190,507**

Sand and gravel was extracted from Finnish waters until the 1980's without systematic permitting procedures. Though, the amounts extracted before that are only speculative. It is known that extraction was taking place at least offshore the biggest coastal cities and the volumes reached at least millions of m^3's.

Extraction from Finnish coastal areas between 1995 and 2004 was negligible. The Port of Helsinki extracted 1.6 million m3 off Helsinki (Gulf of Finland) in 2004, 2.4 million m^3 in 2005 and 2.2 million m3 in 2006. Since then there has been only a small experimental dredging operation in 2010 and a 5 800 m^3 test extraction in 2012 in the Loviisa area, Eastern Gulf of Finland.

At the moment there are three valid permits issued by the Regional State Administrative Agencies (AVI).

1. Loviisa: A permission to extract 8 million m^3 of marine sand from the Loviisa-Pernaja area was accepted in April 2007 by the Environment Permit Authority to Morenia Ltd. Extraction has not yet started besides a small experimental dredging exercise in May 2010 and another feasibility test exercise of 5800 m^3 in 2012. The permit was renewed in June 2017 and is now valid until 30th of April 2027. The permit holder is currently MH-Kivi Ltd.

2. Soratonttu and Itä-Tonttu (Helsinki area): In 2010 The Regional State Administrative Agency of Southern Finland issued a permit to Morenia Ltd. for extracting 5 Mm^3 marine sand and gravel in the Itä-Tonttu and Soratonttu areas off the city of Helsinki. According to the permit, the extraction should start within 4 years of issuing the permit. The permit is valid until 31st of August 2020. In 2014 The Regional State Administrative Agency of

Southern Finland gave a new decision, extending the starting time for extraction until 20th of June 2020. The permit holder is currently MH-Kivi Ltd.

3. Iijoki river mouth: Southern Ii partition unit sent an application in October 2015 to extract 240 000 m^3 of sand within next 12 years in Iijoki river mouth, Bay of Bothnia. The Regional State Administrative Agency of Northern Finland issued the permit in March 2016 to extract the applied amount of material within an area of 10 hectares. The permit is valid until 31st December 2027.

The permit of Yppäri area expired in 2017 as the extraction activities did not start within three years of issuing the permit.

There are plans for several large building projects, especially in the Gulf of Finland, which may require substantial amounts of building material in future. For example harbor enlargements, housing areas in coastal zone and artificial islands are planned to be build.

4.6 France.

Construction industrial aggregate (sand and gravel) extraction figures for 2018.

DREDGING AREA	AMOUNT *
Channel	1 141 697 m^3
Atlantic	2 334 606 m^3
Brittany	0 m^3

Non-aggregate (e.g. shell, maerl, boulders, etc.) extraction figures for 2018.

DREDGING AREA	MATERIAL	AMOUNT *
Brittany	Shelly sand	200 400 m^3 (1)

[1] Licensed data (maximum permitted) because extracted data is subject to statistical confidentiality.

No data available for construction fill or land reclamation in France. No extraction of maerl took place in 2018. Maerl extraction was prohibited by the end of 2013.

France does extract sand for beach replenishment but data is not available because these extractions are in the jurisdiction of the local/regional authorities. An environmental assessment has to be done but mining license is not required.

Historic patterns of marine aggregate extraction 2010-2018.

Year	Quantities extracted (m^3)			Total extracted (m^3)	Maximum quantities permitted by Authorities (m^3)
	Channel	*Brittany*	*Atlantic*		
2010	545 881	225 400	2 598 423	3 369 704	6 448 662
2011	592 539	196 393	2 688 844	3 477 776	6 550 746
2012	406 594	175 264	2 750 178	3 332 036	11 320 746

2013	768 999	230 068	2 557 782	3 556 849	10 597 877
2014	358 686	200 800 [1]	2 157 738	2 700 629 [2]	12 431 000
2015	689 367	250 800 [1]	2 003 261	2 943 428 [2]	13 184 800
2016	711 842	265 400 [1]	2 028 974	3 006 216 [2]	13 184 800
2017	1 037453	563 800 [1]	1 731 205	3 332 458 [2]	15 250 400
2018	1 141 697	200 800 [1]	2 334 606	3 677 103[2]	16 634 400

[1] Licensed data (maximum permitted) because extracted data is subject to statistical confidentiality.

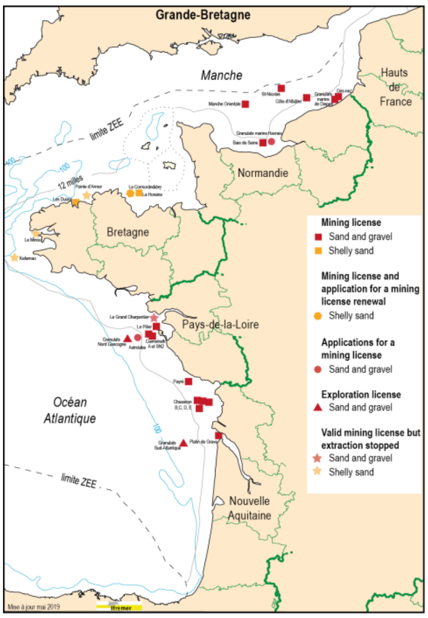
[2] Included licensed data (maximum permitted) for non-aggregate (Brittany) because extracted data is subject to statistical confidentiality.

Twenty-two mining licences (covering 190.74 km²) and two exploration licenses (covering 863.83 km²) have been granted by authorities but extraction works can take place only on 18 licensed areas. Three applications for aggregate extraction (one on actual extraction area for a renewal of license and two on new extraction area) are being considered by Ministry in charge of Economy. These applications represent 24.16 km².

Country	Exploration and exploitation Licensed Area (km²)				Area in which extraction activities occur (km²)			
	2015	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**
FRANCE	264.71[1]	643.6[1]	1035.37[1]	1054.57 [1]	N/A [2]	N/A [2]	N/A [2]	N/A [2]

[1] Includes 95.27 research licenses and 165.44 extraction licenses in 2014; 95.27 research licenses and 169.44 extraction licenses in 2015; 473.43 research licenses and 170.169 extraction licenses in 2016; 863.83 research licenses and 171.54 extraction licenses in 2017 and 863.83 research licenses and 190.74 extraction licenses in 2018.

[2] French dredging vessels are fitted with EMS but the information is not treated to make area in which extraction activity occur available.



4.7 Germany. No details.

4.8 Greenland and the Faeroes. See Table 4.1. It is reported that 20 000 to 25 000 m^3 has been extracted annually from the Faroe Islands.

4.9 Iceland.

2007	1.145.390	158.300	21.666	1.325.356
2008	921.000	134.680	50.445	1.106.125
2009	374.885	69.360	25.435	469.680
2010	125.800	39.760	54.450	220.010
2011	138.700	40.740	46.415	225.855
2012	145.070	12.780	58.800	216.650
2013	182.115	7.100	64.230	253.445
2014	179.440	11.140	77.605	268.185
2015	174.750	5.680	69.036	249.466
2016	215.537	8.520	69.250	293.307
2017	268.099	9.670	87.903	365.672
2018	316.777	7.100	97.943	421.820

4.10 Ireland. No details.

4.11 Latvia. No report.

4.12 Lithuania. No details.

4.13 The Netherlands.

Table 4.13.1 Marine aggregate (sand) extraction figures for 2018.

DREDGING AREA	AMOUNT (m^3)
Euro-/Maas access-channel to Rotterdam	0*
IJ-access-channel to Amsterdam	0*
Dutch Continental Shelf	8,947,131
TOTAL	**8,947,131**

* Sand extraction for commercial use was none, therefore maintenance dredging was done.

Table 4.13.2 Non-aggregate (shell) extraction figures for 2018.

DREDGING AREA	MATERIAL	AMOUNT (m^3)
Wadden Sea	Shells	29,631
Western Scheldt	Shells	0
Voordelta of the North Sea	Shells	15,260

North Sea	Shells	90,420
TOTAL	**Shells**	**135,311**

Based on National Policy for shell extraction there are maximum permissible amounts defined.

These permissible amounts of shells to be extracted yearly from:

- the Wadden Sea max. 85,000 m^3 (but no more than 50% of the total quantity (The Wadden Sea and Sea Inlets))
- the Voordelta (North Sea) 40,000 m^3
- the Western Scheldt 40,000 m^3
- the rest of the North Sea outside -5 m waterdepth until a distance of 50 km offshore is unlimited.

Table 4.13.3 Exports of marine aggregate in 2018.

DESTINATION (landing)	AMOUNT (m^3)
Belgium	3.212.447
France	44.210
United Kingdom	5.732
TOTAL	**3.262.389**

Table 4.13.4 Amount of material extracted for beach replenishment projects in 2018:

DREDGING AREA	MATERIAL	AMOUNT (m^3)
Netherlands coast (general)	sand	12,374,401
TOTAL	**sand**	**12,374,401**

Figure 4.13.1 Licensed sand extraction areas 2018.

Table 4.13.5a Historic patterns of marine aggregate extraction in Mm³.

Extraction Area	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Euro-/Maas channel	1,94	1,22	0,06	0,32	0	0,8	1,8	0	0	0	0
IJ-channel	0	0	0	0,75	0,83	1,5	1,2	0	0	0	0
Channel Voordelta	-	-	-	-	0,05	-	0,03	0	0	0	0
Dutch Continental Shelf	24,53	119,59	122,47	68,88	66,89	10,63	8,9	8,1	6,7	8,3	8,9
Total extracted	**26,47**	**120,81**	**122,53**	**69,95**	**67,87**	**12,96**	**12,1**	**8,1**	**6,7**	**8,3**	**8,9**

Table 4.13.5b Dutch sand extraction (Commercial and beach replenishment) 1975 - 2018

YEAR	TOTAL EXTRACTED m³	YEAR	TOTAL EXTRACTED m³
1975	2,230,889	1997	22,751,152
1976	1,902,409	1998	22,506,588
1977	757,130	1999	22,396,786
1978	3,353,468	2000	25,419,842
1979	2,709,703	2001	36,445,624
1980	2,864,907	2002	33,834,478
1981	2,372,337	2003	23,887,937
1982	1,456,748	2004	23,589,846
1983	2,252,118	2005	28,757,673

1984	2,666,949	2006	23,366,410
1985	2,724,057	2007	28,790,954
1986	1,955,491	2008	26,360,374
1987	4,346,131	2009	120,700,339
1988	6,954,216	2010	122,532,435
1989	8,426,896	2011	62,948,704
1990	13,356,764	2012	41,899,276
1991	12,769,685	2013	23,167,720
1992	14,795,025	2014	51,271,582
1993	13,019,441	2015	25,895,775
1994	13,554,273	2016	15,693,294
1995	16,832,471	2017	19,707,522
1996	23,149,633	2018	24,583,921

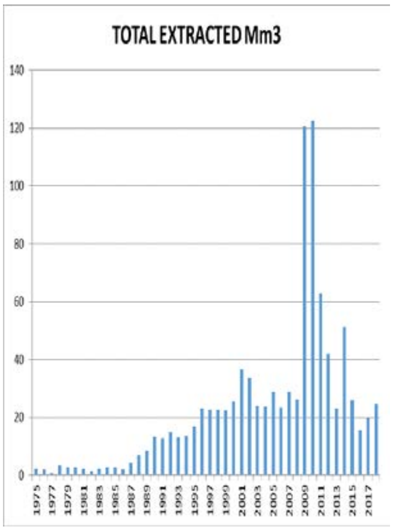


Figure 4.13.2 Dutch sand extraction (Commercial and beach replenishment) 1975–2018.

Table 4.13.6 Licences considered and issued licences Rijkswaterstaat North Sea

In the year:	Amount	In the year:	Amount
1998	35	2009	23
1999	30	2010	15
2000	25	2011	26

2001	25	2012	10
2002	42	2013	19*
2003	26	2014	20*
2004	20	2015	15*
2005	33	2016	12*
2006	33	2017	17*
2007	24	2018	5*
2008	38		

* one of the issued licenses is a general permit for beach nourishments/replenishments in which several extraction areas for the next 5 years are covered in one single permit.

4.14 Norway. No report.

4.15 Poland.

Year	Beach nourishment/replenishment (m^3)	Construction/ industrial aggregates (m^3)	Total Extracted (m^3)
1990	1,046,358	0	1,046,358
1991	766,450	0	766,450
1992	817,056	17,270	834,326
1993	974798	0	974,798
1994	251,410	2,222	253,632
1995	280,720	0	280,720
1996	134,000	0	134,000
1997	247,310	1,112	248,422
1998	88,870	0	88,870
1999	375,860	70,000	445,860
2000	241,000	265,556	506,556
2001	100,253	85,000	185,253
2002	365,000	112,222	477,222
2003	438,414	0	438,414
2004	1,042,896	0	1,042,896
2005	1,043,925	0	1,043,925

2006	548,856	0	548,856
2007	977,358	0	977,358
2008	238,948	51,667	290,615
2009	702,590	0	702,590
2010	970,923	0	970,923
2011	531,218	316,111	847329
2012	396,086	155,000	551086
2013	232,695	161,111	393,806
2014	457,731	429,000	886,731
2015	355,500	269,167	624,667
2016	470,000	360,578	830,578
2017	568,321	343,607	911,928
2018	970,411	459,682	1,430,092

4.16 Portugal.

Volumes (m3)

Extraction Area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Azores archipelago		6083	145519	146791	115613	176285	197636	159968	181691	141991	144647	134021	124132	126381	69392	50729	45964	61266	59553	82573	42101
Madeira archipelago					562353	683521	910179	703620	478473	369008	345890	291290	276090	210720	114360	117980	115262	100935	88770	101630	95850
Administração da região hidrográfica do Norte (northern continental shelf)																					
Administração da região hidrográfica do Centro (central continental shelf)																					No information
Administração da região hidrográfica do Tejo (southern central continental shelf)										500000	1000000	1000000					1000000				No information
Administração da região hidrográfica do Alentejo (southwestern continental shelf)																			30856	28620	
Administração da região hidrográfica do Algarve (southern continental shelf)	1285000								370000				1250000	600000			340000	140000			

Beach nourishment (green)
civil construction (orange)

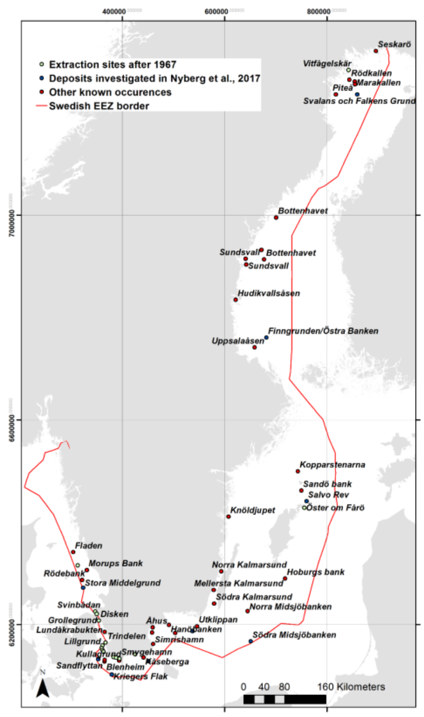
4.17 Spain. No details.

4.18 Sweden.

In 2018, there were two licensed extraction sites in Sweden, Sandhammar Bank for beach nourishment and Trelleborgs hamn, and one pending application according to the Swedish Continental Shelf Act, on extraction in Skälderviken, southern Sweden, for beach nourishment. These areas fall within the HELCOM area. The license on Sandhammar Bank is granted on the terms that extraction shall occur every third year from 2011 to 2020, which means that the next and last extraction will occur in 2020, see table. The Geological Survey of Sweden is the agency that handle and grants licences for extraction within public waters of the Swedish continental shelf and is also the agency that regulates and supervise the conditions for such licences. Monitoring is performed during the extraction on Sandhammar Bank and reveals that approximately 30 % of the licensed area on Sandhammar Bank is extracted and that the extraction intensity for Sweden from 2011 to 2018 is approximately 8 hours on one km² each year.

Historic extraction in Sweden in m³ per area and year from 1998 to 2019 and summed between 1967 and 1998. See figure for locations, Nyberg *et al.* 2017.

Area	1998	Total (1967-1998)	2011	2012	2014	2017
Lilla Middelgrund		785				
Stora Middelgrund		301 992				
Västra Haken, Öresund		466 751				
Bredgrund, Öresund		287				
Disken, Öresund		673 960				
Gislövs läge och Smygehamn		4				
Sandflyttan, Öresund		202 887				
Svinbådan och Grollegrund		6				
Flintrännan, Öresund	2 500 000	2 500 000				
Trelleborgs hamn		5		9 087		
Trindelen		4				
Ystads hamn		6				
Fårö		5 120				
Vitfågelskär, Luleå		8 873				
Sandhammar bank		0	96 502		80 220	80 304



References

Nyberg *et al.* 2017. Förutsättningar för utvinning av marin sand och grus i Sverige. SGU-report 2017:05.

4.19 United Kingdom.

4.20 United States.

There was no marine aggregate (sand and gravel) for construction extraction in 2018. The only active operating for the extraction of marine sand to be used for aggregate continues to be that done by a private company; Amboy Aggregates went out of business in 2014. However, a minimum of 16,928,253 m^3 were extracted for beach nourishment projects in the region (Table 12.20.1) This is a minimum volume because no reports were received from the New England District of the U.S. Army Corps of Engineers, covering the States of Connecticut, Massachusetts, New Hampshire and Maine or from the Baltimore District, covering the states of Maryland or from the Norfolk District covering the States of Virginia.

Table 4.20.1 Beach nourishment in 2018.

Location		Cubic meters
Manasquan Inlet to Barnegat Inlet,	NJ	7,280,321
Barnegat Inlet to Little Egg Inlet,	NJ	1,774,771
Fenwick Island,	DE	206,768
Bethany Beach - South Bethany,	DE	845,186
Absecon Island,	NJ	2,671,049
Brigantine Island,	NJ	576,543
Great Egg Harbor Inlet and Peck Beach,	NJ	976,166
Gilgo beach	NY	334,796
Smith Point County Park	NY	146,795
Long Beach	NY	2,115,859
Total		16,928,253

An additional 525,783 m^3 of sand and silt were dredged from navigation channels in and around New York Harbor; this dredged sediment (Table 10.20.2) was used as submarine capping material in the restoration of a former, offshore disposal site known as the Historic Area Remediation Site (HARS), approximately 22 km outside on New York Harbor., dredged sediment was also placed for disposal as covered at the HARS site

Table 4.20.2 dredged sediment placement at the Historic Area Remediation Site in 2018

Location		Cubic meters	Material
HARS	NY	525,783	Sand and silt

There were no exports of marine aggregate in 2018.

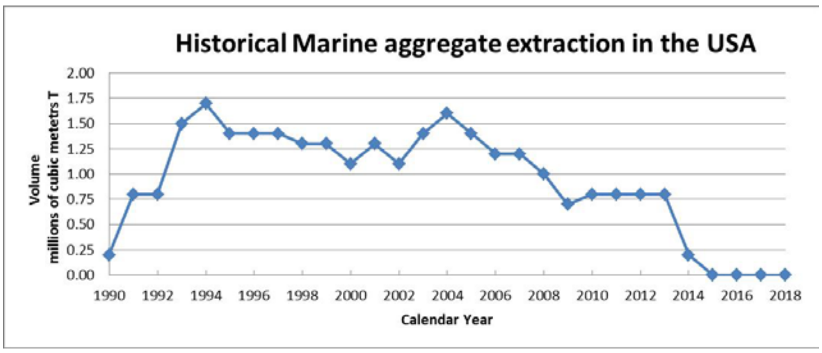


Figure 4.20.1 Historic patterns of marine aggregate extraction.

Annex 5: ToR A2. Review of development in marine resource mapping, legal regime and policy, environmental impact assessment, research and monitoring and the use of ICES Guidelines on marine aggregate extraction

In order to refocus this Tor for the coming year, two tables were developed to collect and compare information from member countries (Tables 5.1 and 5.2). WGEXT members are asked to provide input to this effort for the 2020 meeting.

Table 5.1. Jurisdictions in coastal waters.

	the right of ownership/jurisdiction of seabed areas			Institution which manage the areas for sea aggregates extraction		
	internal waters	territorial sea	EEZ	internal waters	territorial sea	EEZ
Belgium						
Canada						
Denmark						
Estonia						
The Faroes						
Finland						
France						
Germany						
Greenland						
Iceland						
Ireland						
Latvia						
Lithuania						
The Netherlands						
Norway						
Poland						
Portugal						
Spain						
Spain						

Sweden						
Sweden						
United Kingdom						
United States						

Table 5.2. Fee structure extraction activities.

	prospecting		obtaining a concession/license/permit		exploitation		nature/restoration protection fund		compliance monitoring		environmental effect monitoring	
	Occurs (Y/N)	Fee	Occurs (Y/N)	Fee	Occurs (Y/N)	Fee	Occurs (Y/N)	Fee	Occurs (Y/N)	Fee	Occurs (Y/N)	Fee
Belgium												
Canada												
Denmark												
Estonia												
The Faroes												
Finland												
France												
Germany												
Greenland												
Iceland												
Ireland												
Latvia												
Lithuania												
the Netherlands												
Norway												
Poland												
Portugal												
Spain												
Spain												
Sweden												
Sweden												

United Kingdom												
United States												

Country reports

5.1 Belgium.

In the framework of the Transnational and Integrated Long-term Marine Exploitation Strategies research project (TILES), a geological knowledge base is being built for the Belgian and southern Netherlands part of the North Sea. Partners in this effort include the Royal Belgian Institute of Natural Sciences, Ghent Universitu (Department of Geology and Department of Telecommunications and Information Processing), and TNO - Geological Survey of the Netherlands, with the active cooperation with FPS Economy, Continental Shelf Service.

Voxel models of the subsurface are used for predictions on sand and gravel quantities and qualities, to ensure long-term resource use. The voxels are filled with geological data from boreholes and seismic lines, but other information can be added also. The geology provides boundary conditions needed to run environmental impact models that calculate resource depletion and regeneration under various scenarios of aggregate extraction. Such analyses are important in monitoring progress towards good environmental status, as outlined in the Marine Strategy Framework Directive. By including uncertainty, data products can be generated with confidence limits, which is critical for assessing the significance of changes in the habitat or in any other resource-relevant parameter. All of the information is integrated into a cross-domain, multi-criteria decision support system optimised for user-friendliness and online visualisation. More information: http://odnature.naturalsciences.be/tiles

Reference

Van Lancker, V., Francken, F., Kint, L., Terseleer, N., Van den Eynde, D., De Mol, L., De Tré, G., De Mol, R., Missiaen, T., Chademenos, V., Bakker, M., Maljers, D., Stafleu, J. & van Heteren, S. (2017). Building a 4D Voxel-Based Decision Support System for a Sustainable Management of Marine Geological Resources. pp. 224-252. In: Diviacco, P., Leadbetter, A. & Glaves, H. (eds.). Oceanographic and Marine Cross-Domain Data Management for Sustainable Development. IGI Global.

5.2 Canada. No report.

5.3 Denmark. No report.

5.4 Estonia. No report.

5.5 Finland.

Organisation undertaking seabed mapping programme: Geological Survey of Finland (GTK)

Scope of seabed mapping programme: A study of marine geology by the Geological Survey of Finland (GTK) concerning late-Quaternary deposits on the seabed is being conducted using acoustic and seismic methods: echo sounders, single-channel seismic and side-scan sonar and multibeam sonar equipment. Investigations are supplemented with seabed sampling and visual observations. The basic scope of the study is to acquire data on the distribution and thickness of various types of sediments and information on stratigraphy, mineralogy and geochemistry of the deposits. New methods of sounding and sampling as well as data processing and analyses of samples are also developed and tested.

The aim of the study is also to increase knowledge of the physical properties and the geochemical variations in seabed sediments induced by both nature and human activity. Also the demand of various practical and scientific needs arising in a surrounding community should be met.

