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Report of the Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED)

21–25 April 2015

Oban, Scotland, United Kingdom

ICES
International Council for the Exploration of the Sea

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Contents

Executive summary

The third annual meeting of the working group on Marine Benthal and Renewable Energy developments was attended by 15 experts, representing seven countries (Belgium, Estonia, France, Germany, United Kingdom (England and Scotland) and the Netherlands; with remote input from Poland and Sweden) and was held on 21–25 April 2015 in Oban, Scotland/United Kingdom. The meeting was co-chaired by Jennifer Dannheim (Alfred Wegener Institute, Germany) and Andrew B. Gill (Cranfield University, United Kingdom). As in the previous two years, the terms of references were summarised in three thematic sub-groups: (A) The 'knowledge group' (ToR A, E) focused on evaluating and reviewing the existing knowledge on the effects of offshore renewable constructions and related topics (e.g. artificial reefs). (B) The 'monitoring group' (ToR B, F) reviewed and evaluated the scientific efficiency of ongoing monitoring programmes of offshore renewable energy development projects by identifying knowledge gaps and providing outputs that could be used in the future to standardised research and ensure monitoring occurred at the appropriate scale. (C) The 'metadatabase group' (ToR C, D) looked at a database of metadata that will help to cross-foster research and target monitoring, as well as future modelling approaches.

The two main themes that had clearly emerged from our previous two meetings formed the focus of activity during the meeting, namely the knowledge and monitoring themes, which address the ToRs A, B, E and F. Progress via intersessional activity meant that we were able to discuss and finalise outstanding issues relating to the conversion of our activities (both within workshops and intersessionally) into journal publications. There was an update of activities from across Europe that highlighted the growing interest in understand the benthic ecosystem and interactions with marine renewable energy developments. Also many of the WGMBRED have been active across conferences, workshops and publishing in journals. During the workshop we built on all these activities and worked together to address the ToRs of the WG.

The monitoring group narrowed down the scope in their paper to ask and provide a suggested solution to the question around what we should monitor and at what scale. Fundamental questions that occupy much debate and effort when considering the benthic ecosystem in relation to marine renewable energy development effects on the benthos (and also has wider application to benthic monitoring in general). The plan that was agreed and is being implement was to finalise the paper between the main authors and then looking to submit a paper around September/October 2015. This was later than previous scheduled but the delay has meant that the paper is not just a review but a more specific analysis of the issues that exist and a solution proposed by our expert group.

The knowledge group had a set of identified tasks relating to the cause-effect relationships that they had identified in previous meetings and they spent a significant amount of time within workshops and intersessionally on providing the narrative with supporting citation of published sources of reference. For each cause-effect relationship a hypothesis was formulated and text paragraphs of 5–15 lines were written by responsible authors of WGMBRED, summarising the current knowledge. Further, the group defined a scoring system to quantify the spatial, temporal and quantitative effect size on each hypothesis. This scoring matrix constitute the base for scientifically justification of the hy-

pothesis and thus to identify knowledge gaps and prioritise the known unknowns. They are on target to have a paper for journal submission by December 2015.

The metadatabase theme only occupied a relatively small amount of time as in the last workshop a decision was taken to link with the existing Tethys Annex IV database. A link to WGMBRED has been arranged to be hosted on the Tethys database. The WGMBRED members have all signed up either intersessionally or during this workshop.

In addition to the three main themes and the ToRs the WG discussed the future of the topic and also the future of the MBRED working group. Current knowledge on effects of offshore renewable energy devices on the benthal ecosystems and methods to determine these effects strategies were deemed just as important now as when the WGMBRED started three years ago, if not more so in the future. The importance of scale issues and cumulative impacts was highlighted and these were integrated into a new set of ToRs to set out the case for the continuation of the WG.

The WG continues to functioning extremely well with high active participation across northern Europe and we now have an agreed member from the USA and potentially Canada too. In the three years of the WG to date, we have almost met the ToRs (by the end of 2015 we will have met them). The new set of ToRs and the unanimous active encouragement of the members to continue on with Jennifer Dannheim and Andrew B. Gill remaining as co-Chairs, gives us confidence to propose to ICES that WGMBRED should have another three years. With the growing interest in marine renewable energy developments we believe that the activity of the WG will be of key importance for ICES in the event that they need to advise on marine renewable energy developments in relation to the benthic ecosystem.