Future marine resource mapping objectives: The annual goal of seabed mapping is about 300 km². In following years main focus of mapping is in the Gulf of Bothnia and possibly in the Åland Islands, which are largerly unmapped. Mapping is usually concentrated in areas under utilization pressures and close to major construction sites.

Completed seabed resource maps in 2018: The marine geological mapping index is shown in Figure 13.5.1. The mapping information as well as a generalized seabed substrate map is also available using GTK's map service Hakku http://hakku.gtk.fi/fi/.

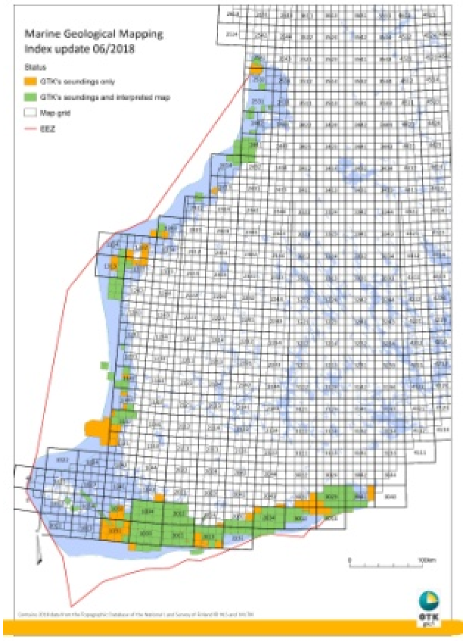


Figure 13.5.1. The Marine Geological Mapping Index.

5.6 France.

Three national organizations are responsible for seabed mapping. These are:

(1) the Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer), Z.I. Pointe du Diable, CS 10070, 29280 Plouzané, France. Contact: Laure Simplet; e-mail: laure.simplet@ifremer.fr.

(2) the Service Hydrographique et Océanographique de la Marine (SHOM), CS 92803-29 228 BREST Cedex 2, France. Contact: Thierry Garlan, email: thierry.garlan@shom.fr.

(3) the Bureau de Recherches Géologiques et Minières (BRGM), 3 avenue Claude Guillemin, BP 36009, 45060 Orléans Cedex 2, France. Contacts: Isabelle Thinon: tel: +33 2 38643345; e-mail: i.thinon@brgm.fr, and Fabien Paquet: e-mail: f.paquet@brgm.fr.

Ifremer is in charge of mapping offshore aggregates and publishing atlases of coastal areas dealing with seabed type, morpho-bathymetry, morpho-sedimentary, geology, sediment thickness, and bedrock morphology. Ifremer is also involved in mapping the continental shelf, slope, and abyssal plain.

The French Naval Hydrographic and Oceanographic Service (SHOM) is in charge of bathymetric surveys dedicated to marine safety. Their nautical charts and seabed sedimentological charts ("G" type maps) cover the area between 5 and 15 nautical miles from the coast at various scales (typically 1:50,000). These are compiled from existing data, for example, derived from tallow-lead samples that cover 95% of the continental shelf, grab samples, cores, sidescan sonar, multibeam bathymetry and reflectivity, and aerial photography, in collaboration with universities and national organisations.

The French Geological Survey, BRGM, is in charge of the offshore geological ("hard substrate geology") mapping of the continental shelf at scales of 1:50,000, 1:250,000, and 1:1,000,000. The geological mapping of the continental shelf continues through the RGF national programme (Référentiel Géologique de la France)

BRGM and Ifremer were involved in the second phase of the EMODNet Geology Project (2013-2016). Seafloor geology and seabed substrate have been mapped at scales of 1:1,000,000 and 1: 250,000, within the French EEZ for European seas. SHOM and Ifremer were involved in EMODNet Bathymetry lot. Ifremer also coordinated the Habitat mapping lot of EMODNet Project (2013-2016). Data can be downloaded from EMODnet website < http://www.emodnet.eu/ >. EMODNet has just begun its third phase of its two-year project.

Since 2014, eight seabed substrate and geomorphological maps have been issued. These are

(1) Ehrhold A. coord. (2015). Cartes sédimentologiques et morpho-bathymétriques de la baie de Morlaix et de sa région. *Éd. Quae*. 3 feuilles, échelle 1/30 000 et une clé USB.

(2) Gregoire Gwendoline, Ehrhold Axel, Le Roy Pascal, Jouet Gwenael, Garlan Thierry (2016). Modern morpho-sedimentological patterns in a tide-dominated estuary system: the Bay of Brest (west Brittany, France) . Journal Of Maps , 12(5), 1152-1159 . http://doi.org/10.1080/17445647.2016.1139514

(3) Cirac Pierre, Gillet Hervé, Mazières Alaïs, Simplet Laure (2016). Carte des formations superficielles du plateau aquitain (2016). EPOC-Université de Bordeaux. http://doi.org/10.12770/602a30c5-c338-4e75-a591-baccb8ba1f79

(4) Bourillet Jean-Francois, De Chambure Laurent, Menot Lenaick, Simplet Laure, Loubrieu Benoit (2016). Classification Géomorphologique de la pente continentale du Golfe de Gascogne (1/500,000). Ifremer - Géosciences Marines. http://doi.org/10.12770/d5da916a-163c-47b9-8a8e-73dcaeec7986

(5) Bourillet Jean-Francois, De Chambure Laurent, Menot Lenaick, Simplet Laure, Loubrieu Benoit (2016). Classification Géomorphologique de la pente continentale de la façade méditerranéenne (1/500 000). Ifremer - Géosciences Marines. http://doi.org/10.12770/7a96a6c4-fcbe-4969-b554-5a94fe49e8ee

(6) Simplet Laure, Gautier Emeric (2016). Carte des formations sédimentaires superficielles de l'anse de la Mondée (Biéroc la Mondrée, 2014). Ifremer. http://doi.org/10.12770/049fad57-7595-48c7-a4f0-d40bee1a5dc6

(7) Bourillet Jean-Francois, Simplet Laure, Sterckman Aurore, Moreau Julien, Veslin Mathieu, Biville Romain (2017). Formations superficielles du Plateau aquitain (2017) au 1/20,000 (projection de Mercator à N44°45'). Ifremer. http://doi.org/10.12770/2efa6d8b-7caf-444f-813a-c4178215b2ce

(8) Simplet Laure, Gautier Emeric, Salaun Jessica (2017). Carte des formations sédimentaires superficielles au large de la baie de Somme (2017). Ifremer. http://doi.org/10.12770/de87d248-d217-4b32-9ee3-fa40980cdaf0

Publications can be ordered from IFREMER: Editions QUAE < http://www.quae.com/fr/c75-atlas-cartes.html >, BRGM: Editions < http://www.brgm.fr/editions.jsp >, and SHOM: Editions < http://www.shom.fr/les-produits/produits-nautiques >. Further information is available online at http://sextant.ifremer.fr/fr/, http://sextant.ifremer.fr/fr/web/granulats-marins, http://infoterre.brgm.fr/viewer/MainTileForward.do, and http://data.shom.fr/ .

The French Mining code was created in 1956 (based on resumption of the law of 1810). Its recodification in 2011 resulted in the current order 2011-91. Its reformation is in progress to bring it into conformity with national environmental requirements. The proposal for an act to adapt Mining code to environmental rights includes the consideration of environmental challenges in the issuance of mining titles, the enhancement of information-sharing and conciliation procedure, the creation of a high council for mines and the definition of a national policy for resources and mining purpose. It was debated in a public meeting at National Assembly on January 24 and 25, 2017 and remains currently pending before the Senate.

More information can be found at https://www.senat.fr/dossier-legislatif/ppl16-337.html and http://www.assembleenationale.fr/14/dossiers/droit_environnement_adaptation_code_minier.asp .

The law 2016-1087 for biodiversity, nature and landscape restoration of August 8, 2016 introduced an article in the Mining code. This new article created a specific licensing fee for the exploitation of non-energy mineral resources, including marine aggregates, on the French continental shelf and EEZ seafloor. The licensing fee should be calculated on the basis of the advantages of any kind provided to the license-holder, the environmental impact of the activity, water depth and distance to the coastline of the licensed area, and the amount of expenditure incurred during the duration of exploration and extraction license. The license-fee could be increased for exploitation occurring in a marine protected area (as defined in article L. 334-1 of Environment code). It will be applied as of 2019 on the basis of quantities extracted in 2018 and will be returned to the French Agency for Biodiversity to help preservation, management and restoration of marine biodiversity.

More information can be found at:

https://www.legifrance.gouv.fr/eli/decret/2017/1/12/ECFL1630724D/jo/texte

https://www.legifrance.gouv.fr/affichCodeArticle.do;jsessionid=CEB2D33D4DF5C9076FC6A050D587028A.tpdila09v_3?idArticle=LEGIARTI000033028884&cidTexte=LEGITEXT000023501962&dateTexte=20170303

Ifremer completed a study, commissioned by French Environment Ministry, whose aim was to define and identify areas for sand and gravel extraction with minimal constraints for benthic fauna, fishing activity and fisheries resources. The results are available at : http://sextant.ifremer.fr/fr/web/granulats-marins

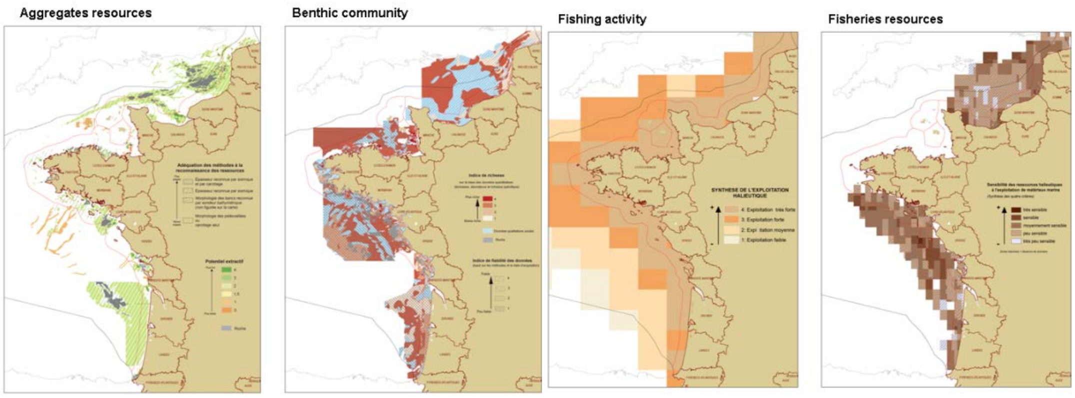


Figure 5.6.1 Synthesis maps for aggregates resources, benthic fauna, fishing activity and fisheries resources (Ifremer 2005-2012).

The ESPEXS (2007-2013) project, led by the Languedoc-Rousillon Regional authority with the collaboration of Ifremer and the University of Perpignan, published its final reports. This project aimed to complete knowledge on marine environment and to define environmental issues on two areas of potential sand extraction for beach replenishment identified in the European BEACHMED project. Reports can be downloaded at: http://littoral.languedocroussillon.fr/ES-PEXS-Phase-2.html

The SCOOTER (2012-2015) project studied the effect of marine aggregate extraction on water quality due to the remobilization of contaminants from sediments. The objectives of this project were (1) to bring information on the dynamics of contaminant remobilization within the dredging-induced turbid plume and on the fate of contaminant between the dissolved and particulate phase, and (2) to examine water quality evolution under natural and dredging conditions to identify any need for long-term monitoring in period covered by the mining license. Final report can be downloaded at: http://archimer.ifremer.fr/doc/00310/42078/41381.pdf

The IMPECAPE project (2016-2018), funded by the French Agency for Biodiversity, tackles to assess ecological impacts on benthic habitat due to physical disturbance including sediment extraction and scallop dredging. It aims to produce indicators for environmental status of coastal benthic habitat in relation with the Habitats and Marine strategy framework directives and to propose monitoring program:
http://www.sb-roscoff.fr/fr/observation/programmes/impecape
France does not incorporate ICES Guidelines in a formal way in its legal regime but takes into account all of them for its marine aggregate extraction management, such as requirements for an EIA before authorization, and monitoring prior to and during the period covered by the license and after the extraction takes place to examine restoration of the area.

Preliminary data from the monitoring of two extraction sites at Dieppe, 3 nm and 12 nm offshore, confirm previous observations on the impact of extensive dredging intensity. In an Eastern Channel here the dredging intensity was about one hour/hectare/year and Spring tidal currents were about one m/s, EUNIS habitats A5.142 and A5.444 showed a short-term recovery (one year for western stations), and no significant impact on species richness and abundance.

5.7 Germany. No report.

5.8 Greenland and the Faeroes. Greenland's Mineral Licence and Safety Authority receives co-ordinates for where extraction activity takes place. An EIA is never required but sensitive areas are monitored by taking samples every year and inspected when deemed necessary. Mitigation measures include the following:

1. The extraction activities shall only take place 500 meters from the estuary, where there are a rise of arctic char.

2. Extraction activities must respect a 1 km sailing zone for bird colony, which means that where there are bird colonies, no activity must take place during the summer period April to September.

3. A minimum distance of 50 meters must be kept to the coast.

5.9 Iceland. No report.

5.10 Ireland. No report.

5.11 Latvia No report.

5.12 Lithuania. No report.

5.13 The Netherlands.

In the framework of the research project TILES (Transnational and Integrated Long-term Marine Exploitation Strategies) a geological knowledge base is built for the Belgium and southern Netherlands part of the North Sea (Stolk, 2015). For details see the above section "A5.1 Belgium". The main development in policy in the last years is the regulation of other activities in the area reserved for sand extraction. In the Policy Document on the North Sea 2016-2021 (I&E and EA, 2015) it is formulated as follows: *The zone between the continuous NAP -20m isobath and the 12-mile boundary is regarded as a reserve area for sand extraction for the purposes of coastal replenishment and flood protection as well as for sand extraction for filling purposes and concrete and masonry sand for construction and infrastructure. The spatial pressure in this area will increase due to the construction of wind farms at sea and the laying of electric cables through the areas with the most cost-effective sand reserves and where sand extraction has the highest priority. If parties engaged in other activities of national interest, such as oil and gas extraction and wind energy, wish to use the area reserved for sand extraction, then a solution tailored to the specific situation will be sought. In the case of cables and pipelines, including interconnector and telecommunications cables, the following will be examined in succession: 1) whether a route is possible with the new cables and pipelines being bundled with existing cables and pipelines; and 2) whether a route is possible without appreciably affecting the supply of extractable sand. These preferred routes are shown on the framework vision map and are based on:*

- *location of less suitable sand extraction zones (thin package*
- *existing bundling of cables and pipelines, enabling maintenance zone to be limited;*
- *landing points for gas, oil and electricity;*
- *location of sand extraction sites that have already been depleted.*

If use of a preferred route is impossible for economic or environmental reasons, or if no route has been designated in an area, then customised work will be necessary. In exceptional cases it may be possible to extract sand in this area prior to it being used for cables or pipelines. If this is not possible and the new route will force the sand extraction activities out to another site entailing extra costs, the initiator will have to compensate these extra costs.

The far-field effects on benthos of the sand extraction (about 200 million m^3) for the construction of Maasvlakte 2, an extension of Rotterdam harbour, are analysed by Heinis and Van Tongeren (2016). The main conclusion is that, in the area where a significant increase was seen in the silt content in the second and third years of sand extraction (the high-impact area), there was a small change in the composition of the benthos. However, this was a subtle change involving a slight increase in the biomass of a small number of silt-tolerant species and a slight decrease in the biomass of species that are averse to silt. In the area with significantly increased silt content (high-impact area), there was no emergence or disappearance of species that could not be accounted for by autonomous development (emerging from a comparison of the baseline years and the effect years). The conclusion with respect to the possible effect on animals higher in the food chain (including birds) is that any possible effects of higher silt content in the seabed can be excluded.

In the framework of 'Building with Nature', a small part inside the deep (20m) extraction pit for the sand extraction for Maasvlakte 2 was not extracted. As a result a ridge was formed in the pit. On and around this ridge research was done on fish and benthic fauna to investigate the short-term effects of deep sand extraction and ecological landscaping (De Jong, 2016).

References

De Jong, M.F. (2016) The ecological effects of deep sand extraction on the Dutch Continental shelf. Implication for future sand extraction. PhD Thesis, Wageningen University, Wageningen, The Netherlands, 164 p.

Heinis, F. and O.F.R. van Tongeren (2016) Monitoring of the effects of Maasvlakte 2. Far-field effects on benthos of the construction of Maasvlakte 2. Maasvlakte 2 Project Organisation, World Port Center, Rotterdam, 53 p.

I&E and EA (2015) Policy Document on the North Sea 2016-2021, including the Netherlands' Maritime Spatial Plan. Appendix to the National Water Plan 2016-2021.

The Dutch Ministry of Infrastructure and the Environment and the Dutch Ministry of Economic Affairs, The Hague, the Netherlands, 119 p.

Stolk, A. (2015) Synthesis and future course of monitoring marine sand extraction in the Netherlands. Proceedings EMSAGG 2015 Conference: Marine sand and gravel – finding common grounds, 4-5 June 2015, Delft, The Netherlands.

5.14 Norway. No report.

5.15 Poland.

Activities related to elaboration of the high resolution geological mapping program of the bottom of the Polish maritime areas were continued in 2017 by the Polish Geological Institute. Collecting of existing data and metadata from external sources have progressed (e.g. bathymetry). The scope of investigations/analysis as well as preliminary time/cost frame of the mapping program implementation have been designed with respect to existing data as well as various geological complexity of the area. Technical aspects of data gathering (including field efforts) and its integrity with existing data base were analyzed. The framework sets guidelines for data processing and definitions dedicated to different mapping products (e.g. lithology, perspective for natural resources and sand for beach nourishment). Subsequently, the creation of repository of geological and geophysical mass data from the Polish maritime areas was to follow. Elaboration of Geo-environmental map of Polish maritime areas for rational seabed resources management (currently at the GIS processing stage) allowed to support the marine spatial planning processes which are currently going on in Poland (PIG-PIB consultations in the aspect of natural resources occurrence and the perspectives).

5.16 Portugal.

Madeira

Extraction of marine sand in Madeira is used primarily for construction but some beach nourishment is also done. Extraction peaked at about 5,000,000 m^3/year in 2004 coinciding with expansion of infrastructure. Extraction of Pleistocene, carbonate-algal sands is prohibited and no extraction is done along the north shore because it is far from the port, conditions are harsher and there are few studies of the resource. The sea floor is entirely a Federal jurisdiction; municipalities have no legal authority. Macronesian Marine Spatial Planning (MARSP) is done for ecosystems between 15m and 50m depth. It has been used to designate dredging sites and aquaculture locations in order to reduce conflicts. Licensed area along the south coast are designated between about 500m and 2km from shore because the shelf is very narrow, reaching a depth of 100m 2km from shore, and the inshore sea floor is rocky. Seven companies share a quota of about 100,000 m^3 per year. Three available dredgers range in capacity between 650 m^3 and 2000 m^3. They pay an extraction tax of 0.83 Euro per m^3. They are required to do environmental assessments; five of the seven share a single assessment, but two prefer to do their own. Dredges are limited to 20m depth. There is no evidence that the extraction causes either beach erosion or turbid conditions affecting aquaculture. Monitoring is required of the companies, but monitoring is also done by the government. Real-time positioning monitoring is required to monitor compliance.

5.17 Spain. No report

5.18 Sweden.

From an assignment by the Department of Enterprise, the Geological Survey of Sweden (SGU) has mapped the marine geology in nine areas on the Swedish continental shelf. These had been identified as possible for sustainable marine sand and gravel extraction. The nine areas are chosen primarily from marine geological data retrieved by SGU through a systematic mapping of the Swedish seabed between the late 1970s and 2010, although resolutions and methodology varied over time. The nine areas are located from Kattegatt, in the southwest to the Bothnian Bay, in northeast (Figure A5.18.1).

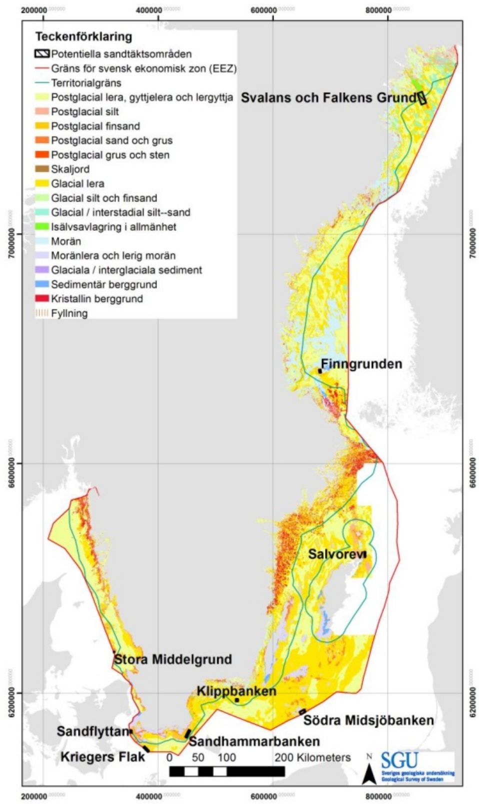


Figure 5.18.1. The nine areas identified as possible for marine sand and gravel extraction, from a sustainable point of view, that were surveyed by SGU during 2016.

The multibeam, side-scan sonar, sub-bottom profiler and seismic data, sampling data and observations of the seabed retrieved by SGU in 2016, as well as qualitative environmental assessments the Swedish Agency for Marine and Water Management (HaV) made from the data, show that environmentally sustainable extraction of marine sand and gravel may be possible in parts of the four areas of Sandflyttan, Sandhammar bank and Klippbanken in the southern Baltic Sea, and Svalans /Falkens grund in the Gulf of Bothnia. The areas that are identified as suitable:

- are located on slopes and depressions deeper than the photic zone
- consist of larger and thicker sand and gravel deposits, up to the seabed
- have seabed substrates consisting mainly of the sand and gravel fractions
- have such a high movement in the bottom water that larger transports and accumulations of sand and gravel occur on the seabed
- are located at such distance from shore that the risk of increased coastal erosion is negligible
- have material with the right quality for use in the construction industry.

Shallow, biologically sensitive hard seabed, located closer to shore, is to be avoided, thus, enhancing the likelihood that the ecosystem services and biodiversity in those areas are maintained. Below the photic zone, substrates predominantly of sand and gravel are delineated and volumes of aggregates are estimated from the thickness of the deposits. The sediment dynamics for potential resource areas and water depths have also been estimated through observations of movement patterns of sand and gravel. Continued biodiversity and ecosystem services after extraction are estimated also. The conflict of interests and distances to regions where the material primarily could be used for each investigated area are shown. The report with an English summary could be found at www.sgu.se.

5.19 United Kingdom.

In many cases, the area available to be dredged within a licence area will be restricted through zoning. This may be as a result of a licence condition or as a voluntary initiative introduced by the dredging operator. The value of such zoning lies in minimising the spatial footprint of marine aggregate dredging activity, which in turn can reduce the potential footprint of environmental impact, and reduces the potential for spatial impacts with other users of the sea. Zoning also allows operators to manage their resources more effectively.

Since 2003, BMAPA and The Crown Estate have undertaken to produce Regional Active Dredge Area (RADA) charts for all dredging regions on a bi-annual basis. These charts provide a snapshot of the extent of active dredge areas on the 31 January and 31 July, with any changes to working areas highlighted in red.

Where there is a need to highlight regional changes to existing marine aggregate production licence areas, the industry will occasionally also issue updated RADA charts outside of the bi-annual cycle. This ensures that the most up-to-date information on active dredge areas is available to other marine users.

The charts are distributed to the fishing industry through the District offices of the Marine Management Organisation, and the latest versions can also be downloaded here:

http://www.bmapa.org/issues/other_sea_users.php.

Background. English marine aggregate operators have increasingly been required to undertake a range of marine surveys (bathymetry, side scan sonar, seabed sediment sampling and benthic sampling) to deliver the compliance conditions attached to site specific marine licences. Often, the scope and frequency of these compliance requirements would vary between individual licences, and as a consequence the surveys would be designed and commissioned by individual industry operators in consultation with regulators and advisors at a licence specific scale. Given the proximity of many marine licence areas to one another, this approach resulted in considerable duplication of time and effort by all parties involved in the process together with inconsistent data outcomes. This duplication of effort was also reflected in the costs expended by industry to undertake such work, as a consequence of multiple surveys being commissioned to acquire data from adjacent sites at different times.

In 2014, the marine aggregate industry commissioned a series of Regional Seabed Monitoring Plans (RSMP) to determine the baseline environmental conditions across five geographic regions; the Humber, the Anglian, the Outer Thames, the Eastern English Channel and the South coast.

These works were undertaken to fulfil the seabed sampling conditions attached to marine licences for marine aggregate extraction issued by the Marine Management Organisation (MMO) from 2013 onwards. Additionally, marine aggregate operators chose to apply this new approach to a number of existing marine aggregate licence and application areas that were present in each region. In total the RSMP programme applies to over 60 marine aggregate production licence and application areas operated by 10 operating companies, and has required seabed data to be collected from 3500 sample stations.

For each region, a baseline array of sample stations focussing on primary and secondary impact zones of the licence/application areas being surveyed has been defined, together with a supporting array of regional context sample stations and regional reference areas.

Development of a wider approach to Regional Monitoring & Management. The practical delivery of the RSMP baseline surveys, simultaneously across five regions during 2014/15, highlighted the significant time, effort and costs that were involved for industry and also for the regulators and advisors that would ultimately receive and review the data for compliance purposes. Repeat monitoring surveys would be required to deliver the compliance requirements throughout the term of each marine licence, which are typically 15 years, but with the potential for licences being renewed for a further 15 years. As a result, there was the potential for the workload and cost to be concentrated into particular years with implications for practical resourcing and delivery.

Given the practical savings in time, effort and cost that could be realised through a more coordinate approach, it was agreed that the benefits derived from the RSMP approach, of planning, undertaking and reporting the compliance surveys required at a licence specific scale using a common standard, could be extended across to all the standard compliance monitoring requirements that applied to all licences. For this to occur in practice, it was recognised the common monitoring requirements that applied to every licence area would need to be standardised, so their scope and frequency was consistent. In turn, this would allow the timings of all standard monitoring survey events to be aligned at a regional scale so that all licences were required to deliver the same surveys at the same time. By aligning the timings at a regional scale, it should then be possible to stagger the various regional survey events across multiple years so the pressures on workload and cost could be spread more evenly, rather than being concentrated into particular years.

An agreed monitoring plan is now being developed by the industry for each region, with the South Coast region representing the first of these. This will define the management blueprint that sets out the timings and scope of all the various standard compliance and reporting events that will apply to all existing marine licences for aggregate extraction in a region. This framework is also intended to apply to any new marine licences that may be permitted in the future.

Given the potential long term benefits of this approach, the marine aggregate sector has been working closely with MMO and their advisors to agree the terms of reference for each regional monitoring plan.

The regional monitoring approach is intended to apply across the full term of all marine licences for marine mineral extraction, typically 15 years. During this period, interim regional multibeam bathymetry will be required in the second, seventh and twelfth years. Full multibeam bathymetry, sidescan sonar and seabed monitoring will be required in the fourth, ninth and fourteenth years. The results from the interim and full regional surveys will be used to inform the substantive reviews for site specific marine licences undertaken by regulators every five years in the sixth, eleventh and sixteenth years.

The integrated approach used to define each regional survey array will allow acoustic coverage and/or sample stations data acquired to be applied across multiple licence areas, therefore reducing duplication of effort. This approach also increases the robustness and consistency of the baseline data that is being acquired, and of any monitoring data obtained thereafter. The principle benefits derived through this new approach arise through a combination of factors:

(1) Reduction in compliance survey effort – The regional monitoring surveys will be designed to take into account the direct and indirect impact footprints from all of the licence and application areas that are present. Due to their proximity to one another, survey coverages can often overlap with one another therefore the regional data will be able to fulfil the requirements of multiple licence areas, reducing amount of survey time that has to be expended. This reduces survey time and associated weather risk.
(2) Reduction in compliance survey data analysis – As the scope of the regional monitoring will encompass all licensed interests, the regional data acquired should be able to be processed to the same consistent standard.

(3) Simplified compliance reporting – Licence-specific compliance surveys will be able to be reported on a more consistent basis, drawing on a single regional survey report.
(4) Spread of time/effort/cost over time – By phasing the regional survey requirements across a number of years, the time/effort/costs associated with delivering the requirements should be able to be managed more effectively. This allows the resourcing requirements within operators, regulators and advisors to be managed more effectively as the workload over time will be more consistent. Staggering the delivery regional surveys also delivers more practical advantages given the capacity available within the survey contractors can vary.
(5) Reduction in survey costs – By commissioning a single regional survey rather than multiple site specific surveys, savings are realised by reducing the number of mobilisation events and the general management associated with delivering a survey. A larger survey also enables economies of scale to be realised when booking vessel time.

5.20 United States.

The Federal Bureau of Ocean Energy Management (BOEM, formerly the Mineral Management Agency) completed reconnaissance geophysical track lines and geologic sample locations along the Atlantic Outer Continental Shelf (OCS) for a national OCS sand inventory. Thirty-six survey areas were identified (Figure A5.20.1); survey areas 1 to 22 are considered as being in the ICES territory. Along the US coast this is considered to be north of Cape Hatteras (35.2546;-75.5200). This area comprises the responsibility of North Atlantic Division of the U.S. Army Corps of Engineers, NOAA's Large Marine Ecosystem for the NE U.S. Continental Shelf, and the Mid Atlantic Fisheries Council (under the Magnuson-Stevens Act).

In this area, the jurisdiction of individual States (Maine, New Hampshire, Massachusetts, Rhode Island, New York, New Jersey, Delaware, Maryland and Virginia) to the marine natural resources extends 3 nautical miles (5.6 km) into the Atlantic. The BOEM study area begins 5.6 km offshore within water depths less than 30 m or to 14.8 km offshore whichever is closer to shore. The limitation of 30-m water depth is the maximum practical dredging capability of U.S. dredges. Data is managed in the Marine Minerals Information System (MMIS) with the goals of (1) collecting geophysical and geological mapping data, (2) identifying and analysing sediment/sand resources, (3) resource planning and administration, and (4) facilitating coastal restoration requiring offshore sand extraction.

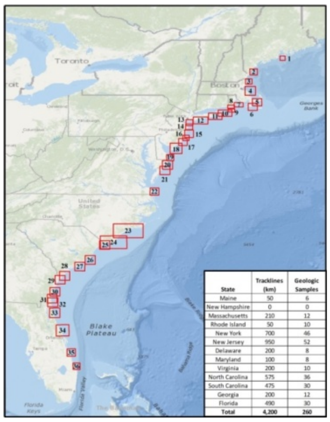


Figure 5.20.1. BOEM survey areas.

There are two areas leased and one area pending for sand extraction currently in the ICES area. The leased area in New Jersey is offshore Long Beach Island. A request for 9.2 million m^3 for beach nourishment has been approved by MOU with (Memorandum of The US army Corps of Engineers and the State of New Jersey's Department of Environmental Protection. Understanding) for a three-year period. There are no royalties and the lease is non-inclusive. An environmental assessment was required and environmental and cultural resource consultations are required. The US Army Corps of Engineers are responsible for stewardship and environmental compliance. State Water Quality Certification and assurance of consistency with State coastal policy are also required. Monthly reports are to be supplied to BOEM as well as pre- and post-dredging surveys. Pending in Virginia is a request to BOEM for 1.7 million m^3 to be taken from Sandbridge Shoal.

Some marine sand extractions in State waters can be found at:

(1) Northeast: http://www.nj.gov/dep/shoreprotection/projects.htm
(2) Virginia: http://www.nao.usace.army.mil/About/Projects/
(3) Southeast

- Wilmington: http://www.saw.usace.army.mil/Missions/Regulatory-Permit-Program/Public-Notices/Tag/12934/shore-protection-project/
- Charleston: http://www.sac.usace.army.mil/Missions/Civil-Works/
- Savannah: http://www.sas.usace.army.mil/
- Florida: http://www.saj.usace.army.mil/Missions/Civil-Works/Shore-Protection/
- http://www.sac.usace.army.mil/Missions/Civil-Works/Hurricane-and-Storm-Damage- Reduction/

The Bureau of Ocean Energy Management (BOEM) has launched the Marine Minerals Information System (MMIS, https://www.boem.gov/note02142019/) for access to some 30 years of geological and geophysical research data. The viewer contains more than 20 available data layers (https://mmis.doi.gov/BOEMMMIS/), including offshore sediment data. MMIS provides statistics on sand volume, number of projects, and use trends. It has GIS-mapping capabilities with tools to download data into geodatabases, shapefiles, or .csv files. There are also links to environmental studies and assessments.

Annex 6: ToR C. Incorporating MSFD into WGEXT

Marine Aggregate Extraction and the Marine Strategy Framework Directive: A review of existing research

Michel Desprez (12th draft of the WGEXT Collaborative Paper)

INTRODUCTION

Global biodiversity is threatened by human activities which are increasingly impacting marine ecosystem (Halpern *et al.*, 2008). These impacts are usually cumulative and can lead to degradation of habitats and ecosystem functionality (Ban *et al.*, 2010).

Understanding relationships between human pressures and ecosystems is the second major challenge identified by Borja (2014) for future research within the field of marine ecosystem ecology.

The European Marine Strategy Framework Directive aims at Good Environmental Status (GES) in marine waters, following an ecosystem-based approach, focused on 11 descriptors related to ecosystem features, human drivers and pressures (EC, 2010).

An inventory is made in several documents about the Marine Strategy Framework Directive (MSFD) on the incorporation of extraction as a human impact factor and in what way it is mentioned. In Annex III of the MSFD, extraction of minerals (rock, metal ores, gravel, sand, shell) is mentioned as a human activity affecting the marine environment (EC, 2016a).

For a single, specific pressure, such as aggregate extraction, the relationship between pressure and impact varies according to the pressure level (e.g. spatial extent, duration and/or frequency, intensity), the habitat type and component species and their recovery potential (Foden *et al.*, 2010; Lambert *et al.*, 2014; Duarte *et al.*, 2015). Effects of a sustained activity can ultimately change abundance, biomass and function at community or ecosystem level (Thrush *et al.*, 2016). Finally, the effects of dredging can result in human welfare being affected through the reduction in the provision of ecosystem services and societal benefits (Smith *et al.*, 2016).

This review provides information on research related to various effects of marine aggregate extraction on the seafloor and the watercolumn, and the connection with criteria for good environmental status which is relevant to the following descriptors of the MSFD: biological diversity (D1), commercial fish and shellfish resources (D3), marine food webs (D4), sea-floor integrity (D6), hydrographical conditions (D7), contaminants (D8) and underwater noise (D11).

The following table summarizes the impacts on the marine ecosystem, developed in different sections, and the links between these impacts and the descriptors:

Table 1: Main impacts of marine aggregate extraction and links with the MSFD descriptors.

Effects of Aggregate extraction:	Impact on:	Potentially influenced MSFD descriptors:
Seabed removal	Topography/Bathymetry	(D1), D6, D7
	Sediment composition	D1, (D3), D6
	Habitat & biological communities	D1, (D3), D4, D6

Sediment plumes	Turbidity Deposition	D3, D4, (D8) D1, D3, D4, D6, (D8)
Ship activities	Underwater noise	D11

This review also aims to highlight gaps to expand on the current knowledge to fulfil MSFD requirements.

RESULTS

As far back as 2003, ICES Guidelines for the Management of Marine Sediment Extraction encouraged an ecosystem approach to the management of extraction activities and the identification of areas suitable for extraction. Moreover, these guidelines, as adopted by OSPAR, provide for the implementation of mitigation and monitoring programmes ensuring that methods of extraction minimise adverse effects and preserve the overall quality of the environment once extraction has ceased (Table 2).

Table 2: Contribution to the potential MSFD descriptors according to the various impacts detailed in the ICES Guidelines for the Management of Marine Sediment Extraction (2003).

Potentially influenced MSFD descriptors	***Effects (=pressures?)***	***Impact on***	***Level of contribution of WGEXT guidelines (2003) to MSFD descriptors***				***Number of references per descriptor***
			INTRODUCTION	***BASELINE SURVEY***	***IMPACT ASSESSMENT***	***MITIGATION***	
***D1**: Biological diversity is maintained: Habitat level 1.6. Physical condition*	***Seabed removal***	***Bathymetry & Topography***	*Yes*	*Yes*			
***D3**: Commercial fish and shellfish populations are within safe biological limits*						*Yes*	
***D6**: Sea-floor integrity.* *6.1. Physical damage, having regard to substrate characteristics* *6.2. Condition of benthic community*			- 	 *Yes* 	 *Yes* *Yes*	 *Yes* 	 *4*
***D7**: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems*			*Yes*	*Yes*	*Yes*	*Yes*	
***D1**: Biological diversity is maintained: quality and occurrence of habitats, and distribution and abundance of species*		***Sediment composition***			*Yes*		*21*
***D3**: Commercial fish and shellfish populations are within safe biological limits*					*Yes*		
***D6**: Sea-floor integrity* *6.1. Physical damage, having regard to substrate characteristics*				 *Yes*	 *Yes*		 *19*

***D1**: Biological diversity is maintained: quality and occurrence of habitats, and distribution and abundance of species*		***Habitats & communities***		*Yes*	*Yes*	*Yes*	*22*
***D3**: Commercial fish and shellfish populations are within safe biological limits*			*Yes*	*Yes*		*Yes*	
***D4**: All elements of the marine food webs occur at normal abundance and diversity (functional aspects), 4.3.Abundance/distribution of groups/species targeted by human activities*				*Yes*	*Yes*	*Yes*	
***D6**: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems are not adversely affected.*			***Yes***	*Yes*	*Yes*	*Yes*	
6.2.1. Presence of particularly sensitive species			*Yes*	*Yes*	*Yes*		*7*
***D3**: Commercial fish and shellfish populations are within safe biological limits*	***Sediment plume***	***Turbidity***			*Yes*		*2*
***D4**: All elements of the marine food webs occur at normal abundance and diversity (functional aspects)*					*Yes*		*4*
D6.2.1. Presence of particularly sensitive species				*Yes*	*Yes*	*Yes*	
***D7**: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems*				*Yes*	*Yes*		
***D8**: Contaminants*				*Yes*	*Yes*		*0*

***D1**: Biological diversity is maintained: quality and occurrence of habitats, and distribution and abundance of species*		***Deposition***		*Yes*	*Yes*		*5*
***D3**: Commercial fish and shellfish populations are within safe biological limits*					*Yes*		*3*
***D4**: All elements of the marine food webs occur at normal abundance and diversity (functional aspects)*					*Yes*		
***D6**: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems are not adversely affected. D6.2.1. Presence of particularly sensitive species*					*Yes*	*Yes*	*13*
***D8**: Contaminants*				*Yes*	*Yes*		*1*
***D11**: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment*	***Ship activity***	***Underwater noise***	*Yes*	*Yes*	*Yes*		*11*

In each of the following sections, the impacts of marine aggregate extraction on the potential MSFD descriptors of the marine ecosystem are considered.

Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions. Assessment is required at several ecological levels: ecosystems, habitats and species.

Approaches to support the conservation of marine biodiversity include measures of rarity, diversity, identification of the number and abundances of species and habitats in different locations, but also the identification of biological indicators (Hiscock and Tyler-Walters, 2006).
The Working Group for Marine Habitat Mapping (ICES, 2016) is mainly reporting on national mapping progress including mapping techniques and modelling, data analysis, habitat classification schemes used in seabed mapping; this group is also reviewing practice about the use of habitat maps (for the MSFD (Cogan *et al.*, 2009), marine spatial planning, management of MPAs) and is a major support for the development of common and candidate OSPAR biodiversity indicators for benthic habitats.
Ambitious mapping programmes of biological characteristics of marine habitats were recently developed at international, national and regional scales (Coggan and Diesing, 2011; Coggan *et al.*, 2012; Vasquez *et al.*, 2015; Michez *et al.*, 2015; Strong *et al.*, 2015; Baffreau *et al.*, 2016; Delage and Lepape, 2016; Galparsoro *et al.*, 2016; La Rivière *et al.*, 2017), much bigger than research permits and extraction areas.
The urgent need for large-scale spatial data on benthic species and communities resulted in an increasing application of distribution modelling (Reiss *et al.*, 2014; Cooper *et al.*, 2019).
The marine sediments -targetted by the extraction industry- correspond to sand and gravel bottoms which represent only a fraction of the high diversity of habitats and marine life (variety of bottom types, habitats of common interest, rare and endangered species). In general, the biodiversity of the seabed tends to increase with the size and heterogeneity of the sediment (microhabitats) and with the stability of the substrate.

- Sandy bottoms, with low diversity in microhabitats, particularly mobile banks of coarse sand searched for extraction, are typically poor in species and biomass.
- Gravelly bottoms are the most diversified among the marine habitats, the larger size of gravel allowing settling and providing shelter for many sessile and mobile organisms. This knowledge resulted in many studies related to the commercial extraction of marine aggregates (Seiderer and Newell, 1999; Desprez, 2000; Cooper *et al.*, 2007). The gravel habitats deep water are more diverse than those closer to the coast, with a diverse and abundant epifauna with sponges, tunicates, bryozoans, hydroids and polychaetes. Biogenic reefs under threat and of high heritage value are associated with these gravels.

According to a decreasing gradient of impact, Browning (2002) identified three main classes of anthropogenic pressures on biodiversity in the English Channel-North Sea area:

- a class of maximal impact is including fishing activity (threatened species, destruction of protected biotopes);
- a class of higher medium impact is including many types of pollution;
- a class of lower medium impact is including marine aggregate extraction and deposition of harbour maintenance sediments.

Effects

A loss of 60 % for the number of benthic species is generally observed within dredging sites (Newell *et al.*, 1998; Desprez, 2000; Boyd *et al.*, 2002; Boyd and Rees, 2003; Newell *et al.*, 1998, 2004; ICES, 2009, 2016; Krause *et al.*, 2010; Desprez *et al.*, 2014).

Potential impacts of marine aggregate extraction on key habitats and species of the European Directive Natura 2000 were summarized in the following table (Posford Duvivier Environment, 2001):

Table 3: Potential impacts of marine aggregate extraction on key habitats and species of the European Directive Natura 2000 (S = Short Term, M = Mean term L = Long term).

Potential Impact	Habitats (Ann. I)	Species (Ann. II)	
	Sand and Gravel Banks	Fish	Mammals
Benthos and substrate loss	M	M	M
Turbidity	S	S	S
Sediment	ML	ML	

This loss of structural biodiversity is local and its duration varies according to extraction strategy. It is local and important in coarse bottoms where intensive extraction takes place (cumulative effects); it is counterbalanced in the case of extensive extractions (< 50 % of the total licensed area) by the increase in diversity of benthic communities linked to the diversification of habitats (Thrush *et al.*, 2006; Hewitt *et al.*, 2008; de Backer *et al.*, 2014; Desprez *et al.*, 2014).

Cusson *et al.* (2014) observed that changes within community assemblages in terms of structure are generally independent of biodiversity.

Recovery

The lower impact of extensive extraction favours the benthic recovery, notably through spatial and temporal zoning which enable the recolonisation by drift from adjacent areas (Birchenough *et al.*, 2010).

In the case of intense deposit of fine sediments due to screening, the damage by dredging to functional diversity and to the capacity of the macrofaunal assemblage to recover is immediate and not so dependant on dredging intensity (Barrio-Frojan *et al.*, 2008).

Moreover, the return to the initial biodiversity can be artificially accelerated by creating a heterogeneous substrate with the seeding of shells or gravel (Collins and Mallinson, 2007; Cooper *et al.*, 2010a) but the cost of these works may be considerable (Cooper *et al.*, 2010b).

Habitat engineering can exert facilitating and inhibiting effects on biodiversity (Bouma *et al.*, 2009; de Jong *et al.*, 2015).

Biodiversity and ecosystems functionality

Study of the ecological function of biodiversity is very recent (Loreau *et al.*, 2001; Bremner *et al.*, 2003, 2006ab, 2008; Duffy *et al.*, 2007; Cooper *et al.*, 2008; Mouillot *et al.*, 2013) but it has been recognised to have fundamental implications for predicting the consequences of biodiversity loss. This missing of the functional aspects of biodiversity was highlighted by the WG GES (EC, 2010).

Understanding the role of biodiversity in maintaining ecosystems functionality is a main challenge in marine ecosystem ecology (Borja, 2014). Theoretically, a higher number of functional group types will provide higher functional biodiversity organization to the system and contribute to more stable and resilient ecosystems (Borja *et al.*, 2009 ; Tomimatsu *et al.*, 2013 ; Cusson *et al.*, 2014 ; Strong *et al.*, 2015). However, Törnroos *et al.* (2014) observed that a decrease in species richness lead to a global decrease in functionality, but that functional richness remained comparatively high at the lowest level of specific richness, thus showing that a potential was existing for substitution of species to maintain the ecological functioning of marine benthic systems (Frid, 2011). Clare *et al.* (2015) confirmed that the ecological functioning was statistically comparable between periods which were significantly different in terms of specific composition.

Differences in functional traits between habitats are more influenced by differences in organisms densities than by presence/absence of individual traits, what is showing the importance of variations in densities for functionality (Hewitt *et al.*, 2008).

The MARBEF project demonstrated that alteration of key species abundances affects ecosystem functioning more than changes in species diversity (Heip *et al.*, 2009).

It is now fully recognised that understanding the entire ecosystem requires the study of all biodiversity components (Borja, 2014), from species to habitats, including food-webs (descriptor 4) and complex bio-physical interrelationships within the system.

<u>Biodiversity indicators</u>

Biodiversity can be seen as an overarching descriptor and is too broad a topic to list all possible indicators. In any case, not all indicators can be applied everywhere and there is therefore a need for more guidance on which habitats and species to consider (EC, 2010).

In the marine assessments like the MSFD, biodiversity is defined at the level of species, communities, habitats, and ecosystems, as well as in the genetic level (Cochrane *et al.*, 2010).

Whilst their population equivalents do not always reflect biodiversity changes, the sample Simpson, Shannon and Richness indices are useful indicators of changes in biodiversity (Barry *et al.*, 2013).

Demersal fish communities consisting mainly of mobile species, neither the habitat-level indicators nor the single species distribution indicator, explicitly directed at sessile/benthic species, are pertinent; appropriate fish biodiversity metrics cannot be derived to support this D1 indicator (Greenstreet *et al.*, 2012).

Impact indicators for major drivers of marine biodiversity loss are currently lacking (Woods *et al.*, 2016). Moreover, the value of an ecological indicator is no better than the uncertainty associated with its estimate; indicator uncertainty is seldom estimated, even though legislative frameworks such as the European Water Framework Directive stress that the confidence of an assessment should be quantified (Carstensen and Lindegarth, 2016). With increased knowledge and understanding about the strengths and weaknesses of competing index approaches, the field needs to unify approaches that provide managers with the simple answers they need to use ecological condition information effectively and efficiently (Borja *et al.*, 2009, 2016).

<u>Conclusion</u>

With respect to descriptor (1) WGEXT recognises that extraction of marine aggregates can potentially be a serious threat to biodiversity when exploitation projects affect gravelly areas either of small size or under-represented in the geographical area (loss of habitat).

The ICES Guidelines for the Management of Marine Sediment Extraction (2003), as adopted by OSPAR, provide for the adoption of appropriate extraction site locations, with the aim to prevent any harmful effect on habitats of prime importance.

Descriptor 3: Commercial fish and shellfish resources

The proposed indicators mortality and biomass are the base for this descriptor, while the third one (size) should be linked to the ones on food webs (D 4).