1 Administrative details

Working Group name

Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED)

Year of Appointment

2013

Reporting year concluding the current three-year cycle

3rd year

Chair(s)

Jennifer Dannheim, Germany

Andrew B. Gill, United Kingdom

Meeting venue(s) and dates

19–23 March 2013, Caen , France (21 experts)

25–28 March 2014, Tallinn, Estonia (19 experts)

21–25 April 2015, Oban, Scotland/ United Kingdom (15 experts)

2 Terms of Reference a) – f)

a) Critically evaluate current knowledge on the effects of offshore wind farms and other renewable energy constructions on benthal organisms (i.e. marine invertebrates, demersal fish and macroalgae) in the North Atlantic;

b) Review and develop guidelines for sampling techniques on renewable energy construction monitoring techniques by providing an overview of existing guidelines, in order to standardise and simplify future research and monitoring;

c) Develop a meta-database for cross fostering research to target monitoring and future potential modelling approaches;

d) Populating and keeping the meta-database updated;

e) Review existing knowledge from related topics (e.g. artificial reefs) and how these are applicable to cause-effect relationships in the benthal associated with renewable energy constructions;

f) Evaluate scientific efficiency of on-going monitoring programmes by identifying knowledge gaps and overlap in research.

3 Summary of Work plan

Year 1 ToR – A, C, D, E

Year 2 ToR – A, B, D, E

Year 3 ToR – A, B, D, F

4 Summary of Achievements of the WG during 3-year term

WGMBRED discussed several aspects in the WG and evaluated which will lead to publications, datasets, methodological developments and advisory products. During the first three years cycle of the WG, two main themes were identified, the knowledge and monitoring theme which address the ToRs A, B, E and F. Significant progress on both these topics was made particularly in relation to formulating publications. Further, WGMBRED members contributed to several talks and posters at international conferences, as well as publications in peer-reviewed journals (e.g. special issue in Hydrobiologia (volume 756, issue 1).

Knowledge theme (ToR A, E)

Activities 2013–2015

- Development of a schematic presentation of cause–effect relationships
- Literature review on related topics of hypothesis that are part of the specific cause-effect relationships of effects of offshore energy constructions on the benthal
- Evaluation of the effect-size of a cause-effect relationship in space, time and magnitude
- Identification of priority cause–effect relationships

Output

- Matrix of related topics with specific cause–effect relationships; to include assessment of level of uncertainty in understanding
- Basis for scientifically underpinning the identified cause–effect relationships, a literature review on all relationships to be then used to identify and prioritize the known unknowns
- Review paper (submission December 2015)
    - Feasible and readable paper, relevant to managers, policy-makers, developers and academics
    - Including an assessment of sensitivity, certainty and consistency of cause-effect-relationships via literature review
    - Highlighting knowledge gaps and prioritization (cf. known unknowns)

Monitoring theme (ToRs B, F)

Activities 2013–2015

- Outline structure, focus and content for paper discussed and developed in the WG by different experts
- MS has been through a few stages of discussion and was finally edited by different experts leading to the version addressed during the last meeting

Output

- Review paper (submission 2015)
    - Highlights the current issues related to benthic monitoring, particularly in relation to spatial and temporal scale and biologically relevant size of effect to be monitored
    - Focus on addressing questions on why the benthos is important, scale aspects and the relevance to monitoring, defining suitable objectives and approaches to determine relevant changes to the benthic ecosystem.
    - Case study to be used to illustrate concepts reviewed and presented in paper
    - Highlights knowledge gaps and prioritization in relation to monitoring
    - Aimed at audience of scientists who are involved in translating fundamental and applied science for those involved in decision and policy making

The Metadatabase: ToRs C and D

Activities 2013–2015

- A link has been established to the already existing global database (Tethys, Annex IV, US DoE) that will bring together projects, experiments, research and scientists that relate to the effects of marine renewables on the benthal
- Consideration of a webpage portal entry for WGMBRED with a link to ICES, metadata from (most) members of the WGMBRED were stored in the database

Output

- Submission of metadata details for marine benthal monitoring related to MRED.
- Dedicated webpage link within Tethys with all members of WGMBRED signed up and with expertise details visible;
- Relevant reports, metadata and publication notices that expose the work of the WGMBRED to the outside world as the come to experts on the topic
- Link through to ICES website and WGMBRED outputs

5 Final report on ToRs, workplan and Science Implementation Plan

5.1 Group evolution and achieved work status of the expert group on marine benthal and renewable energy developments

Offshore renewable energy devices, particularly offshore wind farms, are expected to develop into one of the largest-scale anthropogenic activities in our marine shelf systems.