Changes in or loss of a prefered grain size can disturb mobile species. Species such as herring (*Clupea harengus*), black bream (*Spondyliosoma cantharus*), sandeel (Ammodytidae), require certain substrate conditions for spawning or breeding activity. Studies such as de Groot (1979) have highlighted the importance of historical spawning grounds for herring and its specialist requirement for coarse gravel (ICES, 2011), increasing its vulnerability to disturbance if marine aggregate extraction occurs within spawning areas. In addition, ovigerous female brown crabs prefer to overwinter on coarse gravelly material and are, therefore, susceptible to direct dredging impacts.

Mobile species are also more likely to be influenced by other impacts or anthropogenic activities outside of a licence area, again making direct predictions between marine aggregate extraction and mobile species difficult. A study by Boyd *et al.* (2001) compared the commercial fish landings for fish caught in an aggregate zone, to those obtained from ports distant to dredging. A localised decline in catches in Dover sole was observed, and the study considered that this may be a result of the reduced abundance of prey items within the extraction area as Dover sole derive much of their food from benthic species (Pearce, 2008; Desprez *et al.*, 2014).

A study by Kenny *et al.* (2010) looked at the long-term trends of the ecological status of the east coast aggregate producing region, which included consideration of fish stocks. This study noted that long-term trends appear to be dominated by wider factors that govern trends at the North Sea scale, as declining fish stocks were observed in both the North Sea and east coast aggregate producing region.

Stelzenmüller *et al.* (2010) investigated the vulnerability of 11 species of **fish and shellfish** to aggregate extraction. The authors calculated a Sensitivity Index (SI) for each species and modelled their distribution around the UK. These species were likely to be affected by aggregate extraction and had either commercial or conservational importance; target fish communities include the flatfish sole, thornback ray and plaice, the gadoids cod and whiting, and the bivalve mollusc queen scallop. The highest sensitivity occurred in coastal regions and where nursery and spawning areas of four important commercial species occurred [cod (*Gadus morhua*), plaice (*Pleuronectes platessa*), sole (*Solea solea*), and whiting (*Merlangius merlangus*)].

In 2003, the Franco-British project CHARM (Eastern Channel Habitat Atlas for Marine Resource Management) was initiated to support decision-making for the conservation, protection and/or management (anthropogenic disturbances) of essential fish habitats such as spawning grounds, nurseries or areas carrying bio-diverse fish communities (Vaz *et al.*, 2007).

An inventory of coastal areas of conservational importance was defined in France to protect commercial fish resources and functional areas of prime importance for their life cycle, to maintain their renewal and the associated fishing activity (Delage and Le Pape, 2016).

Turbid plumes can cause avoidance behaviour in visual predatory fish, such as mackerel and turbot; for herring and cod, critical levels were demonstrated at very low silt concentrations (3 mg/l). They can also cause mortality of larvae of herring and cod at slightly higher levels (20 mg/l), while eggs can tolerate concentrations >100 mg/l (Westerberg *et al.*, 1996).

There have been few direct studies on changes in fish populations due to marine aggregate extraction (ICES, 2016).

Experimental fish monitoring in the eastern Channel between 2007 and 2011 showed a strong impact of an intensive aggregate extraction on fish presence, both for the number of species (-50%) for abundance and biomass (-92%). On the contrary, the impact of an extensive dredging (spatial and temporal zoning) was limited, without any decrease in species number and biomass, and abundance reduced by 35 % (Desprez *et al.*, 2014).

Dab (*Limanda limanda*) and whiting (*Merlangius merlangus*) were the two fish species most adversely affected by dredging; however, sole and rays appeared to flourish in areas where the sediment had been modified by the deposition of sandy material, allowing a permanent fishing activity.

The impact of aggregate extraction activities on the displacement of fishing activities was based primarily on anecdotal evidence, till changes in fishing patterns were studied in the Eastern English Channel following the start of aggregate extraction activities in the area. Three different approaches considered temporal changes and could not identify any significant reduction of activity within the licensed aggregate extraction sites. Overall an increase of activity was observed within these areas and the wider English Channel (Vanstaen *et al.*, 2010).

The effects of dredging intensity and the distance to extraction sites on the distribution of fishing effort were more recently investigated for a broad selection of French and English demersal fleets operating in the Eastern English Channel. The most prominent result was that most fleets fishing near to aggregate extraction sites were not deterred by extraction activities (Marchal *et al.,* 2014). The distribution of fishing effort of French netters remained consistent over the study period and increased substantially in the impacted area of the Dieppe site. The fishing effort of dredgers and potters could be greater adjacent to marine aggregates sites than elsewhere, and also positively correlated to extraction intensity.

<u>**Conclusion**</u>

Recent studies suggest that fishing activity is not deterred by extraction activities. However, WGEXT recognises that extraction of marine aggregates can potentially be a serious threat to commercial fish species when functional impacts can affect sensible and threatened species (e.g. through loss of spawning areas).

The ICES Guidelines for the Management of Marine Sediment Extraction (2003), as adopted by OSPAR, provide for the adoption of appropriate extraction site locations, with the aim to prevent any harmful effect on habitats of prime importance.

Descriptor 4: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.
This descriptor concerns important functional aspects such as energy flows and the structure of food webs (size and abundance).

Thompson *et al.* (2012) emphasize that food-web ecology will act as an underlying conceptual and analytical framework for studying biodiversity and ecosystem function, if some challenges are addressed such as relating food-web structure to ecosystem function, or understanding the effects of biodiversity loss on ecosystem function. Trophic structure is an important driver of community functioning and biological traits, in particular body size, in turn determine which species interact (Nordström *et al.*, 2015).

<u>Indirect effects of substrate loss</u>

Functionally, the qualitative and quantitative depletion of benthic communities may affect the higher trophic levels (e.g. fish & birds), as the increase in extraction surface in a given geographical area leads to the loss of habitat and potential food web (Birklund & Wijsman, 2005). Several fish species are more or less closely related to the bottom by their way of feeding ; plaice, sole, dab, gurnard, red mullet, haddock, whiting and cod, feed primarily on benthic organisms like bivalves, worms, crustaceans and sea urchins. Coastal bottoms actually are important feeding areas for diving birds (ducks, terns, penguins, northern gannet…), due to their high productivity (Michel *et al.*, 2013).

Top predators, such as seabirds and mammals, can be highly sensitive to changes in the abundance and diversity of their primary prey; nevertheless, many bird species are able to switch to alternative prey (Rombouts *et al.*, 2013).
More than 48 species of fish in the north-east Atlantic area are associated with sandy gravel bottoms for spawning (herring, black bream, sole...); about forty others are associated with these habitats (e.g. rays, dogfish, plaice, sand eels, sharks...). On the other side, most flatfish species of commercial interest develop and reproduce in fine and silty sands without interest for extraction.

Shellfish make up an important component of the coastal food web, for example for shellfish-eating birds such the common scoter as well as demersal fish (Kaiser *et al.*, 2006; Tulp *et al.*, 2010). As such, the impacts of aggregate extraction on shellfish species are being investigated in the Netherlands; the American razor shell (*Ensis directus*) was taken as a model organism because of its high dominance in biomass in the Dutch coastal zone (ICES, 2016).

Predicting the disturbance of mobile **fish** species is particularly difficult as there are few studies that have directly investigated disturbance in relation to marine aggregate extraction, or suggested that significant impact will occur (Stelzenmüller *et al.*, 2010; Vanstaen *et al.*, 2010; Marchal *et al.*, 2014).
In Korea, significantly lower species richness (-60 %), species diversity and fish abundance (-90 %) were associated with bottom disturbance related to the mining of seabed sediments (Hwang *et al.*, 2013). In a French experimental site of eastern Channel (Desprez *et al.*, 2014), fish monitoring between 2007 and 2011 showed a strong negative impact of aggregate extraction on fish presence, either in the number of species (-50 %), or in abundance and biomass (-92 %). However, such a strong impact was not observed in the commercial site of Dieppe (respectively +50 %, -35 % and +5 %); this difference could be explained by the difference in extraction strategy (zoning), with a low intensity in Dieppe (<1h/ha/year), whereas medium to high (4 to 10 h/ha/year) in the Baie de Seine.
In a Dutch deep sand extraction site (de Jong *et al.*, 2014), significant differences in demersal fish species assemblages were associated with variables such as water depth, median grain size, fraction of very fine sand, biomass of shells and time after the cessation of sand extraction. One and two years after cessation, a significant 20-fold increase in demersal fish biomass, dominated by plaice, was observed in deeper muddy parts of the extraction site colonised by high densities of white furrow shell (*Abra alba*).

A study by Pearce (2008) investigated the importance of benthic communities within marine aggregate areas as a food resource for higher trophic levels. The study noted that changes to the benthos due to dredging were likely to cause alterations in the diet of demersal fish, which may be unfavourable. However, given the natural levels of trophic adaptability observed, a change in dietary composition may not be damaging to the fish population as the majority of species studied were likely to switch prey sources, providing sufficient biomass was available to support them.
Between 2004 and 2011, three combined studies (benthos, fish, and stomach contents monitoring) were undertaken at two French sites (Dieppe and Baie de Seine) of the eastern Channel (Desprez *et al.*, 2014). Evidence of trophic adaptability was observed with an increase in the abundance of sole within the extraction and particularly the deposition areas.
In Dieppe, black sea bream, gurnards and cod were absent from the sandy reference and deposition areas, but were attracted to dredging areas by the abundance of opportunistic benthic species (mainly opportunistic crab species *Pisidia* and *Galathea*), which recolonize dredging areas between extraction periods (fallow areas) and after cessation of activity.

Effects of turbid plume

A direct consequence of increased turbidity from aggregate extraction is the reduction of light penetration into the water column which can affect the whole trophic web. **Indirect impacts through the creation of turbidity plumes** are:

- reduction of the primary production of phytoplankton which constitutes the basis of the food web,
- disruption of feeding and respiration of zooplankton,
- impeding of phytoplankton intake by shellfish, and potential additional stress (i.e. higher energetic costs) to these organisms as they need to excrete silt in the form of pseudo-faeces (Michel *et al.*, 2013),
- cause avoidance behaviour in visual predatory fish, such as mackerel and turbot. For herring and cod, critical levels were demonstrated at very low silt concentrations (3 mg/l);
- cause mortality of larvae of herring and cod at slightly higher levels (20 mg/l), while eggs can tolerate concentrations >100 mg/l (Westerberg *et al.*, 1996).

In addition to a reduced phytoplankton abundance in the water column, elevated silt concentrations may.

Cook and Burton (2010) reviewed the potential impacts of aggregate extraction on **seabirds**. One direct effect was the issue of increased turbidity, and to what extent this affects a bird's ability to see prey. Vision for foraging is important for a number of species of seabirds, including terns, the common guillemot and the northern gannet. However, for the most part, material falls out of suspension relatively quickly (mostly within 500 m), meaning this increased turbidity is short term and within a limited area. During spring tides in a macrotidal environnement, Duclos *et al.* (2013) underlined the disappearance of the turbid plume in 2 hours, with a maximal extent of deposits of 800 m for sands and 6.5 km for silts.

In a review of impacts of marine dredging activities on **marine mammals**, Todd *et al.* (2014) also conclude that sediment plumes are generally localized, and marine mammals reside often in turbid waters, so significant impacts from turbidity are improbable because temporary, as observed with seals around extraction sites in North Sea. However, entrainment, habitat degradation, noise, suspended sediments, and sedimentation can affect benthic, epibenthic, and infaunal communities, which may impact marine mammals indirectly through changes to prey.

Food web indicators

Many food web indicators are also relevant to other MSFD descriptors 1, 3 (groups/species targeted by human activities) and 6 (early warning indicators)

The existing suite of indicators gives variable focus to the three important food web properties (structure, functioning and dynamics) and more emphasis should be given to the latter two. Indicators based on the structure and processes of benthic groups can help to describe trophic functioning. Whereas the currently proposed indicator 4.1.3 is suggested to a single group/species, biomass can be considered over several trophic levels simultaneously and can therefore become an ecosystem-based indicator (Rombouts *et al.*, 2013).

The proposed indicators, in particular those based on abundance and biomass, can inform on the structural properties of food webs but they may provide only partial information about its functioning. Hence, the development of criteria for D4 should be directed towards more integrative and functional indicators that consider (1) multiple trophic levels or a whole-system approach (i.e. ecosystem-based indicators), (2) processes and linkages (e.g. trophic transfer efficiencies) and (3) the dynamics of food webs in relation to specific anthropogenic pressures.

Conclusion

With respect to descriptor 4, direct and indirect effects of m.a.e. are proportional to the size of dredging areas, with "limiting" factors like the trophic adaptability of fish and bird species and their mobility to avoid disturbed areas, or like the tolerance of marine mammals for turbidity.

Descriptor 6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

D 6.1. Physical damage, having regard to substrate characteristics

The physical impact of extraction is site-specific and linked to many factors such as hydrodynamics, sediment grain size, dredging method and intensity.

- The action of extracting aggregate alters the topography with creation of isolated furrows (dredge tracks) in extensive sites (Cooper *et al.*, 2005; Le Bot *et al.*, 2010) up to persistent depressions up to several meters deep after several years of localised extractions (Degrendele *et al.*, 2010; Gonçalvez *et al.*, 2014; de Jong *et al.*, 2015).
- Removal of aggregate can lead to a change in the seabed substrate, by removing surficial layers of sediment to leave a new substrate exposure of coarser sediments (Cooper *et al.*, 2007; Le Bot *et al.*, 2010) or by altering the particle size distribution as a result of intensive deposition from overflow (Boyd *et al.*, 2005; Cooper *et al.*, 2007; Krause *et al.*, 2010; Barrio-Frojan *et al.*, 2011; Wan Hussin *et al.*, 2012; de Jong *et al.*, 2015).
- Extraction generally results in an increased variability in terms of particle size composition within both high and low dredging intensity sites (Cooper *et al.*, 2007).

As the distribution of marine organisms and communities is strongly related to hydrodynamic, morphological and sediment parameters (McLusky and Elliott, 2004; Baptist *et al.*, 2006; Degraer *et al.*, 2008; Pesch *et al.*, 2008), any physical changes in the sea bed will lead to a response in the composition of its natural benthic assemblages. This will affect the habitat quality in a wider area, the transport of fish larvae and the abundance of food for fish, birds and mammals.

The direct removal of surface aggregate sediments and associated fauna results in an immediate and local loss of the benthic fauna in the order of 60% for the number of species and 80-90% for the abundance and biomass (Newell *et al.*, 1998; Desprez, 2000; Newell *et al.*, 2004; Boyd and Rees, 2003; ICES, 2009; Krause *et al.* 2010; Desprez *et al.*, 2014). This may range from almost total defaunation (Simonini *et al.*, 2007) to a more subtle and less significant change (e.g. van Dalfsen *et al.*, 2000; Robinson *et al.*, 2005).

Impacts of extensive dredging tend to be less pronounced and with limited functional consequences (e.g. lower reduction in biomass) on the higher trophic levels, mainly in areas under strong hydrodynamic conditions with mobile sediments (Bonvicini *et al.* 1985; Desprez *et al.*, 2014). In sandy areas of the North Sea and the Baltic Sea, the effects of sand extraction only became evident when the annual extractions affected 50 % of the licensed area, causing a drop in biomass values (Birklund and Wijsman, 2005).

The cumulative impact, in time and/or space, of multiple extractions results in a continuous disruption of benthic communities, which are reduced to their simplest form (few tolerant species, reduced abundance and minimal biomass due to the elimination of long living bivalves and echinoderms) (Newell *et al.*, 2004a; Boyd and Rees, 2003; Robinson *et al.*, 2005; Cooper *et al.*, 2007; Barrio-Frojan *et al.*, 2008).

Differences in impact and subsequent recovery also depend on local hydrodynamics (Mestre *et al.*, 2013), sediment characteristics, as well as on the nature and type of stress to which the community is adapted in its natural environment (ICES, 2009). In the sandy bottoms of the North Sea, small-scale disturbances in seabed morphology and sediment composition result in limited effects on the benthic community (van Dalfsen *et al.*, 2000), but large scale and deep sand extractions (de Jong *et al.*, 2015) result in a net increase in sediment fines and in the biomass of the white furrow shell (*Abra alba*).
In gravelly areas, the impact is higher as a consequence of the heterogeneity and the stability of the sediment which favours more diversified and abundant communities (Seiderer and Newell, 1999; Newell *et al.*, 2001; Cooper *et al.*, 2007).

The main indirect impact of dredging is linked to the deposition of sediment from the overflow or screening plume, which can cause smothering / damage to sensitive benthic receptors. Extensions of deposits have been calculated for spring tides conditions in the English Channel: 800m for sand and 6.5km for silt (Duclos *et al.*, 2013).
The majority of studies (Desprez, 2000; Newell *et al.*, 2004b; Boyd and Rees, 2003; Cooper *et al.*, 2007; Desprez *et al.*, 2010) suggest that adverse biological change is constrained to the 100 - 200 m from the dredge area, even where sedimentary change has been detected at greater distances up to 2 km from the dredge site in the direction of and after remobilisation by strong local tidal currents (Newell *et al.*, 2002; Robinson *et al.*, 2005; Cooper *et al.*, 2007; Desprez *et al.*, 2010).

Several types of indirect effects have been observed depending on the intensity of oversanding and the nature of the bottom:

- On gravelly bottoms, the elimination of the benthic fauna can be almost complete, identical to that observed in the dredged area (ICES, 2009; Desprez *et al.*, 2010), the original communities being unable to withstand a big deposition of fine sands. Due to the permanent extraction activities and remobilization in areas under strong hydrodynamic conditions, the original stable bottom is replaced by a continuously remobilized substrate (Newell *et al.*, 2004b; Robinson *et al.*, 2005; Desprez *et al.*, 2010). Beyond a few hundred meters from the extraction site, there is a rapid increase in the number of species and abundance consistent with the low dispersion of overflowing sediments. Boyd and Rees (2003) also showed that faunal composition changed gradually with the distance from the extraction site. This is mainly due to the fact that the distribution of species is correlated with the sedimentary characteristics of the deposition area (medium to fine sand);
- A transition from a sandy-gravelly bottom with a diverse epifauna to a sandy bottom with a less diverse infauna can occur as a result of overflow (Boyd *et al.*, 2005; ICES, 2009; Desprez *et al.*, 2010).
- On sandy bottoms, the benthic fauna is less affected in the deposition area than in the extraction site (Newell *et al.*, 2004b). The benthic species which are less sensitive to overflow deposits are those able to move rapidly through the sediment and free-swimming epifaunal species (e.g. crabs, shrimps);
- Species richness, abundance and biomass can increase in overflow areas, when sediment deposition is limited and the available food is increased through organic enrichment (Newell *et al.*, 1999, 2002; Desprez *et al.*, 2010).

Generally, the creation of sediment plumes have the potential to adversely impact benthic organisms through an increase in sediment induced scour, smothering and through damage and blockage to respiratory and feeding organs (Tillin *et al.*, 2011). Effects of suspended sediments and sedimentation are species-specific, but invertebrates, eggs, and larvae are most vulnerable.

Studies such as Last *et al.* (2011) investigated the impacts of increased suspended particulate matter (SPM) and smothering on a number of benthic species of commercial or conservational importance under a range of environmental and depositional conditions. Two test conditions of SPM were tested (high SPM, equivalent of near dredge conditions and low SPM, equivalent of wider secondary impact conditions). All species survived the higher SPM conditions. The ross worm (*Sabellaria spinulosa*) was highly tolerant to short term burial (< 32 days) and its growth rate showed significantly higher tube growth under high SPM conditions.
Szostek *et al.* (2013) showed that elevated SPM had no short-term effects on survival of the king scallop (*Pecten maximus*), but observed a reduction in growth rate; this species appeared more tolerant of burial and elevated levels of SPM than the queen scallop (*Aequipecten opercularis*).

D 6.2. European Commission selected as indicators for the sea-floor integrity (Rice *et al.*, 2012):

(i) type, abundance, biomass and aeral extent of relevant biogenic substrates:
Sabellaria reefs & *Mytilus* beds (Cooper *et al.*, 2007; Gibb *et al.*, 2014; Pearce *et al.*, 2007, 2014), *Chaetopterus* beds (Rees *et al.*, 2005), *Lanice* meadows (Braeckman *et al.*, 2014) and other biogenic reefs (Farinas-Franco *et al.*, 2014) are examples of the coastal ecosystems dominated by epibenthic engineers which belong to the most valuable ecosystems among the world, but remain threatened and declining.
An example of a reverse in the decline of biodiversity has been observed on extraction sites (Cooper *et al.*, 2007; Pearce *et al.*, 2007; Gibb *et al.*, 2014; Desprez *et al.*, 2014) with the return of the tubeworm *Sabellaria spinulosa* (key species of the Habitats Directive and the OSPAR list of endangered species), observed from the early stages of recolonization, facilitated by the deposit of sand overflow.

(ii) extent of the seabed significantly affected by human activities for the different substrate types:
Halpern *et al.* (2008) estimated that 41 % of marine areas are already strongly affected by multiple anthropogenic perturbations. In the six direct physical pressure types affecting the seabed of England and Wales, Eastwood *et al.* (2007) estimated that selective extraction caused by demersal trawling affected between 5 % to 21 % of the total area, while the pressure arising from aggregate dredging affected only 0.1 % for the direct removal, plus 1.2 % for the siltation caused by screening plumes. Disturbance of the seabed by demersal fishing gear shows a footprint reaching over 99 % of the known footprint of all human pressures on the UK seabed (Foden *et al.*, 2010).
Becker *et al.* (2013) describe a generic method to calculate source terms for far field dredge plume modelling as it is used in practice in the dredging industry. The method is based on soil characteristics and dredge production figures, combined with empirically derived, equipment and condition specific 'source term fractions'. A source term fraction relates the suspended fine sediment that is available for dispersion, to the amount of fine sediment that is present in the soil and the way it is dredged.

(iii) presence of particularly sensitive and/or tolerant species:
Sensitivity measures the degree of the response to stress using indicators (species, communities, habitats). Identifying the sensitivity of species and biotopes relies on accessing and interpreting available scientific data in a structured way (sensitivity information can be overlaid with the distribution of protected or threatened species and habitats, designated areas, and the location and intensity of specific activities considered damaging to the marine environment) to disseminate suitably presented information to decision makers (Hiscock and Tyler-Walters, 2006).
Mapping of different benthic habitat components is considered to be key information for the implementation of the MSFD, particularly for the identification of sensitive habitats.
The Working Group for Marine Habitat Mapping (ICES, 2016) is examining the managerial uses (e.g. assessments of environmental status) of habitats maps.

The ICES Guidelines for the Management of Marine Sediment Extraction (ICES, 2003) point out the importance of this objective in the selection process of extraction areas to protect benthic threatened communities and to allow a good resources management. The most sensitive species/habitats are maërl beds (high structural diversity), spawning areas (fundamental functional diversity) and biogenic reefs (both structural and functional diversity) which have specific protection measures (OSPAR, Natura 2000).
Presence of particularly sensitive or tolerant species should inform on the condition of the benthic community (D 6.2) However, Zettler *et al.* (2013) recently demonstrated that the use of static **indicator species**, in which species are expected to have a similar sensitivity or tolerance to either natural or human-induced stressors, does not account for possible shifts in tolerance along natural environmental gradients and between biogeographic regions. Their indicative value may therefore be considered at least questionable.

Table 4: Risk analysis of marine aggregate extractions for the main types of seabeds exploited on the French littoral (Poseidon matrix). (in Desprez, 2011)

Risk Analysis		Habitats Sensitivity		
Impact Indicator			NATURA 1110.2	NATURA 1110.3
Dredging Intensity	Recovery rate	Sandy gravels with epifauna	Gravelly sands with *Amphioxus*	Medium sands with *Ophelia*
High	> 10 years	High	High	Medium
Medium	1-10 years	High	Medium	Low
Low	< 1 year	Medium	Low	Negligible

The level of pressure on habitats and species will be different depending on the nature of the impact related to extraction. The following table details the impact level observed in Dieppe (Desprez, 2011) on the different habitats and species identified in the major international conventions that regulate the management of the activities and the protection of the marine ecosystem.

Table 5: Sensitivity of key-species and habitats (identified by international conventions) to various levels of impact of marine aggregate extraction (E=Extraction; T=Turbidity; D=Deposition) in Dieppe.

Sensitivity to extraction		***Pressure Levels***				
Indicators of impact		High	Mean	Low	Negligible	Positive
OSPAR species	Cod	T	D			E (zoning)
	Rays			E / T	D	
OSPAR habitats	Sabellaria reefs	E			T	D

	Maerl banks	E / T / D				
	Hard substrates with Modiolus	E / D		T		
ICES habitats	Spawning areas	E / T / D				
	Nurseries	E / D			T	
	Shell beds	E	D		T	
NATURA 2000	1110.2 (gravelly sands)		E / T / D			
	1110.3 (medium sands)			E / T	D	

<u>(iv) Multi-metric indices assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species.</u>

Ware *et al.* (2009) provided options for aggregate indicators based on impacts to the physical and biological environment, including the percentage of silt/sand and gravel and benthic indices such as diversity and biomass (van Hoey *et al.*, 2007, 2010). Efficacy of both the Infaunal Quality Index and M-AMBI cannot be supported in inshore gravel currently (Fitch *et al.*, 2014).

Other indicators such as biological traits of benthic community (Bremner *et al.*, 2006ab, 2008), habitat heterogeneity (Hewitt *et al.*, 2008) and functional diversity (Törnroos *et al.*, 2014) have also been proposed. Functional indices may provide a more detailed assessment of the benthic communities than structural ones, but the overall outcome is broadly similar for both types of indices; this suggests measurement of functional indices may be unnecessary for routine monitoring purposes (Culhane *et al.*, 2014; Strong *et al.*, 2015), although they may have value in revealing more specific aspects of change in a system.

Metrics which are closely associated with species number and density of individuals scored highest in terms of sensitivity in relation to aggregate extraction impacts. Similar findings are found in the literature in relation to a variety of activities that typically result in physical impacts on the seafloor and its associated fauna (Ware *et al.*, 2009, 2010). A Benthic Ecosystem Quality Index (BEQI) was developed by Van Hoey *et al.* (2007) for the monitoring of windfarms, maintenance dredging deposits and aggregate extraction on the Belgian Continental Shelf (De Backer *et al.*, 2014). However, while some indicators are used to a certain extent already, further work is required to develop approaches for assessing the physical impacts of aggregate extraction (Schleuter *et al.*, 2010; Fitch *et al.*, 2014).

The relative lack of sensitivity of traditional indices (AMBI, M-AMBI, ITI and BENTIX) may be attributed to their dependence on species responses to organic enrichment (Ware *et al.*, 2009; Targusi *et al.*, 2014), an impact not routinely associated with aggregate extraction activities (Salas *et al.*, 2006).

Impact indicators for major drivers of marine biodiversity loss are currently lacking (Woods *et al.*, 2016). With increased knowledge and understanding about the strengths and weaknesses of competing index approaches, the field needs to unify approaches that provide managers with the simple answers they need to use ecological condition information effectively and efficiently (Borja *et al.*, 2009, 2010a).

Indicators that show the ecosystem response to human pressures form the basis of the tool kit with which we can describe environmental status (Borja *et al.*, 2016).

For Green (2011), indices are appealing because they can be used to reduce complex data to single numbers, which seem easy to understand. But that is not biological or environmental reality, which is rarely one-dimensional. This author suggests that indicators should not be used because of information loss and the likelihood of misleading conclusions. He concludes that if you absolutely must use indices for some non-scientific reason, it is better to use them together with other statistical methods that retain more of the information in the biological data set.

Structure & Function

Understanding the role of biodiversity in maintaining ecosystem functionality is a significant challenge (Borja, 2014). Theoretically, a higher number of functional group types will provide greater functional biodiversity and thus contribute to a more stable and resilient ecosystem (Tomimatsu *et al.*, 2013).

The study of the ecological function of biodiversity (Loreau *et al.*, 2001; Bremner *et al.*, 2003, 2006ab, 2008; Duffy *et al.*, 2007; Cooper *et al.*, 2008; Mouillot *et al.*, 2013) is very recent but has been recognized to have fundamental implications for predicting the consequences of biodiversity loss on ecosystem function, i.e. translate structural biodiversity measures into functional diversity to generate better Biodiversity–Ecosystem Functioning relationships (Strong *et al.*, 2015). Theoretically, a higher number of functional group types will provide higher functional biodiversity organization to the system, and thus, contribute to more stable and resilient ecosystems (Borja *et al.*, 2009; Cusson *et al.*, 2014). However, Törnroos *et al.* (2014) observed that a decrease in taxon richness lead to an overall reduction in function, but functional richness remained comparatively high even at the lowest level of taxon richness. It confirmed that a potential for species substitutions existed to maintain ecological functioning in marine benthic systems (Frid, 2011). Frid and Caswell (2014) showed evidence, during some periods, for changes in functioning linked to changes in several (key or rivet) taxa, whereas during other periods, resilience maintained functioning in the face of taxonomic change. Clare *et al.* (2015) confirmed that ecological functioning (trait composition) was statistically indistinguishable across periods that differed significantly in taxonomic composition.

Habitat variation as a driver of functional composition and diversity suggests that habitat heterogeneity should be explicitly included within studies trying to predict the effects of species loss on ecosystem function. Between-habitat differences in functional traits are driven by differences in organisms densities rather than presence/absence of individual traits, emphasising the importance of density shifts in driving function (Hewitt *et al.*, 2008)

Impact & natural variability

Ecological and environmental variability in natural ecosystems precludes the widespread use of simplistic design and analysis tools to detect the effects of human activities on natural ecosystems (Frid, 2011; Frid and Caswell, 2014; Clare *et al.*, 2015). Scale is one of the most important concepts in impact assessment (Hewitt *et al.*, 2001). As spatial or temporal scale increases, both the number of processes and their importance in influencing local populations and communities will change, increasing the variability encompassed by the study.

The implementation of the ecosystem approach means there is a need to monitor an increased range of environmental conditions and ecological components in the marine environment. Kupschus *et al.* (2016) propose a more integrated approach based on ecosystem processes, which has significant advantages over the coordinated approach that uses ecosystem states independently and focuses on maximizing precision of each indicator. This process-based integrated monitoring is essential for the ecosystem approach, the focus on ecosystem processes providing the essential elements for future proof efficient management.

Recovery

Recovery time is strongly related to environmental characteristics (Woods *et al.*, 2016).

The prime role of hydrodynamics was observed around the UK (Foden *et al.*, 2009, 2010) where 96% of extraction activity occurs in sand or coarse sediment; the mean period of biological recovery is 8.7 years in deeper target coarse sediments with moderate tidal stress while shallow coarse sediments with weak tidal stress have a longer period (10.75 years).

Clean sand communities, adapted to high energy environments, have the most rapid recovery rate following disturbance (Dernie *et al.*, 2003; Foden *et al.*, 2009; Coates *et al.*, 2014). Simonini *et al.* (2007) observed the end of the recovery phase (structure and community composition) after 30 months in sand bottoms where dredging operations did not change the physical characteristics of the sediment, but lead to a complete defaunation at the dredged site.

To minimise recovery times following the cessation of dredging, it may be preferential to grant new aggregate extraction licences in sites of high natural disturbance where the macrofaunal communities present are less sensitive to the physical impacts caused by dredging (Cooper *et al.*, 2011a).

Extraction intensity may also influence the rate of recovery (Boyd *et al.*, 2003, 2004; Thrush *et al.*, 2008; Birchenough *et al.*, 2010; Wan Hussin *et al.*, 2012; Waye-Barker *et al.*, 2015) with times of 7 years at low dredging intensity (< 1h/ha) and up to 15 years after cessation of high dredging intensity (> 10h/ha).

Unless the physical conditions can first be restored, impacted sites may not fully recover the pristine biological community (Cooper *et al.*, 2010). Fifteen years after cessation of extraction in Dieppe, pebble crests and their associated benthic and fish communities are still present in a natural environment of coarse sands (Desprez *et al.*, 2014); this situation is similar to that of wind farms introducing artificial hard substrates in sandy sediments of the North Sea (De Troch *et al.*, 2013; Wehkamp and Fischer, 2013; Vandendriessche *et al.*, 2014; Stenberg *et al.*, 2015), with a highly species-specific attraction effect of fish (adequate refuge in combination with additional food resources).

The attainment of a functioning ecosystem is more important and more relevant to the definitions of recovery than merely achieving the presence of structural features (e.g. species presence) (Verdonschot *et al.*, 2012). The rate of stabilisation and recovery of ecological functioning appears to depend on environmental context, but can be of the order of 5-10 years in marine benthos (Coates *et al.*, 2014; Waye-Barker *et al.*, 2015).

Physical disturbances of the seabed by fishing gears (trawling and dredging) can result in permanent community changes when the frequency and extent of disturbance outstrips the recovery potential (Thrush *et al.*, 2008). For marine aggregate extraction, if exact values of acceptable limits for disturbance have yet to be developed (Cooper *et al.*, 2010), different functional metrics, used to investigate the rate of recovery in ecosystem function after dredging, indicated that the disturbed area was capable of full recovery given enough time: one or two years at a low dredging intensity site, 2-4 years after short intensive dredging events (Kenny *et al.*, 1998; Sarda *et al.*, 2000; Van Dalfsen *et al.*, 2000; Van Dalfsen and Essink, 2001); these time-scales, observed with traditional measures of abundance and biomass (Cooper *et al.*, 2005), reach up to 15 years after a long period of commercial extraction (Wan Hussin *et al.*, 2012; Waye-Barker *et al.*, 2015). But are there limits beyond which the capacity of impacted habitats to recover is compromised?

After many years of sustained dredging in North Sea, it was seen that even when one of the measured variables departed significantly from an equitable state, the effect did not persist from one year to the next; the potential for short-term partial recovery of the assemblage had not been compromised, at least in terms of abundance and species richness (Barrio-Frojan *et al.,* 2008).

Complete recovery is the return of an ecosystem to its original, pre-disturbance state, whereby the abundance, diversity, structure and functioning of the biological community are the same as prior to the disturbance (Woods *et al.*, 2016). However, system recovery may not require similar biomass, biodiversity or community composition.

Wan Hussin *et al.* (2012) stated that for measuring the recovery of macrofaunal communities after marine aggregate dredging, functional metrics are considered to be complementary to traditional environmental assessments metrics. Analyses suggest that ecological functioning can be sustained in communities undergoing long-term compositional change, as characteristically similar (redundant) taxa exhibit compensatory changes in population densities (Clare *et al.*, 2015).
Good Environmental Status cannot be defined exclusively as "pristine" status, but rather status when impacts of uses are sustainable; therefore, two conditions need to be met (Rice *et al.*, 2012):

- pressure does not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes;
- recovery from perturbation, such that attributes lie within their range of historical natural variation, must be rapid and secure.

For Borja (2014), recovering ecosystem structure and functioning is a grand challenge; therefore, studies are needed for a deeper knowledge of recovery processes (Borja *et al.*, 2010), and for promoting ecological restoration to repair damaged ecosystems.

<u>Restoration</u>
Restoration ecology is just emerging as a field in aquatic ecology and is a site, time and organism group-specific activity. It is therefore difficult to generalise.
Few studies provide evidence of how ecological knowledge might enhance restoration success (Cooper, 2011b, 2012; Verdonschot *et al.*, 2012), as well as any possible modes of intervention to remedy any critical damage caused (Collins and Mallinson, 2007).
Seabed landscaping aims to create diverse habitat conditions in sand extraction areas by leaving large-scale bed forms on the dredged sea bed after completion of the works. In this way, landscaped mining areas are hypothesized to encourage recolonisation and promote higher biodiversity and productivity after completion of the dredging works (de Jong *et al.*, 2014, 2016; Rijks *et al.*, 2014). Results showed that there were 5 times more fish in the deep landscaped extraction site than outside.
Effects mostly occur only in short-term and at local scale, the organism group(s) selected to assess recovery does not always provide the most appropriate response, the time lags of recovery are highly variable, and most restoration projects incorporate restoration of abiotic conditions and do not include abiotic extremes and biological processes.

<u>Conclusion</u>
With respect to descriptor (6) WGEXT recognises that direct changes to the function and structure of ecosystems, particularly physical parameters, will occur as a result of the extraction of marine sediments. The exploitation of marine aggregates should preferably take place in naturally unstable bottoms (e.g. coarse sand dunes), where benthic communities are poor (<5 g/m²), adapted to regular bottom disturbance, and able to rapidly recolonize exploited sites (Cooper *et al.*, 2005). But many extraction sites are targeted for gravel and sand dunes would not provide the desired material.
However, the group are content that in the context of appropriate consent regimes which provide for rigorous environmental assessment and evaluation of each proposal to extract sediment, these impacts may be considered to be within environmentally acceptable limits and therefore not adverse (Cooper *et al.*, 2011a).
WGEXT suggest that in defining "adverse" it should be accepted that direct changes to the physical structure of the seabed will result from the extraction of marine sediments. Defining "adverse" as being no environmental change from existing (pre-dredge) conditions would, in the opinion of the group, be inappropriate and detrimental to the continued ability of member countries to extract marine sediments from their seabed.

Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

Changes in seabed morphology and associated hydrodynamic effects have the potential to **affect adjacent coastlines** (Kortekaas *et al.*, 2010). If dredging is undertaken within the area of sediment movement known as the 'active beach profile' then material can become trapped within depressions caused by dredging, preventing it from moving back onshore during calmer conditions (Brampton and Evans, 1998).

In the North Sea, below the 25 m depth contour, no impacts were observed on wave regime, sediment transport or stability of the coastline. Further onshore, the removal of sediment during marine aggregate extraction may impact sediment transport pathways that replenish the coastline.

In southern Portugal, sand was dredged on the continental shelf for beach nourishment and a research project (SANDEX) assessed its physical effect on the seabed and coastline. Around 370,000 m^3 of sand were extracted leaving a rectangular sandpit with dimensions of 900 m length and 150 m width, located 4000 m away from the shore at depths between 15-20 m, with average depth of the excavation around 5 m (Gonçalves *et al.*, 2014). Numerical modelling showed that the tidal flow and the orbital wave velocities within the pit and neighbouring areas were modified by the presence of the pit. The excavation influenced the tidal flow in an area of approximately 3000 * 3000 m^2 around it. In that area the maximum velocity increase was 2%, occurring in the nearby surroundings of the pit, and the maximum decrease was 16%, in the deepest zone of the pit. The orbital velocities for the storm wave conditions showed a decrease of 15% within the pit and its influence extended up to the 4 m contour, not reaching the shore (Lopes *et al.*, 2009). Bathymetric analysis between May 2006 and November 2008 showed an accretion of sediments of around 60,000m^3 which would put the recovery time of excavation at about 24 years, very similar to modelling results. Phillips (2008) investigated South Wales areas where critical beach loss has been associated with dredging activities; five years of beach monitoring did not find a qualitative or quantitative link between marine aggregate dredging and beach erosion; natural changes, such as changing wind direction and increased easterly storms were most significant in affecting beach formation processes.

The removal of a significant thickness of sediment results in a localised drop in current strength associated with the increase in water depth. This reduced strength of the bottom current can cause the deposition of fine sediments within the dredged depressions from overflow discharges (Duclos *et al.*, 2013; Krause *et al.*, 2010) and/or from natural sediment transport (Desprez, 2000; Cooper *et al.*, 2007 and Le Bot *et al.*, 2010). For the seaward harbour extension of the Port of Rotterdam, large-scale sand extraction down to 20m below the seabed, generated a strong increase in the fraction of fine muddy sands in the troughs and deepest areas of the extraction site (de Jong *et al.*, 2014).

Conclusion

In general and in relative terms, the dimensions of dredged pits are so small that the deepened area has little influence on the macroscale current pattern. Furthermore, it was concluded that, in most cases, the current pattern would only be changed in the direct vicinity of the dredged area.

Descriptor 8: Contaminants

In an extraction site located near the mouth of the River Seine estuary, IFREMER studied the effect of marine aggregate extraction on water quality due to the potential remobilisation of contaminants from sediments (Menet-Nedelec *et al.*, 2015). The main results of this study were as follows:

- among contaminants associated with the turbid plume, only trace metals could be quantified;
- desorption in the dissolved phase concerned a very low fraction of these trace metals;
- concentrations in trace metals in both particulate and dissolved phases were back to the pre-dredge concentrations one hour after the end of extraction activity; the chemical impact was temporary and not last longer than the turbid plume;

This study concluded there was no need for a long-term monitoring (period covered by the mining license) of the water quality.

Descriptor 11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

Attention to underwater sound in relation to dredging and sediment extraction is increasing during the last years, as sound is utilized by many marine organisms to sense the environment around them to find prey. Consequently, an increase in anthropogenic low-frequency noise, such as that produced by dredging (Dreschler *et al.*, 2009; Robinson *et al.*, 2011), has the potential to cause adverse effects. The value of 200 kHz for sonar sources is an accepted threshold (D 11.2).
The extent to which effects disseminate through the foodweb to marine mammals is unknown, but speculated effects are given, based on available data.
Extensive variability exists between hearing sensitivity of **fish** species, but in general, they are sensitive to low frequencies (Popper and Fay, 2011), which puts them at risk from dredging noise. Few studies have looked at dredging noise specifically (Lepper *et al.*, 2012), but avoidance of low-frequency vessel noise by some fish species has been reported (de Robertis and Handegard, 2013) and Handegard *et al.*, (2003) noted vertical and horizontal avoidance by cod (*Gadus morhua*) of a bottom-trawling vessel. Dredging noise is unlikely to result in direct mortality, or permanent hearing damage of fish, but long-term exposure could theoretically affect fitness of some individuals.
Responses to particle motion of low-frequency sound have also been recorded in **cephalopods** (Mooney *et al.*, 2010), which can form an important part of the diet of some marine mammals. Low-frequency noise in the 1 Hz-10 kHz band altered cephalopod breathing rhythms and movement.

Dredging has the potential to impact marine **mammals**, but effects are species and location-specific, varying also with dredging equipment type. In general, evidence suggests that if management procedures are implemented, effects are most likely to be masking and short-term behavioural alterations and changes to prey availability (Todd *et al.*, 2015). Exclusion of prey from foraging areas has potential to impact marine mammals negatively, but the extent to which this occurs depends on the significance of the feeding ground, ability to switch prey species, and availability of alternative foraging areas. The level of effect is therefore species- and context-dependent.

The **sound level** radiated by a dredger undertaking full dredging activities is in line with the one expected for a cargo shipping travelling at moderate speed (de Robertis and Handegard, 2013; Robinson *et al.*, 2011).

However, extracting gravel does cause additional noise impact (Dreschler *et al.*, 2009; Robinson *et al.*, 2011). In the UK, underwater noise from aggregate extraction has been largely discounted as a significant impact. Similarly, in the Netherlands, the noise levels from dredgers were not in the top seven major underwater sound sources (Ainslie *et al.*, 2009).
During the reclamation works for the enlargement of the harbour of Rotterdam, a monitoring program on underwater sound measured the noise from a large range of trailer suction hopper dredgers (in power and in volume, 2000 to 22000 m^3); for all frequencies, the noise of dredging and dumping was less than the noise of transit (Heinis, 2013).

Conclusion

With respect to this descriptor, WGEXT recognises that extraction of marine sediment does generate underwater noise; however, aggregate extraction is only contributing to the noise of shipping and introduces no negative effects from the extraction itself.

DISCUSSION

A method for assessing the vulnerability of marine ecosystems to various anthropogenic threats by impact categories has been proposed by Halpern *et al.* (2008) and found that, in decreasing order of perturbation, invasive species, pollution, management), toxic blooms, demersal fisheries (Blyth *et al.*, 2004; Lambert *et al.*, 2014) and the phenomena of hypoxia have a higher impact than extraction of marine aggregates.

Prevention
Assessments should take account of the 2003 "ICES Guidelines for the Management of Marine Sediment Extraction", as adopted by OSPAR, which provide for the implementation of appropriate extraction site locations, and implementation of mitigation and monitoring programmes:
- encouraging an ecosystem approach to the management of extraction activities and the identification of areas suitable for extraction.
- protecting sensitive areas and important habitats (such as marine conservation areas) and industries (including fisheries), and the interests of other legitimate uses of the sea.
- ensuring that methods of extraction minimize the adverse effects on the environment and preserve the overall quality of the environment once extraction has ceased.

Impact
Monitoring programs (effort and quality) have to provide sufficient information to allow a confident assessment of GES (van Hoey *et al.*, 2010). But there is a need to consider that the geographical scale at which the MSFD operates is much larger than single project assessments.
As extraction activity is often taking place in a relatively small area and often only for a limited amount of time, the spatial and temporal components of the activity and related pressures and impacts are also limited (ICES, 2016). For licensing, the level of detail of information needed is much greater to make any sense in terms of a time and spatial adequate assessment to fulfill MSFD requirements.

The appropriate scale at which measures are taken is likely to be a key issue for various descriptors and the cost of the monitoring must consequently also be taken in account (Borja and Elliott, 2013).

Recovery

The possibility of recovery after sediment extraction should be acknowledged by incorporating it in the criteria and by taking it into account with the assessment of the Good Environmental Status.

It is important to realize that biological/ecological recovery can be reached without recovery of the physical state, often to a different state according to the new sediment. Even in the case of permanent loss of the original morphological state of the seafloor the benthic fauna can recover and the structure and functions of the ecosystems can be safeguarded and benthic ecosystems not adversely affected.

The time scale on which a specific activity and pressure and impact should be assessed is an issue that needs to be looked into. Nature itself is continuously changing and trends, whether or not human induced, are not easy to include (ICES, 2016).

Mitigation

To enable sustainable use of marine resources (Birchenough *et al.*, 2010), there is a clear need for enforcing management measures such as:

- seasonal closures for specific areas (i.e. during recruitment seasons),

Such seasonal restrictions exist in a few countries (UK, France, Finland) to protect spawning periods of vulnerable fish species such as herring during winter or sole during spring (ICES, 2017)

- rotation of dredging intensity to allow recolonisation and recovery of macrobenthos,

In a local context, controlling the area and intensity of dredging and allowing undisturbed deposits to act as refuges between dredged furrows may be an effective measure for enhancing the rehabilitation of the seabed. There may also be environmental benefits from rotating dredging operations across different zones and leaving "fallow" areas to rehabilitate for several years before reworking. Future case studies are needed on the consequences of marine aggregate extraction on marine biota over sufficiently long time-scales to underpin the derivation of reliable and scientifically credible models (Barry *et al.*, 2010).

- exploratory restoration techniques in areas where the seabed has been impoverished as a result of extraction activities.
- prevention of screening.

Restoration (and Landscaping)

In the Netherlands an experiment was done to deliberately change the topography within a dredging site with the aim of creating another habitat type which potentially could result in a different species composition (van Dalfsen *et al.*, 2004; van Dalfsen and Aarninkhof, 2009; de Jong *et al.*, 2014, 2015, 2016).

To bring forward the interpretation of GES Descriptors from the point of view of sediment extraction, the concept of switching to an approach based on functionality and recoverability should not be lost for future work, as stated in the Advice of ICES. Studies are needed for a deeper knowledge of recovery processes in structure and function through time and for promoting ecological restoration to repair damaged ecosystems (Borja *et al.*, 2010).

Gaps

This review also aimed to highlight the following gaps to expand on the current knowledge to fulfill MSFD requirements.

D 1: requirement of high-resolution maps of habitat types (Woods *et al.*, 2016)

D 3: mapping of spawning areas (ICES, 2011)

D 4.2: proportion of selected species at the top of food webs

D 431: abundance/distribution of groups with fast turnover

lack of primary production indicators.