How these devices might affect the marine environment, locally, regionally and on larger spatial scales, is currently investigated by ecologists who are continuously improving their understanding of these effects. Following this necessity to ensure proper knowledge exchange between scientists, an ICES workshop "Effects of offshore wind farms on marine benthos" (WKEOMB, see ICES 2012) was initiated in 2012. The aim of this workshop was to increase scientific efficiency of offshore wind farm benthos research, to discuss the most actual results and to facilitate a closer international collaboration throughout the North Atlantic region. The workshop highlighted the importance of a regular knowledge exchange which lead to the establishment of the working group on marine benthal and renewable energy developments in 2013.

Figure 1. Countries that have experts in the WGMBRED.

All members of the group agreed that there is a need to mutually inform and work together with ICES groups that are closely related. The group is thematically linked to several other ICES working groups (Figure 2).

Figure 2. ICES groups closely linked to WGMBRED.

Three axes have been tackled through six multi-annual ToRs (2013–2015), being the knowledge theme, the monitoring issues and (meta-) database on marine renewable energy (MRE) benthos monitoring:

a) The 'knowledge theme' (referring to ToR A and E) focused on the evaluation and review of existing knowledge on the effects of offshore renewable constructions and related

topics (e.g. artificial reefs) which might provide information on effects comparable to those of offshore renewables. The literature review and the evaluation of the effect size of MRE on benthos in space, time and magnitude, formed the base for prioritising important cause-effect-relationships, particularly where knowledge is lacking and research is urgently needed.

b) The 'monitoring issue' (referring to ToR B and F) will review, evaluate and develop sampling techniques and scientific efficiency of ongoing monitoring programmes of offshore renewable construction projects by identifying knowledge gaps and simplifying future standardised research.

c) The 'metadatabase topic' (referring to ToR C and D) dealt with the information exchange and publication. Within this topic a database of metadata that will help to improve cross fostering research and target monitoring, as well as future modelling approaches was established. Metadata has been shared with an already existing global database (Tethys, Annex IV, US DoE) that brings projects, experiments, publications, research and scientists together that work in the field of effects of marine renewables on the benthal.

During the three years' work, the group recognised that it should be an active long-term network producing valuable outputs, such as publications. It was noticed that critical scientific gaps might be missed by the interlinked ICES expert group and therefore must be considered in this group (e.g. migratory fish). Scientists from Canada and the USA are more active in some research fields e.g. electromagnetic field studies, than European scientists. This highlighted the importance of trying to get US and Canadian scientists to be involved in this group.

Besides the ICES core work on the ToRs within WGMBRED, several intersessional activities were carried out and organized by members of WGMBRED during the past three years:

- Theme session at ICES Annual Science Conference (ASC) 2012, Session O: How does renewable energy production affect aquatic life? (Convenor: **Jennifer Dannheim, Steven Degraer**)
- Oral and poster presentation at ICES ASC 2012, ICES CM 2012/O:07 (**Jennifer Dannheim** (oral) and **Steven Degrear** (poster) on behalf of the WKEOMB), **Delphine Coates, Jan Reubens** and **Jozefien Derweduwe** also gave an oral presentation and **Elisabeth Debusschere** a poster.
- Several talks and poster on the Stukplus conference: Five years of Ecological Research at alpha ventus – Challenges, Results, Perspectives, Berlin, Germany, 2013 (oral contributions: **Jennifer Dannheim, Steven Degraer, Lars Gutow, Roland Krone**)
- WinMon-conference: Environmental impacts of offshore wind farms – learning from the past to optimise future monitoring programmes, Brussels, Belgium, 2013 (Organiser: **Steven Degraer**; members of the scientific conference committee: **Jennifer Dannheim, Andrew B. Gill, Dan Wilhelmsson**; oral contributions: **Silvana Birchenough, Delphine Coates, Jennifer Dannheim, Ilse De Mesel, Francis Kerckhof, Jan Reubens, Roland Krone**)