D 6.2: size composition of a community reflected by the proportion of small and large individuals
D 6.2.3: proportion of biomass or number of individuals in the macrobenthos above some specified length/size
D 6.2.4: parameters describing the characteristics of the size spectrum of the benthic community
D 7: Permanent alterations of hydrographical conditions

Limits of MSFD descriptors

The European Marine Strategy Framework Directive aims at good environmental status (GES) in marine waters, following an ecosystem-based approach, focused on 11 descriptors related to ecosystem features, human drivers and pressures. Furthermore, 29 subordinate criteria and 56 attributes are detailed in an EU Commission Decision.
The analysis of the decision on GES and the associated operational indicators revealed ambiguity in the use of terms, such as indicator, impact and habitat and considerable overlap of indicators assigned to various descriptors and criteria.
Berg *et al.* (2015) suggest re-arrangement and elimination of redundant criteria and attributes avoiding double counting in the subsequent indicator synthesis, a clear distinction between pressure and state descriptors and addition of criteria on ecosystem services and functioning.
In documents on D1, D3 and D4, marine sediment extraction is mostly not directly mentioned as a pressure.
The interconnection between Descriptor 1 and Descriptor 6 is showed by almost the same wording for D1C5 (for pelagic species) and D6C5 (for benthic species).
In EC (2015a), pressures are not indicated, but it is mentioned that there are strong links with descriptors that do indicate pressures like D6 and D7.
Also in later documents, e.g. EC (2016b), the link between D1, D4 and D6 is present.

Improvements (?) of MSFD descriptors

Often the descriptors 1 (biodiversity), 3 (commercial fish and fisheries products), 4 (food webs) and 6 (seabed integrity) are combined into one integrated descriptor: 'marine ecosystem' (I&E and EA, 2015).
For D6 it is clearer that marine sediment extraction can influence the integrity of the sea-floor. That can also be the case for altering of hydrographical conditions (D7). As a sound producing activity, dredging can influence D11 as well.

- Descriptor 1
The most important criteria for species are already formulated in the Habitat Directive, but in draft 4 of the Proposal for a Commission Decision on GES Criteria (EC, 2016b) the extra criteria under MSFD are formulated:
- D1C1: Species distributional range and, where relevant, patterns is in line with prevailing physiographic, geographic and climatic conditions
- D1C2: Population abundance (numbers and/or biomass) of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured
- D1C3: population demographic [and physiological] characteristics (e.g. body size or age class structure, sex ratio, fecundity, survival and mortality rates) of the species are indicative of a natural population which is not adversely affected due to anthropogenic pressures
- D1C4: the habitat for the species has the necessary extent and condition to support the different stages in the life history of the species

- D1C5: The condition of the habitat type, including its biotic (typical species composition and their relative abundance) and abiotic structure, and its functions, is not adversely affected.

- Descriptor 4

In draft 4 of the Proposal for a Commission Decision on GES Criteria (EC, 2016b) four criteria related to anthropogenic pressures are mentioned. They are focussed on:

- D4C1: species distribution and their relative abundance (diversity) of the tropic guild
- D4C2: abundance (numbers or biomass) across trophic guilds
- D4C3: size distribution of individuals across relevant species of the trophic guild
- D4C4: productivity of the trophic guild.

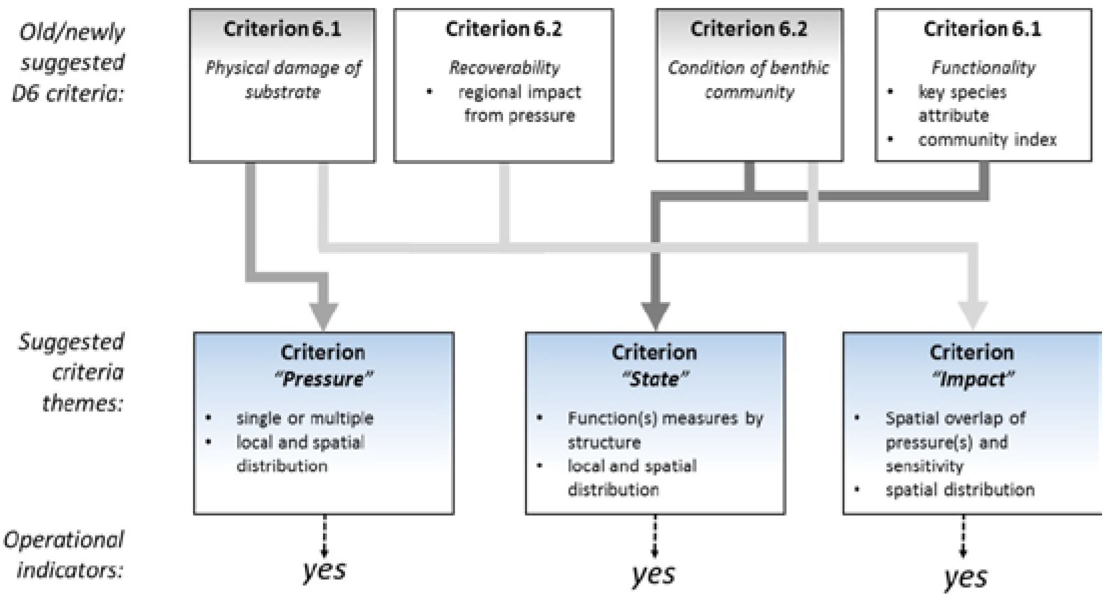
In the ICES Special Request Advice (20/03/2015) (ICES, 2015) on the EU request on revisions to MSFD manuals for D3, 4 and 6, it is mentioned that only a few EU-countries mention pressures of food web components, in particular fisheries. Extraction as such is not mentioned.

But physical disturbance of the habitat and (benthic) fauna is currently the most determining factor for the status of the marine ecosystem and therefore also decisive for the functioning of food webs (I&E and EA, 2015).

- Descriptor 6

At an ICES workshop held in February 2015 (ICES ACOM Committee, 2015), aggregate extraction is mentioned as one of the pressures that are causing physical habitat loss and damage and can influence the integrity of the seafloor. To judge the pressure, a consideration of spatial and temporal scales is crucial. Mostly physical damage is mentioned as the main pressure, but it was put forward to integrate physico-chemical disturbances (e.g. anoxic seafloors in the Baltic Sea).

The main topic was the incorporation of the newly proposed criteria 'Functionality' and 'Recoverability' in combination with the existing criteria 'Physical damage' and 'Benthic conditions' in D6. It was proposed to adopt a concept including three criteria themes (i.e. pressure, state and impact) linked with the existing and newly suggested criteria (figure 1).



Conceptual diagram illustrating how work under both the old (2010) and the newly suggested (2014) criteria can be merged for a conceptually stronger assessment and use of existing indicators/data to measure progress towards GES for seafloor integrity (ICES ACOM, 2015).

From the point of view of marine sediment extraction this is a good approach. Even when the benthos is completely removed, total recovery by recolonization is possible. Therefore the criteria theme 'recovery' is important for marine sediment extraction.

The idea to incorporate recovery in the formulation of criteria has not survived so far. In the document on Progress on art.8 MSFD assessment guidance (EC, 2016a) three criteria are mentioned:

- D6C1: Spatial extent and distribution of physical disturbance
- D6C2: Spatial extent of adverse effect of physical disturbance per habitat type
- D6C3: Spatial extent and distribution of physical loss.

Only the second one gives room for the acknowledgement of recovery.

In draft 4 of the Proposal for a Commission Decision on GES Criteria (EC, 2016c) the formulation and numbering are slightly different:

- D6C1: Spatial extent and distribution of physical loss (permanent change) of the natural seabed.
- D6C2: Spatial extent and distribution of physical disturbance pressures affecting the seabed.
- D6C3: Spatial extent of each habitat type which is adversely affected by physical disturbance through change in its structure and function (species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species). The areas must be expressed as a proportion (%) of the total area (D6C1, D6C2) or as proportion (%) per habitat type (D6C3).

In this proposal physical loss is regarded as a permanent change to the seabed which has or is expected to last for a period of two reporting cycles (12 years) or more. This seems to give room for recovery, but it should be mentioned that biological/ecological recovery can be reached without recovery of the physical state.

In the Proposal for a Commission Decision (EC, 2016c) two extra criteria about benthic habitats are mentioned that are related to both D1 and D6.

- D6C4: The extent of loss of the habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area. In cases where the loss exceeded this value in the reference year baseline used for the Initial Assessment in 2012, there shall be no further loss of the habitat type.
- D6C5: The condition of the habitat type, including its biotic (typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species) and abiotic structure, and its functions, is not adversely affected.

Although the formulation of this last two criteria, especially D6C5, sound more like descriptors the idea is to operationalise these criteria by setting values for the proportion (in %) for the extent of loss and thresholds for the condition of habitats.

In the *ICES Special Request Advice (20/03/2015)* (ICES, 2015) on the EU request on revisions to MSFD manuals for D3, 4 and 6, three actions are proposed:

- develop and test standards for human pressure on benthic habitats.
- address the role of scale and connectivity in setting boundaries for the sea-floor.
- assess the recoverability of sea-floor integrity.

- Descriptor 7

In draft 4 of the Proposal for a Commission Decision on GES Criteria (EC, 2016c) the criteria are formulated:

- D7C1: Spatial extent and distribution of hydrographical conditions (e.g. changes in wave action, currents, salinity, temperature, oxygen) to the seabed and water column, associated in particular with physical losses (permanent changes) to the seabed.

- D7C2: Spatial extent of each benthic habitat type adversely affected (physical and hydrological characteristics and associated biological communities) due to permanent alter-ation of hydrographical conditions.

In EC (2015b) changes of the morphology of the seabed is mentioned as one of the pressures. Sediment extraction will, at least temporally, change the morphology. An important point is the spatial and temporal scale of this change and the scale of its effects. The document also mentions the ICES Guidelines on marine sediment extraction (OSPAR, 2003).

D7 is a pressure descriptor that focuses on the permanently altered hydrographical conditions. The pressure is change in morphology of the seabed/coast or change in habitat (e.g. from sediment to hard substrate) (EC, 2015c). In this sense marine sediment extraction can be a pressure for D7, especially when it is a large-scale extraction or an extraction in a specific vulnerable area. Related to D7C2 is the risk of oxygen depletion in case of extractions with a large depth below the seabed and/or in case of very low dynamic waters.

- Descriptor 11

In draft 4 of the Proposal for a Commission Decision on GES Criteria (EC, 2016b) the criteria are formulated:

- D11C1: The spatial distribution, temporal extent (number of days and their distribution within a calendar year) and the levels of anthropogenic sound sources do not exceed values that are likely to adversely affect marine animals.

- D11C2: Levels of anthropogenic continuous low-frequency sound in two '1/3-octave bands' do not exceed values that are likely to adversely affect marine animals.

CONCLUSION

This review of existing research (185 references) provides information on research related to various effects of marine aggregate extraction on the marine environment, and the connection with criteria for its Good Environmental Status, which are relevant to several descriptors of the MSFD, as summarized in the following table:

Table 5: Number of references contributing to the MSFD descriptors relevant to marine aggregate extraction.

MSFD Descriptors	Number of references contributing to descriptors knowledge
D1: Biological diversity	46
D3: Fish resources	12
D4: Marine foodwebs	18
D6: Seafloor integrity	111
D7: Hydrographical conditions	12
D8: Contaminants	1
D11: Underwater noise	11

This review not only highlights gaps to expand on the current knowledge to fulfil MSFD requirements, but also considers that the geographical scale at which the MSFD operates is much larger than single project assessments. As extraction often takes place in a relatively small area, and often only for a limited amount of time, the spatial and temporal components of the activity and related pressures and impact are limited.

Such a review is a tool to improve understanding of the impact of extraction activity on coastal and marine ecosystems and to optimise the management of this activity and its sustainable development. This work is directly addressing policy and management needs, particularly in support of the EU's Marine Strategy Framework Directive (Austen *et al.*, 2018).

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Annex 7: ToR D. Ensure outputs of the WGEXT are accessible by publishing as a group and creating a webpage on the ICES web-site

WGEXT organized a session on the Annual Science Conference 2016 in Riga. Among the speakers were several members of WGEXT. The work of WGEXT within ICES was good presented as follows both to ICES and to other organizations.

ICES Annual Science Conference 2016: Theme session K (Friday, 23 September 2016)

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)

Introduction: Marine sediment extraction in the North Atlantic, including 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 ICES countries most marine sediment extraction takes place in the Netherlands, The United Kingdom, Denmark, Belgium, France and Germany.

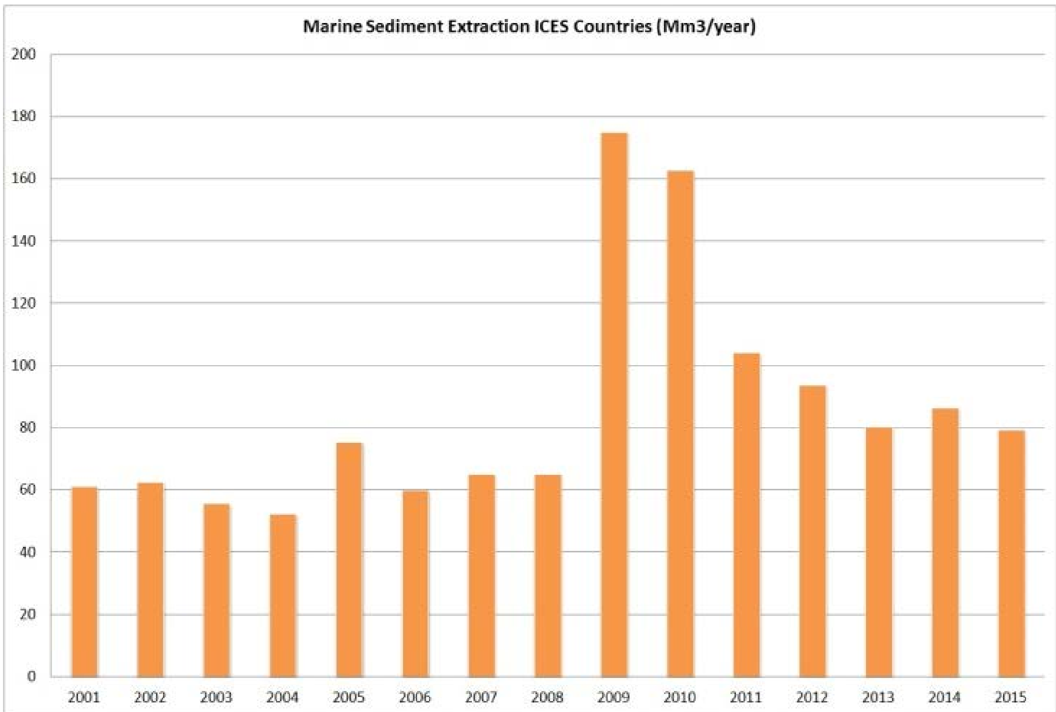


Figure 1. Marine sediment extraction in ICES countries (2001–2015).

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, 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 are minimized by mitigation measures that are beneficial for the recolonization of the benthic fauna and recovery is achieved within an acceptable period of time.

To ensure the goals of mitigation are reached extensive monitoring programmes are executed on suspended matter, recolonization, underwater noise, effects on other use 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. Also terms of reference have 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.

In general the session can be 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: To decide where and how to extract marine sediments it is necessary to have insight in the location of useful resources and in the presence of habitats that are sensitive to the effects of marine extraction.

Research of the resources of marine sediments as sand, gravel and shells is done for a long time by sampling and seismic investigations followed by a geological interpretation. In the last few years several projects are started to improve the knowledge of resources by modeling. 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 ans 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.

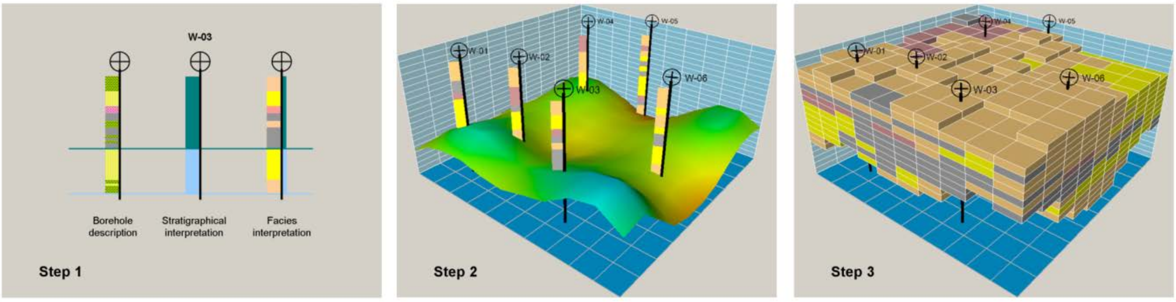


Figure 2. Voxel model.

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 which gives a better definition for the boundary of nature 2000 areas and prevent 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 a 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 an advice to exclude extraction, unless the effect have been assessed and shown not to be detrimental.

Lessons from case studies (impacts/monitoring/recovery): To mitigate the negative impacts of marine sediment extraction on other use of the sea and on the ecosystem, including benthic fauna and fish monitoring of the effects of extraction is necessary. The results of monitoring can lead to improved regulation of extraction both towards a better protection of the ecosystem and towards a less restriction of extraction activities.

In the ICES countries the extraction of marine sediments are very different in items as geological setting, ecological habitats and intensity of dredging. As a consequence the items and the way monitoring is executed are different. For example, the long term extraction in gravelly areas in the English Channel asks for a different monitoring approach than the short but intensive extraction for the Rotterdam harbor.

Jyrki Hämäläinen and Ad Stolk both give a presentation on the monitoring of the extraction for the impact of extraction for enlarging of the harbor of Helsinki and Rotterdam respectively. For the harbor of Helsinki over 6 million m^3 of sand and gravel was extracted. The monitoring was executed before, during and after the activities and was for a large part focused on fish and fisheries. The area was 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 they have not changed in 10 years. Older extraction pits were not changed for 25 years. This gives rise to reconsider extraction methods for the future.

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

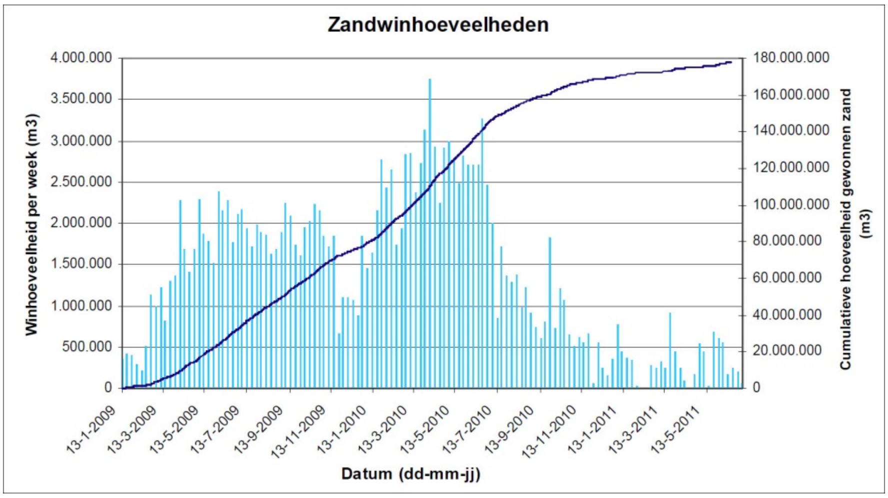


Figure 3. Marine sand extraction for Rotterdam harbor. In light blue (left scale) weekly amounts. In dark blue (right scale) total amount.

The area of the extraction pit was decreased to 16 km² by increasing the depth 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 program was executed focusing on the effects of suspended matter on benthos and N2000 areas, under water noise and recolonization 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 recolonization 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 macrobenthos 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. Annelies De Backer showed how the benthic sandy habitat of the Belgian Continental Shelf is impacted by different values of these parameters (fig.4).

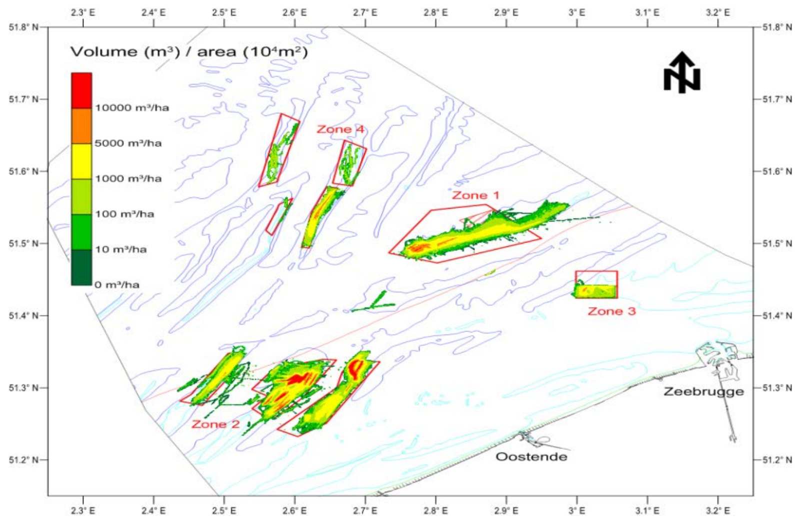


Figure 4. Extraction zones on the Belgium Continental Platform.

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 can be that the area is a very dynamic system whit 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 for the effect on fish in and near extraction sites in 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 Baie de Seine. The study was done in the dredging areas itself, 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 reduces, 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). This gives rise to methods to mitigate the effects of extraction and minimize the traditional completion for space between fisherman and mining companies.

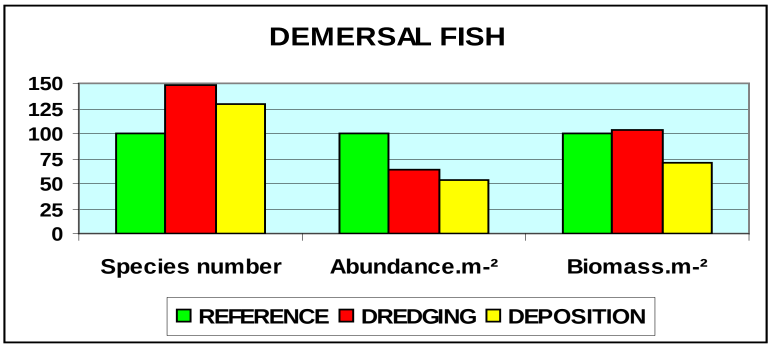


Figure 5. Effect of 10 years of extensive dredging on demersal fish in and near the Dieppe extraction site.

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 the goals of the Marine Strategy Framework Directive if a good extraction strategy is followed.

Low extraction intensity and/or a limited duration of extraction can minimize negative effects.

In a poster Vera Van Lancker described an investigative monitoring with focus on D6 and D7 of the MSFD. Sand extractions 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 elucidates a new monitoring approach characterized 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 (fig.6) that are expected to offer better environmental protection , whilst at the same time significantly reduce the costs of monitoring.

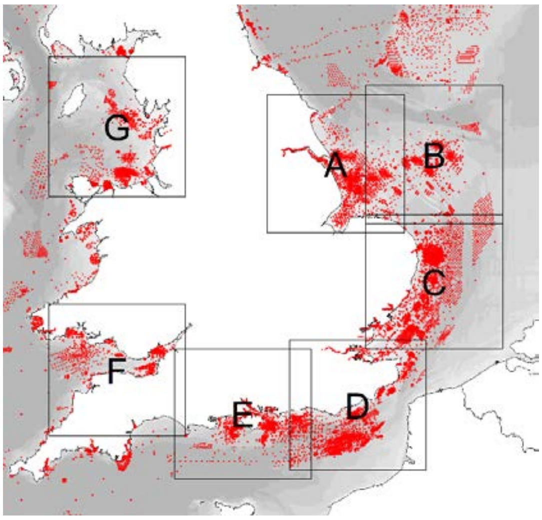
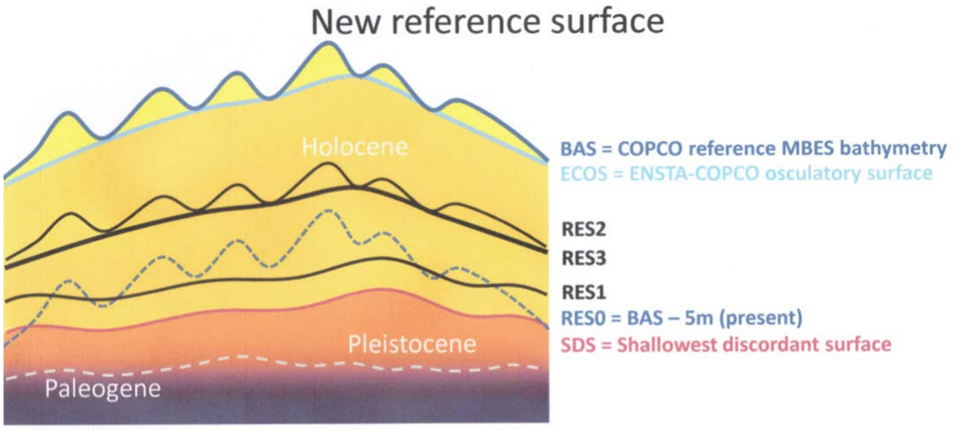


Figure 6. Regional Seabed Monitoring Plans in the UK.

In Belgium research is done effort is done to minimize the impact of extraction to the improve the monitoring of resources for extraction and to monitor the effects of extraction. The legislation in Belgium limits the extraction in a general way 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 most vulnerable areas, allow no changes in surface sediments, conservation of sand bank morphology and be economically sustainable



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

Figure 7. New reference surface for marine extraction in Belgium.

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

The modeling this behavior 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.

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 Appendix).

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 emphasized 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.

Appendix

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, macrobenthos, 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, seafloor 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: Minimization 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

Annex 8: ToR I. Cumulative assessment guidance and framework for assessment should be developed

Jan van Dalfsen

Introduction

Human activities in the marine environment have the potential to impact both coastal and offshore environments through a wide range of effects. The large number of sectors that use and exploit the ecosystem and its components generates a great variety of pressures and through a complex network of interactions this results in a wide range of impacts (Knights *et al.*, 2013). The response of an environmental system to a human induced impact is the product of often complex ecological interactions that give rise to either direct linear but more often to non-linear responses including synergistic effects, threshold effects and compounding effects. The final impact will be the end product of the impacts from all individual activities and will be governed by a combination of direct and indirect impacts, cumulative impacts and impact interactions (Walker 1999).

With growing intensity of marine activities, there is an increasing demand to develop policy and management to cope with their impacts. Existing maritime activities have expanded and coastal and offshore waters around the world are being used in new ways (Anderson *et al.* 2013). This together with inland developments introducing new substances and materials has caused all kinds of mostly unintentional effects such as regime shifts, altered food web structures and other adverse effects, which have been observed especially in coastal environments and in marginal seas (Korpinen *et al.* 2012). Even before the publication of the work of Halpern *et al.* (2008) which brought the combined effect of different stressors to the marine environment clearly to attention to the wider public, attempts were made to address cumulative impacts in marine management. This with the aim of developing widely accepted and harmonized processes and methodologies to assess these impacts.

In order to protect the environment it is a common use to conduct an environmental assessment by which the anticipated effects and implications on the environment of a proposed development, project or plan are described, prior to their approval or authorisation. In the European Union guidance is provided by the Directive 2011/92/EU (known as 'Environmental Impact Assessment' – EIA Directive) or, for public plans or programmes, by the Directive 2001/42/EC (known as 'Strategic Environmental Assessment' – SEA Directive). Soon however, it was recognised that many of the environmental effects may not result from direct impacts from individual projects or developments only, but also from an interaction between effects, generated by often different activities in time and space. In response to this shortcoming of the EIA, the assessment of indirect and cumulative impacts and impact interactions has emerged (Spaling 1993, Parr 1999). In Europe cumulative impacts are considered since the implementation of the EC Directive (85/337/EEC) in 1988. With the amendment (11/97/EC) tot the Directive 85/337/EEC it is now required that an EIA should also cover the direct effects and any indirect, secondary, cumulative, short, medium and long term, permanent and temporary, positive and negative effects of the project as well as that the “inter-relationships” and “interactions” between specified environmental effects must be considered.

In June 2008 the European member states adopted the Marine Strategy Framework Directive 2008/56/EC (MFSD). This MSFD aims to protect the marine environment across Europe. The Directive requires Member States to prepare national strategies to manage their seas to achieve or maintain Good Environmental Status (GES) by 2020 and to protect the resource base upon which marine related economic and social activities depend. These marine strategies shall be put in place with the aim of protecting and preserving the marine environment, preventing its deterioration as well as restoring marine ecosystems in areas where they have been adversely affected. These measures should also prevent and reduce inputs in the marine environment so as to ensure that there are no significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the European seas. In order to achieve or maintain a good environmental status in the marine environment it was decided to apply an ecosystem-based approach as the core concept in the management of human activities under the EU Marine Strategy Framework Directive (Anderson *et al.* 2015).

Dredging activities such as for aggregate extraction, dredging for navigational purposes, dumping of dredged material, offshore construction works and coastal development create direct pressures on seabed habitats including, such as loss of habitat, habitat change and physical damage to the habitat, and with that to the species that depend upon it (Tillin & Tyler-Walters 2013). Although extraction activities often occurs in discrete locations, dictated by the spatial extent of the resource and conducted in single operations, there is a potential for cumulative effects from multiple dredging activities in close proximity to one another, or for effects of aggregate dredging in conjunction with other activities, for example commercial fishing, capital dredging activities or offshore renewable energy (OSPAR 2009b). .

So from the ICES WGEXT it is a logical step to have a look at the consequences of the aforementioned initiatives and EU Directives for the aggregate extraction industry, research and policy and management developments. The development of a more holistic (ecosystem level) approach to marine environmental management, including evaluations of cumulative effects of extraction activities was addressed by the ICES WGEXT (2009).

The overall aim of this chapter is to provide information and guidance on the assessment of cumulative impacts with regard to the goals of the Marine Strategy Framework Directive due to potential impacts of aggregate extraction on marine and coastal habitats and species listed in Annexes I and II of the Habitats Directive.

In particular, this chapter will:

• review and summarise activities undertaken on cumulative impacts assessment in the ICES Area and beyond

• investigate the methods used for cumulative impact assessment with a focus of relevance to aggregate extraction

• make recommendations on how cumulative impacts assessment can be incorporated in aggregate extraction policy making and (licence) procedures.

Cumulative effects in marine legislation

Environmental regulations, are more and more incorporating cumulative effects because there is consensus among scientists and managers that a single activity, single stressor –impact effect approach is not sufficient to assess the implications of multiple stressors on the diversity of ecosystem components and ecosystems. This has resulted in the need for an integrated approach to science and management in which the assessment of cumulative effects considers both the exposure to multiple stressors and the consequence of these stressors for multiple components within and across ecosystems (Murray *et al.* 2014).

The following regulations are relevant to the development and implementation of CEAs

The UN Convention on Biological Diversity which objective is to combine human desires and needs with the conservation of a healthy environment. To reach this goal, it is necessary to manage coasts and seas in a comprehensive and integrated way, accounting for the diversity of these ecosystems and the combined effects of multiple stressors. Ecosystem-based Marine Spatial Planning is a well-recognized approach to such integrated management (Foley *et al.* 2010).

The EU Marine Strategy Framework Directive (2008/56/EC) as it states that coastal waters, including their seabed and subsoil, are an integral part of the marine environment.

The Water Framework Directive (WFD) as, apart from the extensive geographical overlap with MSFD, many of the proposed measures in riverine and coastal waters to meet the objectives of the WFD may also have significant (positive) consequences for the MSFD targets and descriptors (CEDA NAVI 2015).

The EU Directive (85/337/EEC) implemented in 1988 and the European Environmental Impact Assessment Directive (Directive 2011/92/EU). Both address the need to include an analysis of cumulative effects within an EIA.

The EU Habitats Directive (92/43/EEC) adopted in 1992 states that "Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives."

OSPAR has adopted ICES guidance on environmental impacts of aggregate extraction (OSPAR Agreement 2003-15). It promotes the management of marine aggregate operations in such way that the footprint and potential resource conflict with other marine users is minimised. In the OSPAR maritime area CEAs are required for new projects, plans and programmes through the Espoo Convention (incl. Kiev Protocol), the afore mentioned EU EIA Directive (Directive 85/337/EEC, as amended by Directives 97/11/EC and 2003/35/EC), the SEA Directives (Directive 2001/42/EC) and the EU-Habitats Directive (Council Directive 92/43/EEC) (OSPAR 2009).

Under the Marine Strategy Framework Directive eleven so called elements where identified to describe the Good Environmental Status (GES) elements of the ecosystem. Several of these GES elements are of importance to dredging activities (CEDA ref). Relevant descriptors to extraction as an activity are the MSFD GES descriptors: biological diversity (D1), marine food webs (D4), sea-floor integrity (D6), hydrographical conditions (D7) and underwater noise (D11).

Definitions

Although a single formal definition of cumulative effects does not exist and there is also no consensus on how to undertake a cumulative effects assessment, several definitions for cumulative effects and cumulative effects assessment can be found that vary slightly:

Cumulation: outcome of effects to the environment from a single activity or multiple activities overlapping in space and or time.

OSPAR (2008) defined cumulative effects as: "all effects on the environment which result from the impacts of a plan or project in combination with those overlapping effects from other past, existing and (reasonably foreseeable) future projects and activities".

"Cumulative effects assessment is a systematic procedure for identifying and evaluating the significance of effects from multiple pressures and/or activities. The analysis of the causes, pathways and consequences of these effects is an essential part of the process"

Cumulative effects assessment is "the process of evaluating the potential consequences of activities or development relative to existing environmental quality to predict changes to the environment due to the project combined with the effects of other past, present and reasonably foreseeable future activities" (Dubé, 2003).

Basic principles of cumulative effect assessment

The international community is presently active in addressing cumulative environmental impact assessment and in developing methodologies to do so. Even when there is a direct effect between a single human activity which produces a single stressor it is still not always easy to predict its impact on an ecological component or an ecosystem. The reason for this is that stressors interact with each other and can be additive or non-additive, and can multiply (synergistic) or reduce effects (antagonistic) predicted from single stressors (Crain *et al.*, 2008). Because of all these potential interactions it is even more difficult to describe and predict the response of ecological components to multiple stressors.

Although there is to date no common methodology or understanding of CEA, the general approach is that of an "impact chain" in which source → pressure → effect → ecosystem component exposure pathways are identified. Describing the different pathways makes it possible to construct an activity–pressure–ecological component linkage matrix (see Knights *et al.* 2013). The pressure is the mechanism through which an impact occurs. Such a matrix describes the potential for an impact on an ecological component from an activity or sector.

The results are presented in score tables and visualised in distribution maps. To do this the intensity of each stressor is mapped as well as the location of each habitat type or presence of an ecological component sensitive to the stressor. After this a vulnerability weight is applied that translates the intensity of a stressor into its predicted impact on the ecological component habitat, creating a single 'currency' of stressor impact (Halpern *et al.* 2007, Halpern *et al.* 2008b, Teck *et al.* 2010, Kappel *et al.* 2012). The expected impacts are finally summed up into a total cumulative impact score. Each of those steps, however, requires many assumptions (Halpern & Fujita 2013).

The first step for understanding and mapping cumulative impacts starts with mapping the spatial distribution of human activities and determining which pressures and stressors must be included in the assessment. This needs ways to link impacts on ecosystem components to human activities. The OSPAR Intercessional Correspondence Group on Cumulative Effects (ICGC) has produced a list of pressures which is presented in the report of HBDSEG 2013. This step also highlight the need to determine how much to lump versus split groups of stressors (Halpern & Fujita 2013). These decisions have important implications for how much of a potential impact any given stressor or group of stressors can contribute to overall cumulative impact. Should in the case of aggregate extraction or dredging all types of dredging methods be treated equally? Is there a difference between sand and gravel extraction, shallow and deep extraction or single site use versus repetitive extraction in the same area? And if so, to which detail should there be made a distinction? Some of the decisions will be simply driven by data limitations, but in general they require assumptions or expert judgment about how important particular types and groups of stressors are in determining ecosystem condition (Halpern & Fujita 2013).

Next steps involve making distinctions between point source and dispersive pressures and to consider and determine if and how the 'effects' within the exposure pathways interact, taking into account the different types of indirect and direct impact, impact interactions and cumulation over time and in space (Figures 1,2 and 3)figures Walker 1999, Judd and Murray *et al.* 2014).

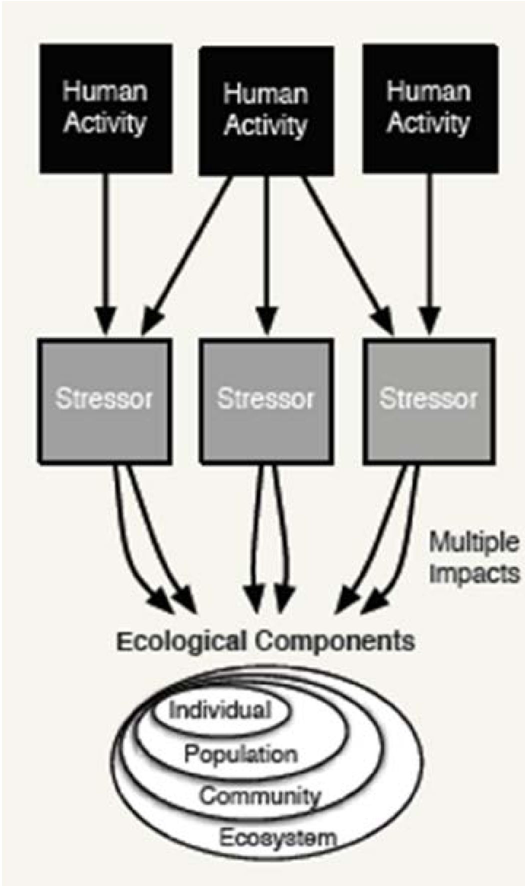


Figure 1. Theoretical framework of pathways by which independent and cumulative effects to ecological components are accounted for. A human activity produces a single or multiple stressors that impact a single or multiple ecological components over space or time and multiple activities produce multiple stressors that have multiple impacts on a suite of ecological components. Stressors from activities can accumulate across space (local, regional and global stressors) and time (past, present and predicted future activities). Adjusted from Murray *et al.* 2014.

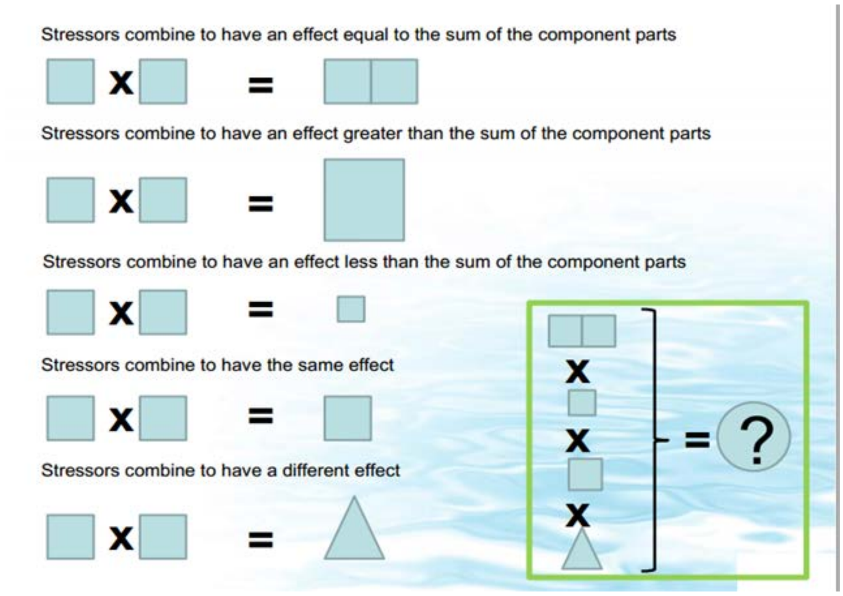


Figure 2. From Judd 2012.

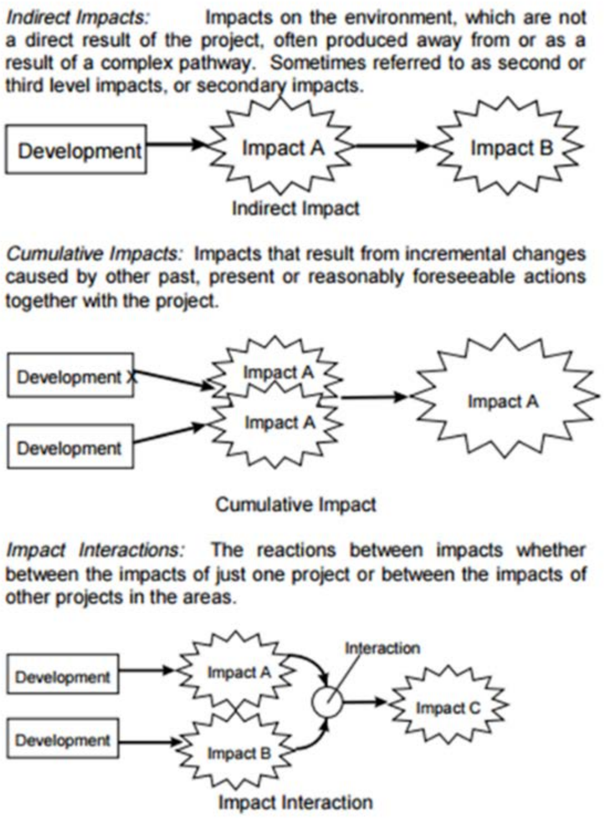


Figure 3. Flow diagrams illustrating indirect and cumulative impacts and impact interactions (Walker 1999).

'Point-Source' pressures are those where there is effectively a one-to-one relationship between the activity and the pressure (and effect), e.g. the pressure 'habitat structure changes' from aggregate extraction will only be exhibited where the minerals are actively extracted; 'extraction of target species' from fishing will only be exhibited where fishing vessels operate (OSPAR 2016). 'Dispersive' pressures are those where the pressure (and effect) cover a larger spatial area than the causal activity, e.g. noise will propagate away from its source (e.g. pile driving); nutrients and hazardous chemicals entering the marine environment from rivers will disperse. An example of the extent of such a dispersive pressure is given in the EIA for the development of the Rotterdam harbour extension Maasvlakte 2 (PMR 2007b). Different modelled scenarios indicated a potential increase in turbidity due to introduction of silt (fraction < 63 μm) as a result of the sand extraction. This increase could develop in the whole Dutch coastal area ranging from the Voordelta south of the extraction site to the Wadden Sea in the north and up to a maximum of 20 km out of the coast. As a result of the increased turbidity a maximum reduction of 10 -25 % in the year averaged chlorophyll-a concentration (as a measure for primary production) was predicted for the coastline between Walcheren and Egmond. The effect could even last for a number of years after the extraction activities have ended, partly due to resuspension. Light reduction due to increase turbidity could result in a delay of one to two weeks in coastal spring algal bloom against the normal spring bloom period.

Next to mapping the distribution of activities, the spatial distribution of ecosystem components (key species and habitats) as well as their vulnerability and sensitivity to the pressures need to be defined. In the last years there has been an enormous progress in mapping the distribution of species and communities in the European marine waters. However, assessing the impact of biological communities to specific anthropic pressures in marine systems is far from easy due to lack of knowledge and data on species vulnerability and sensitivity which prevent the development and use of proper models that predict how the different pressures exerted at the individual level can be progressively integrated and quantified from individual to species and community level (Certain *et al.* 2015). In the case of (aggregate) dredging the sensitivity of an individual, species or community to the activity can defendable be score this as 1 (maximum impact) as dredging initially will result in the complete removal of animals from the dredging area, with the exception of some deep burrowing animals or a few very mobile surface animals. Transfer to and survival of animals placed with the sand at another site will be almost zero as not many benthic animals will survive the destructive process of being pumped up, transported and dumped. Few examples exist of benthic animals surviving the dredging process (Van Dalfsen & Lewis 2001).

After all these steps are made the effects can be cumulated using the most appropriate method.

Currently cumulative effects in Europe are related to the MSFD and the realisation of GES. Biodiversity indicators are mostly used as way to assess the cumulative effects. However, this implies that these biodiversity indicators are the way of describing the ecosystem and its functioning. Support for using biodiversity indicators as a measure of overall ecosystem condition comes from statistically significant (negative) correlations found between biodiversity status and cumulative pressures (Anderson 2015).

(Inter)national actions taken on the issue

Spatial analyses of anthropogenic stressors and their cumulative impacts on the marine ecosystems have been conducted globally and regionally (Halpern *et al.* 2008, 2009; Selkoe *et al.* 2009; Ban *et al.* 2010; Korpinen *et al.* 2012, Korpinen 2015), in order to provide much-needed information for ecosystem-based management.

In the recent past cumulative assessment approaches were developed looking e.g. at multiple-activity assessments (Cooper and Sheate 2002); Eastwood *et al.* 2007; Stelzenmüller *et al.* 2008; de Vries *et al.* 2012 and 2010; Halpern *et al.* 2008 and 2012; Judd ; Van der Wal & Tamis 2014, Andersen *et al.* 2013; Anderson *et al.* 2015; HBDSEG 2013; Korpinen A. 2015; Tillin & Tyler-Walters 2013; Knights *et al.*, 2015)

To help the EU Commission in the process of implementing the MSFD a number of actions with respect to the assessment of cumulative have been carried out recently.

The OSPAR Intersessional Correspondence Group – Cumulative Effects (ICG-C), part of OSPAR commission Environmental Impact of Human Activities (EIHA), studied common approaches on (cross-border) cumulative effects. In 2012 the OSPAR ICG-C discussed three cumulative effects assessment (CEA) methods after which cases studies were conducted to find best approaches and tools: CUMULEO (Van der Wal & Tamis 2014; ODEMM ((Knights *et al.* 2015); and HARMONY (Andersen *et al.* 2013). In 2015 the work of the ICG-C focussed on reviewing methodologies for generating cumulative 'pressure' / 'impact' maps (HARMONY, CUMULEO and ODEMM) (OSPAR 2016). The review indicated that the approaches are broadly similar and that there was nothing to suggest that any approach was better than another. It was therefore decided not to proceed by adopting one single approach. The work will continue with actions on a targeted CEA of pressures and impacts aligned with the content of the Intermediate Assessment 2017 and Quality Status Report 2021 and further development on a CEA that is aligned and makes best use of OSPAR common indicators and their associated data.

The CEDA MSFD NAVI group (a 'thematic cluster' of nine navigation sector bodies in the marine and inland, commercial and recreational navigation and dredging sector) looked into the measures that could be taken under the MSFD on a national, European or international level that have the potential to affect navigation or dredging related activities. This group want to draw attention to some aspects because there may be unwarranted implications for the activities of the sector in some or all Member States in a marine region or sub-region (CEDA 2015). Amongst these is the geographic scale. It is NAVI's view that the measures imposed by the Member States should be relevant at the geographical scale at which the MSFD operates and be directly linked to achieving or maintaining GES. The appropriate scale at which measures are taken is likely to be a key issue for various descriptors and not least for the assessment of cumulative and in-combination effects.

OSPAR's Intersessional Correspondence Group (ICG) on Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM) conducted a case study looking into the multiple causes of physical damage to benthic habitats (ICG-C 2016). The study evaluated the extent to which the seafloor and the associated benthic communities are being damaged or disturbed by current pressures caused by human activities. The study collected information on the distribution and intensity of pressures, the distribution and extent of habitats and an assessment of the sensitivity of those habitats to pressures. The case study has, however, only considered fisheries activity data for vessels >12m to quantify 'damage'. The ICGC case study is expected to extend this initial work by incorporating additional pressures.