- Hydrobiologia special issue (volume 756, issue 1) on Environmental impacts of offshore wind farms – learning from the past to optimise future monitoring programmes (eds: **Steven Degraer, Jennifer Dannheim, Andrew B. Gill, Han Lindeboom, Dan Wilhelmsson**) (publications of WGMBRED experts: **Delphine Coates, Jennifer Dannheim, Steven Degraer, Andrew B. Gill, Ilse De Mesel, Francis Kerkhof, Jozefien Derweduwen**)
- Conference on International Offshore and Polar Engineering, Anchorage, Alaska, USA, 2013, Publication in Proceedings of the Twenty-third (2013) International Offshore and Polar Engineering Benthic Interactions with Renewable Energy Installations in a Temperate Ecosystem, **Emma V Sheehan**
- Workshop leader – **Thomas A. Wilding**. 2nd International Conference on the Environmental Interactions of Marine Renewables (EIMR - II). Theme: Interactions with devices (oral contributions: **Thomas A. Wilding, Andrew B Gill, Silvana Birchenough**)
- Grand Challenges in Ecosystems and the Environment (GCEE) NERC Impact Workshop on 24th November, 2014 at Imperial College London. Prof./Dr. Steven Degraer presented on the theme of "New approaches to monitoring in offshore wind farms". **Andrew B Gill** presented an overview of WGMBRED and Silvana Birchenough presented ICES BEWG and marine renewables energy
- Keynote speaker on the Conference on Wind energy and Wildlife impacts, Berlin, Germany, 2015 (**Andrew B. Gill**) and oral presentation (**Jennifer Dannheim**)
- **Jennifer Dannheim** presented the overview of work from WGMBRED at the ICES BEWG meeting in Calvi Stareso (4-8th may 2015).

The outcome and recommendations of the three years' work of WGMBRED will enable to focus on specific processes in the benthal research that deserves urgent investigation but which, at the same time, are important for marine ecosystem goods and services in the context of marine spatial planning strategies in future ecosystem-based management approaches. Further it will contribute to optimise future monitoring, i.e. by evaluating already ongoing monitoring programmes in those countries that already have MRE in coastal waters, but also by giving advice on proper and efficient monitoring strategies for countries where renewable energy developments are still formulated on paper only.

Literature cited

ICES. 2012. Report of the Workshop on Effects of Offshore Windfarms on Marine Benthos - Facilitating a closer international collaboration throughout the North Atlantic Region (WKEOMB), 27–30 March 2012, Bremerhaven, Germany. ICES CM 2012/SSGEF:13. 57 pp.

5.2 National summaries: ongoing activities and research

Belgium

Belgium has allocated a 238 km² zone of the Belgian part of the North Sea to offshore renewable energy production, for example offshore wind farms. Prior to construction, a developer needs obtaining a domain concession and an environmental permit. The latter includes a number of terms and conditions to minimise or mitigate the environmental

impact of the wind farm project. This also imposes a monitoring programme to assess the potential impacts on the marine environment.

The environmental monitoring programme targets physical (hydro-geomorphology and underwater noise), biological (epifouling community on the hard substratum, macro and epibenthos of the soft substratum, fish, seabirds and marine mammals), as well as socio-economic (seascape perception and offshore renewables appreciation) aspects of the marine environment. The Operational Directorate Natural Environment (OD Nature) of the Royal Belgian Institute of Natural Sciences (RBINS) coordinates the monitoring programme. To cover all necessary scientific expertise OD Nature collaborates with several institutes: the Research Institute for Nature and Forest (INBO), the Institute for Agricultural and Fisheries Research (ILVO - Bio-Environmental research group), Ghent University (Marine Biology Research Group and INTEC), International Marine and Dredging Consultants (IMDC) and Grontmij Belgium NV.

The Belgian offshore wind farm environmental monitoring programme started in 2005 with the t_{-1} data collection at C-Power wind farm on the Thorntonbank, where the first windmills were installed in 2008. The monitoring programme is running continuously since 2008 (i.e. t_0) and now (July 2015) covers three wind farms (i.e. C-Power, Belwind and Northwind). The environmental monitoring programme led to a variety of scientific findings that have been published in yearly reports (Degraer and Brabant, 2009; Degraer *et al.*, 2010, 2011, 2012) and summarized for the period 2005-2013 in Degraer *et al.* (2013). The next yearly scientific report is due in 2016.