In the UK, the Marine Management Organisation (MMO) has an obligation to ensure potential cumulative effects are taken into account in its decision making under the UK Marine Policy Statement (MMO 2014). The MMO developed a framework for scoping cumulative effects at the strategic level (MMO 2014). The framework considers the scoping stage only. It provides a step by-step approach to the identification of potential cumulative effects. This framework process was tested using a number of offshore wind developments in the Greater Wash as well as by a hypothetical CEA case in which both a large and a small scale activity was analysed in a hypothetical area. In order to apply the framework an evidence database was which identifies activities taking place in the marine environment, the pressures that they exert, and the receptors which may potentially be sensitive to those pressures (MMO 14). It provides summary matrices, highlighting where there may be potential for cumulative effects between activities based on overlapping pressures with potential to affect a common receptor, to support an initial assessment.

The European Topic Centre on Inland, Coastal and Marine Waters (ETC-ICM) is working to propose a cumulative effects assessment (CEA) method for the European Environment Agency's (EEA) of the state of the European seas (OSPAR 2016). A task team reviewed the existing CEA methods in 2015, focusing on spatial assessments of cumulative anthropogenic pressures and impacts on marine environments, and recommended a method for further testing (Korpinen *et al.* 2015). The purpose of the review was to recommend a method for assessing the cumulative degree and spatial distribution of human activities, pressures and their impacts in the European marine environment (OSPAR 2016). The review concluded that the current approaches used to assess cumulative pressures and cumulative effects in the marine environment are all relatively similar. All of them rely on three factors: spatial extent of pressures, spatial extent of ecosystem components and an impact weight score transforming the pressures to impacts on the ecosystem components. In 2016, the objective of the work is to further develop the recommended method to better serve European-wide assessments and to find out spatial data layers on human activities and pressures. In 2017, the method will be tested and more practical preparations for the European CEA assessment will be initiated.

In the Netherlands the ministries of Economic Affairs and of Infrastructure and Environment set up a framework for assessing ecological and cumulative effects of offshore wind farms (Ministry of Economic Affairs and Ministry of Infrastructure and Environment 2015). Extensions have been developed for the effects on population development of birds and one marine mammal, the harbour porpoise.

Anderson *et al.*, 2015 analysed the linkages between human activities, pressures and impacts and the status of the marine biodiversity in the Baltic Sea. Describing the biodiversity status for the period 2001 – 2007 using a multi-metric indicator-based assessment tool and combining this with detailed mapping data on the human pressures in the Baltic area. They were able to provide scientific evidence on the linkage between cumulative impacts and biodiversity status on a wider scale. Moreover, by ranking the pressures and impacts for each of the studied sub-regions in the Baltic Sea this study provided a prioritisation of area specific measures targeting relevant human activities and the subsequent development of ecosystem-based management strategies (Anderson *et al.*, 2015).

Knight *et al.* (2015) illustrated how the exposure-effect approach can be used to assess the risk to ecosystems from human activities at considerably larger spatial scales being the Europe’s regional sea ecosystems. This was done considering a range of sectors, pressures, and ecological components. This study included up to 17 sectors, 23 pressure types, and broad ecological components. They used an “impact chain” approach by constructing a sector–pressure–ecological component linkage matrix (see Knights *et al.* 2013) in which each cell in the matrix describes the potential for an impact on an ecological component from a sector, wherein a pressure is the mechanism through which an impact occurs. After this the threat from each chain was assessed by way of a pressure assessment (sensu exposure-effect) approach (see Robinson *et al.*, 2013, for full details of the methodology). This pressure assessment methodology was designed with the concept of risk assessment in mind, such that the assessment criteria developed could be used to evaluate the likelihood and consequences of a specific or combination of impact chains. The assessment was based on expert judgement for which they approached a good number of participants from a range of institutions and countries from around the EU and more broadly.

Rijkswaterstaat, Ministry of Infrastructure and Environment, the Netherlands prepared a discussion paper on the need for a common cumulative effect assessment (CEA) approach in assessing the ecological effects of offshore wind farms (OWFs) in the southern North Sea (Boon & Prins 2016 prep).

Brief review of EIA and CEA studies addressing cumulative impacts in relation to extraction

EIA Maasvlakte 2, the Netherlands

For the Rotterdam Harbour extension Maasvlakte-2 an EIA was made (PMR 2007). Because of the very large quantity of material needed to build this second extension, the Basic Alternative estimated 324 Mm^3 of sand needed to be extracted from the North Sea, the EIA addressed the design, the location of the dredging areas and the way the extraction was executed (timing and equipment). Extraction depth looked upon varied between depth of 10 to even 20 meters below the seabed surface, the latter doubling the water depth. Next to this attention was also given to nature, recreational use, nautical aspects and archaeology. Different environmental aspects were assessed among which seabed disturbance, loss of habitat and biota, turbidity, emissions, noise (both air and under water), and disturbance (visual, light, noise). When looking at cumulative effects of the Maasvlakte-2 development, attention was given to other developments such as offshore wind energy and especially to the combined effects with activities as bottom trawling, other extraction activities and maritime transport. For the latter the additional annual extraction of 35 Mm3 in the Netherlands was taking into account. Notwithstanding the large amount of sand needed for the development of the Maasvlakte-2, the EIA concluded that for most of the aspects accounted for, no serious effects were to be expected. The cumulative assessment for most of the aspect was done either quantitative or qualitative and represented in scoring tables. No integrated methodology, however, was applied to assess the cumulative effects of the sand extraction with all other activities including other sand extraction in the coastal zone of the Netherlands.

Extraction & Fisheries (United Kingdom)

To contribute to an informed debate and sustainable use of resources Cooper (2005) reported the views of the fishing industry on the perceived impacts of aggregate dredging on their activities in an area to the east of the Isle of Wight. The study was based on information from interviews with local fishermen working in the vicinity of areas of aggregate extraction, a review of published information, information from fisheries authorities and fisheries scientists combined with information on extent of dredging operations obtained from Electronic Monitoring System (EMS) data. Charts were made to map the cumulative extent of different activities.

Results indicate a general avoidance of licensed areas by static gear fishermen and by trawlers. The latter due to perceived changes in the nature of the seabed (e.g. dredged tracks and depressions) that may persist for several years. This could have a subsequent effect of increasing fishing pressure in alternative grounds with already heavily exploited stocks remote from dredging areas. Concerns were found on vessel safety of small vessels in relation to the increased distances offshore. Furthermore the study concluded that dredging operations affected the abundance and distribution of some commercially targeted species e.g. the brown crab (*Cancer pagurus*) and of smooth hound (*Mustelus mustelus*) targeted by recreational fisherman.

However, the assessment was complicated by absence of quantitative data on localised spatial and temporal scales and no simple cause-effect attributions can be made due to the interaction of anthropogenic and natural influences.

Extraction & Fisheries (France)

The effect of extraction activity on the benthic community and with that on the distribution of fishing effort of French and English demersal fleets was studied at a number of French and English extraction sites in the eastern Channel (Desprez *et al.*, 2014, Marchal *et al.*, 2014). The most prominent result of the study was that most types of fishing near the extraction sites were not deterred by the dredging activity. The fishing effort of scallop dredging and potters were even found to have increased adjacent to aggregates sites. Where the distribution of French netters remained consistent over the study period, the effort of this fishing type increased substantially for sole in the impacted area of the Dieppe site. This increase of fishing was found to be correlated with the extraction intensity. The attraction of the different types of fishing is likely due to a local temporary concentration of their main target species as a result of changes in the seabed habitat.

Although the finding of the study seem logical and explicable, the study shows how complex it is to integrate and quantify the cumulative effects of different pressures affecting the seabed from species to community level as there is also a sequence in cause and effect between the different pressures. Moreover, can changes to the seabed leading to different benthic communities be foreseen as positive outcomes and if so, how could this be incorporated into the assessment?

Discussion

Worldwide initiatives are undertaken to understand and develop methods to assess the potential for cumulative effects in the marine and coastal waters. In relation to dredging activities such actions are also taken to address cumulative effects looking beyond the site specific effects of single operations (OSPAR 2009).

A number of issues that go along with cumulative impacts are still under discussion.

Spatial scale

Looking at a single human activity such as aggregate extraction, there is a need to inform and have information on it's extend in time and space and its contribution to an impact on a certain ecosystem component in terms of policy making and management. OSPAR (2009) suggest to assess the potential cumulative effects of multiple dredging operations in close proximity to one another on a temporal and spatial scale by means of a regional environmental assessment. Such cumulative impacts may also occur when aggregate extraction occurs close to another seabed activity, for example an offshore wind farm. For reasons of marine spatial planning, designation of marine protected areas and ecosystem-based management this certainly makes sense.

However, from a practical day to day point of view from a single project, there is an obligation to have information on the cumulative impacts, because of licensing. For the latter, the level of detail of information needed is much larger to make any sense in terms of a time and spatial adequate assessment. The activity is often taking place in a relative confined space, a small area and often only for a limited amount of time.

On a project base spatial impacts will be most likely on the relative small local scale as dredging amount are rarely large. Even when taking into account the side effects of increased turbidity which could impact a much larger area due to hydrographic conditions (PMR 2007), the effect is expected to be relative limited. Even for the very large extractions such as the Rotterdam harbour extension only the worst case model scenario predicted a substantial increase in turbidity leading to a possible delay of maximum 2 weeks in the annual spring algal bloom (PMR 2007b). Choice of scenario and mitigation measures taken will help to reduce the spatial extend of the effects. Cumulative effect assessment will then be focussed only on that project area, either by looking into multiple dredging activities over time and potential impacts of other activities in that area, e.g. fishing.

The Ecosystem Approach is the main tool of the OSPAR Commission for the management of human activities. A key feature of the ecosystem approach is the conservation of ecosystem structure and functioning, whereas under the Malawi principles ecosystems must be managed within the limits to their functioning. It is therefore important to consider where the boundaries for management and related measures lie when looking at aggregate extraction and moreover, to what extend is management feasible and practical?

This is also brought forward in CEDA NAVI's (2015) view that it is important to realize that the measures imposed by the Member States should be relevant (i.e. capable of making a difference) at the geographical scale at which the MSFD operates and be directly linked to achieving or maintaining GES (CEDA NAVI 2015). The appropriate scale at which measures are taken is likely to be a key issue for various descriptors and not least for the assessment of cumulative and in-combination effects.

In terms of single project assessments, the spatial component of the activity and related pressures and impact is limited whereas in more policy and management driven assessments spatial distribution in general is much larger. In Annex I of the OSPAR Guidelines for the Management of Dredged Material (OSPAR 2009) the spatial coverage is preferably given in percentage of the respective OSPAR Region or classified in seven classes ranging from less than 10 km2 to more than 1.000.000 km2. In the CEA case study on offshore windfarms and fisheries using the CUMULEO approach (Van der Wal & Tamis 2014) the footprint of five pressures where calculated in terms of habitat loss i.e. area no longer suitable as habitat for the different ecosystem components taken into account in the study. For instance, the fisheries pressure was expressed in term of relative area trawled (RAT) in ICES-rectangles or geographic areas which are approximately 30 x 30 nautical miles and the offshore wind. This spatial size is far beyond the regular dredging activity.

Time scale

The time scale on which a specific activity and pressure and impact should be assessed is an issue that needs to be looked into. Nature itself is continuously changing and trends, whether or not human induced, are not easy to include. In the Halpern 2008 methodology an activity with its pressure stays "forever" on the map. It could be discussed how long the impact of trenching a cable into the seabed on the biodiversity of the benthic community remains detectable. So the question remains on how far into the future and how far into the past one should look to in addressing and assessing "past, present and reasonably foreseeable" effects? Certainly with the experience that dredging impacts on the seabed community is relative short

Furthermore, the appreciation of changes in nature expressed in some sort of value is a human concept and therefore susceptible to changing policy over time (see Valuation of changes).

Indicators

In many studies and methodologies developed cumulative effects were analysed using biodiversity as an indicator to calculate impact. Approaches using other GES elements as basic indicator are not under study. For a biodiversity assessment many indictors exist amongst which are those for benthic and pelagic habitats, population indicators of zooplankton, benthic communities, demersal and pelagic fish communities, seabirds and marine mammals. Additional to these also indicators on more physio-chemical properties as and water transparency, sediment characteristics and nutrient concentrations could be added. It is, however to be discussed which of these indicators should be included while assessing the cumulative impacts of dredging.

In addition to the above, there is the issue of different receptor groups that are relevant in different countries, due to the variability in species distribution but also due to different protection levels of species in the different countries (Boon & Prins in prep).

Impacts could be looked upon as function of habitats or systems while in some cases, like in the relative localized impacts of dredging, it might be more appropriate to look at population level of certain species or at a community level.

CEDA NAVI (2015) advised to pay attention to how the potential unintended consequences of introducing a measure for improvement of one GES descriptor of the MSFD could affect measures proposed to improve other descriptors. Introducing speed restrictions in order to reduce underwater noise has the potential to impact on the descriptor relating to levels of contaminants because ship's engines are designed to run at a particular speed to be at their most efficient and reducing the speed could potentially result in an increase of unburnt fuel entering the marine environment.

Valuation of changing habitats

During the life span of an activity such as dredging and after the activity has stopped, habitat changes are frequently observed. These changes in the seabed may provide a new habitat, potentially susceptible to settlement to other species than originally occurring in the area before the activity started. The work of Desprez *et al.* (2000, 2012) and Marchal *et al.* (2014) on dredging sites along the French coast illustrated the economic consequences for fisherman as fish species with a higher market value showed up as a result of dredging activities. In the Netherlands an experiment was done to deliberately change the topography within a dredging site with the aim of creating another habitat type which potentially could result in a different species composition (Van Dalfsen *et al.* 2004, Van Dalfsen & Aarninkhof 2009, De Jong *et al.* 2014, 2015a, 2015b, 2016).

Depending the magnitude of changes the impacts for a community may be limited to the proportion of the different species groups in that community. The element of valuation of habitat change, being negative or positive, in the calculations of impact, either in a straightforward EIA or a CEA is yet not included. How to deal with the valuation of changing habitats structures and associative communities in cumulative impact assessment and what indices should be used to deal with this remain questions for further investigation.

Other mining activities

When looking into assessing the cumulative effects of human activities in the marine environment with a focus onto extraction, a decision should be made on the activities addressed. Should it be limited to aggregates extraction (sand and gravel) only or should it include all dredging activities as well as mining for marine minerals (being a relative new industry but in the near future expected to grow and having potentially other impacts)?

Conclusion

Cumulative impacts are considered essential in the implementation of an ecosystem based approach to the management of human activities. Substantial effort is currently undertaken to address the assessment of cumulative impact to the environment in order to help marine management and policy.

The above mentioned issues of geographical and time scale are yet under study but solutions are likely not to be provided in short time. Next to the issue of how to valuation change in the assessment a discussion should also be started on how to include changing circumstances like trends over time and space. Although these phenomena are widely known, incorporating these in cumulative assessments of human activities is challenging. Potentially some of these issues could be included in a CEA by introducing something as a "life cycle assessment".

With a focus on the marine minerals extraction it will be important to come up with a common CEA approach that is feasible and practical in terms of measures proposed to be taken and information to be provided as well as appropriate to the scale at which the industry is active.

With all the activities presently undertaken to develop tools and methodologies to address the issue of cumulative effects of all human activities, including for example aggregate extraction, it seems to be not relevant to start developing a separate tool for cumulative assessment focussing on marine minerals extraction. The WGEXT activities could better assist in these developments by focussing on providing relevant information on this topic within OSPAR and ICES.

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Annex 9: ToR K. Impact of marine aggregate extraction on fish and fisheries

Belgium

	Belgium
Sources	ILVO
Contact person	Annelies de Backer (annelies.debacker@ilvo.be)
Data on impact (Y/N)	Yes
Guidelines availability	
Monitoring of impact (Yes/No)	Yes
public/private initiative	Public initiative, included in EIA
Scale of monitoring	Extraction area and reference
° Extraction areas	No
° Regional Habitat Assessments	Seasonal (march and sept/october), beam trawl samples (8m beam, stretched mesh size 22 mm). Focus on epibenthos and juvenile/young demersal and benthopelagic fish
Frequency of monitoring	Yes, monitored in area 2kb, 2br, 2od, 1 and 4c
° demersal fish community	No
° specific resources	
Mitigation measures	No
Others,,,	
Fisheries activity	VMSdata and logbook data are available on request but not used currently. Extraction takes place on top of the banks, fisheries in the gullies mainly, so spatially more or less separate.
Impact evidence	No clear impact, but not looked in detail into impact on fish spawning or fisheries activities (e.g. anecdotic observations by recreational fisherman that seabass spawning was affected but no scientific proof).
References	de Backer *et al.* (2014)

Denmark

	Denmark
Sources	
Contact person	Signe Lemcke (silem@mst.dk)
Data on impact (Y/N)	EIA has to include an impact assessment of the extraction on the fishery in the area
Guidelines availability	No

Monitoring of impact (Yes/No)	No
public/private initiative	No
Scale of monitoring	No
° Extraction areas	No
° Regional Habitat Assessments	No
Frequency of monitoring	
° demersal fish community	No
° specific resources	No
Mitigation measures	Extraction areas are open for fisheries.
Others,,,	Spatial restrictions to protect habitats e.g. stone reefs
Fisheries activity	Available information on fisheries, important fish habitat, spawning and nursery areas have to be included in the EIA
Impact evidence	
References	

Finland

	Finland
Sources	GTK (Port of Helsinki)
Contact person	Jyrki Hamalainen (jyrki.hamalainen@gtk.fi)
Data on impact (Y/N)	Yes
Guidelines availability	
Monitoring of impact (Yes/No)	Yes
public/private initiative	Monitoring required in the extraction terms of the permit, permit holder is responsible
Scale of monitoring ° Extraction areas ° Regional Habitat Assessments	 Extraction area and reference No
Frequency of monitoring	Monitoring programme is determined case by case
° demersal fish community	
° specific resources	Monitoring of spawning areas, juvenile fish seining, monitoring of professional and recreational fishing. Determined case by case in monitoring programme.

Mitigation measures	Temporal restrictions may apply (extraction should usually take place late summer or autumn)
Others,,,	
Fisheries activity	Monitoring of spawning areas, juvenile fish seining, monitoring of professional and recreational fishing
Impact evidence	No impact on baltic herring spawning (Vuosaari harbour building project)
References	Vatanen, Haikonen & Piispanen; Kala- ja vesimonisteita nro 57 (2012)

France

	France
Sources	IFREMER
Contact person	Camille Vogel (camille.vogel@ifremer.fr)
Data on impact (Y/N)	Yes
Guidelines availability	Yes
Monitoring of impact (Yes/No)	Yes: experimental trawling from 2004 to 2011
public/private initiative	Monitoring officially included in EIA since 2017
	(Code de l'Environnement)but practically
	ongoing since 1999 based on scientific advice and local legislation
Scale of monitoring	
° Extraction areas	Extraction area, surrounding (up to 500 m) and reference stations
° Regional Habitat Assessments	No
Frequency of monitoring ° demersal fish community ° specific resources	• Seasonal (winter and summer at a minimum, up to 4 seasons) • Eastern Channel and Atlantic coast extraction sites • Scallop (Granulats Marins Havrais, Baie de Seine, Manche Orientale) • Herring (Graves de Mer , Gris Nez, Côte d'Albatre) • Sand eel (Kafarnao, Pointe d'Armor) • Sand eel and scallop (La Horaine) • Herring, lesser sand-eel, cod, sole, lemon sole, plaice, sprat, whiting (spawning areas) and mackerel, lesser sand-eel, lemon sole (nursery areas) (Saint-Nicolas • Sole (spawning area) (Astrolabe)

Mitigation measures	• Extraction areas open to fishing with on-time communication of extraction periods to fishermen • Seasonal restrictions of dredging activity associated .with either fishing activity (scallop, cuttlefish) or biological requirements (re-production period. • ° winter restriction (01/11 to 31/01) for biological constraints for herring (Dieppe) • ° winter restriction for scallop fishing activity(Granulats Marins Havrais, Baie de Seine) • ° C14 • ° spring restriction for biological constraints (March and April) for all commercial species (Granulats Manche Orientale) and for sole (North Biscaye)
Others,,,	Ichtyoplankton monitoring
Fisheries activity	• Logbook data • Fishing activity surveys (VALPENA, Portail halieutique DPMA). • Also available but under-used by aggregate companies: VMS and production data for fisheries
Impact evidence	According to GIS SIEGMA experimentation (2003-2012) on 2 extraction sites, no impact was detected for extensive extraction (Dieppe) and a temporary exclusion was noticed for intensive extraction (Baie de Seine).
References	Desprez *et al.* (2014); Marchal *et al.* (2014);
	ICES ASC 2016 : 2 presentations (impact & recovery)

The Netherlands

	NL
Sources	Rijkswaterstaat
Contact person	maarten.de.jong@rws.nl, ad.stolk@rws.nl
Data on impact (Y/N)	No
Guidelines Availability	Yes, in theory and only regarding shellfish banks
Monitoring of impact (Yes/No)	Not specifically, effects of deep sand extraction and demeral fish was investigated during a PhD research, https://www.sciencedirect.com/science/article/pii/S0272771414001577
public/private initiative	No
Scale of monitoring	
° Extraction areas	No
° Regional Habitat Assessments	No, maybe for shellfish banks in the nearby future
Frequency of monitoring	Prior to sand extraction
° demersal fish community	No

° specific resources	Maybe shellfish banks
Mitigation measures	No
Others,,,	
Fisheries activity	
Impact evidence	Significant differences in demersal fish species assemblages in the sand extraction site were associated with variables . such as water depth, median grain size, fraction of very fine sand, biomass of white furrow shell (*Abra alba*) and time after the cessation of sand extraction. Large quantities of undigested crushed white furrow shell fragments were found in all stomachs and intestines of plaice (*Pleuronectes platessa*), indicating that it is an important prey item. One and two years after cessation, a significant 20-fold increase in demersal fish biomass was observed in deep parts of the extraction site
References	De Jong *et al.*, 2014

Portugal

	Portugal
Sources	
Contact person	
Data on impact (Y/N)	No
Guidelines availability	
Monitoring of impact (Yes/No)	
public/private initiative	
Scale of monitoring	
° Extraction areas	
° Regional Habitat Assessments	
Frequency of monitoring	
° demersal fish community	
° specific resources	
Mitigation measures	
Others,,,	
Fisheries activity	
Impact evidence	
References	

Sweden

	Sweden
Sources	
Contact person	
Data on impact (Y/N)	No
Guidelines availability	
Monitoring of impact (Yes/No)	
public/private initiative	
Scale of monitoring	
° Extraction areas	
° Regional Habitat Assessments	
Frequency of monitoring	
° demersal fish community	
° specific resources	
Mitigation measures	
Others,,,	
Fisheries activity	
Impact evidence	
References	

United Kingdom

	United Kingdom
Sources	CEFAS
Contact person	louise.cox & robin.masefield @cefas.co.uk
Data on impact (Y/N)	Yes
Guidelines availability	
Monitoring of impact (Yes/No)	Yes. Mitigation rather than monitoring
public/private initiative	
Scale of monitoring	
° Extraction areas	Historically
° Regional Habitat Assessments	Anglian, Humber, South Coast, Eastern Channel
Frequency of monitoring	Annual

° demersal fish community	No (Historical beam-trawl monitoring have ceased)
° specific resources	• Scallop & sole (Hastings) • Herring & sandeel (Regional Habitat Assessment) • Scallop trawling (new sites Eastern Channel) • Black seabream (South) • Brown crab (eastern Channel, area 406 since mid 1990's) with baited pots
Mitigation measures	• Temporal restrictions to protect vulnerable habitats and species • ° winter restriction (herring spawning period) • ° spring restriction (black seabream spawning grounds, sandeel ?) • Habitat restriction (herring, sandeel, black seabream…)
Others,	
Fisheries activity	Logbook data since 1984 for brown crab
Impact evidence	Unclear
References	Pearce (2008); Kenny *et al.* (2010); ICES HAWK (2015)

Annex 10: OSPAR National Contact Points for Sand and Gravel Extraction

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Sweden	Johan Nyberg Geological Survey of Sweden P.O. Box 670 SE-75128, Uppsala SWEDEN Tel: +4618179194 Email: Johan.nyberg@sgu.se