Below is an overview of the part of the monitoring programme tackled by ILVO is given as an example of the scientific information that is gained by the monitoring programme.

Published references coming from these activities:

Degraer, S. & R. Brabant (eds.) (2009). Offshore wind farms in the Belgian part of the North Sea. State of the art after two years of environmental monitoring. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit. 287 pp. + annexes.

Degraer, S., R. Brabant & B. Rumes (eds.) (2010). Offshore wind farms in the Belgian part of the North Sea. Early environmental impact assessment and spatio-temporal variability. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit. 212 pp. + annexes.

Degraer, S., R. Brabant & B. Rumes (eds.) (2011). Offshore wind farms in the Belgian part of the North Sea. Selected findings from the baseline and targeted monitoring. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit. 157 pp. + annex.

Degraer, S., R. Brabant & B. Rumes (Eds.) (2012). Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Unit. 155 pp. + annexes.
Degraer, S., R. Brabant & B. Rumes (Eds.) (2013). Environmental impacts of offshore wind farms in the Belgian pert of the North Sea: Learning from the past to optimise future monitoring programmes. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Contact: Steven Degraer, Royal Belgian Institute of Natural Sciences (RBINS), Operational Directorate Natural Environment (OD Nature), Marine Ecology and Management (MARECO), Brussels, Belgium

Six years of Belgian research on the environmental impact of offshore wind farms, was compiled in the report http://odnature.naturalsciences.be/downloads/winmonbe2013/winmonbe_report.pdf and presented by Belgian scientists at an international scientific symposium (26, 27 and 28 November 2013), organised by the Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment. The research executed by the Institute for Agricultural and Fisheries Research (ILVO) takes part of this monitoring project and focusses on the wind farm effects on epibenthos and demersal fish of soft substrates and on the effect of wind farm underwater sound on fish.

For the baseline monitoring, epibenthos and fish of soft substrates were investigated within a BACI design. Samples were taken before and after wind farm construction, in impact and control areas. Several significant results were observed within the BACI design and within a certain year, for several parameters.

Within the targeted monitoring, several topics were investigated, i.e. changes in feeding behaviour of commercially important demersal fish species, wind farms as spawning and nursery areas for commercially and ecologically important species, changes in commercial and recreational fisheries in and in the vicinity of the wind farms, the needs in order to optimally sample pelagic fish in the wind farms and the effect of wind farm underwater sound on fish. This latter topic is part of the Phd of Elisabeth Debusschere who acknowledges an IWT predoctoral grant.

A number of papers and MSc theses on these topics have been published:

- Vandendriessche, S., Derweduwen, J., & Hostens, K. (2014). Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. Hydrobiologia, 1-17.
- Debusschere, E., De Coensel, B., Bajek, A., Botteldooren, D., Hostens, K., Vanaverbeke, J., Vandendriessche, S., Van Ginderdeuren, K., Vincx, M., and Degraer, S. (2014). In situ mortality experiments with juvenile sea bass (Dicentrarchus labrax) in relation to impulsive sound levels caused by pile driving of windmill foundations. PLoS ONE 9(10): e109280. doi:10.1371/journal.pone.0109280.
- De Backer, A., Van Hoey, G., Coates, D., Vanaverbeke, J., & Hostens, K. (2014). Similar diversity-disturbance responses to different physical impacts: Three cases of small-scale biodiversity increase in the Belgian part of the North Sea. Marine pollution bulletin, 84(1), 251-262.
- da Costa, A.M.R. (2014) Do offshore wind farms influence the occurrence of ichthyoplankton and squid larvae? Master Thesis. Marine Biology Research Group, Ghent University, Ghent.
- Vercauteren, M. (2014) Behavioural responses of European sea bass juveniles to pile-driving sound. Master Thesis. Marine Biology Research Group, Ghent University, Ghent.

- Persoon, K. (2015) Who is the recreational fisherman and what does he catch? An overview of recreational fisheries at sea in Belgium. Master Thesis. Marine Biology Research Group, Ghent University, Ghent.

Belgian offshore wind farms currently consist of 181 wind turbines with a total capacity of 706.2 MW. From May 2016 onwards, additional wind farms will be built and the basic and targeted monitoring will be continued. The basic monitoring however, has been optimised for all investigated ecosystem components (macrobenthos, epibenthos, fish, mammals, birds, bats).

Contact:

Jozefien Derweduwen, Institute for Agricultural and Fisheries research (ILVO), Animal Sciences, Aquatic Environment and Quality, Bioenvironmental Research, Oostend, Belgium and Elisabeth Debusschere, University of Ghent, Belgium

Estonia

Estonia has jurisdiction over 36 500 km² of sea area in the NE Baltic Sea. 11300 km² belongs to Exclusive Economic Zone (EEZ). At the moment there is no major offshore wind parks currently in operation in the northern part of the Baltic Sea. In Estonian waters have 3 offshore wind farm development projects – Hiiumaa, Kihnu and Neugrund. Environment Impact Assessment (EIA) programmes have been conducted in all of these areas. Two projects are located in the areas of pilot Marine Spatial Planning regions (done currently at county level).

Overview of Estonian offshore wind farms in development phase:

Wind farm name	Neugrund	Hiiumaa	Kihnu
Sea name	Gulf of Finland	Baltic Sea	Gulf of Riga
Developer	OÜ Neugrund	Hiiumaa Offshore Tuulepark OÜ	Eesti Energia AS
Development status	consent application submitted	consent authorised	consent application submitted
Number of turbines	27–29	146–212	160
Capacity	ca. 180 MW	594–730 MW	600 MW
Foundation	not decided	not decided	not decided
Area	13 km²	155 km²	100 km²
Water depth	3–20 m	8–38 m	17–24 m
Depth range stated by Developer	5–15 m	10–30 m	17–18 m
Distance from shore (computed from wind farm center)	9,5 km	15 km	12 km

There is no official monitoring strategy or procedure established In Estonia concerning monitoring the effects of offshore installations including wind farms. Standard EIA procedures apply to the offshore windfarm projects before the actual project establishment phase. Usual licensing conditions include monitoring during construction and post construction monitoring. The aim of post construction monitoring is to establish and quanti-

fy possible impact on the marine environment and give the background material for future projects to be able to determine cumulative impacts from the similar projects in the future.

The methodological basis for the EIA and monitoring of offshore windfarms is national EIA legislation and recently developed guidelines: „Guidelines for the investigation of the impacts of offshore wind farms on the marine environment in the Baltic States“ (Baltic Environmental Forum 2009).

According to guidelines an EIA for an offshore wind farm has to cover the following topics:

The description of the status quo of the protection objectives (EIA, habitat & bird directives, protection of species)

- validation of the status quo,
- description of potential impacts/interactions,
- description of potential cumulative effects,
- potential mitigation measures,
- monitoring concept (feed-back, compliance).

An EIA should assess impacts on the following protection objectives:

- humans,
- abiotic environmental components: water, soil, climate;
- biotic environmental components: spermatophytes & algae, benthic invertebrates, fishes, seabirds, marine mammals, migrating birds and bats;
- biodiversity,
- landscape,
- objects of cultural value (i.e. archaeological sites).

Topics to be covered by EIA and monitoring

- hydrological conditions (currents, wave pattern);
- ice conditions,
- geological structure,
- biodiversity issues (benthos, benthic and pelagic fish, birds (migrating and local populations), bats, marine mammals, habitats).

Monitoring methods should comply with national and international standards (national accreditation is required). Main international standards used in Estonia for marine environment monitoring are based on ISO and HELCOM requirements (HELCOM COMBINE Manual).

Recent development plans on the establishment of offshore wind parks in the northern Baltic Sea (included Estonian coastal sea) have raised a series of questions on different legal and environmental topics. As this kind of experience is currently lacking we have initiated several investigations to clarify all possible environmental risks of establishment of offshore wind parks in the Baltic Sea area.

Offshore windpark related studies on benthic communities have been carried out in Estonian waters in connection with EIA process of two offshore windfarm projects currently under development. Main aspects so far has been concentrated on:

- possible effects of construction works on local benthic communities in the construction site,
- possible effect on benthic communities through addition of new substrate (new substrate in depth intervals previously lacking hard substrate),
- new substrate as possible „stepping stones“ for dispersal of non-indigenous species,
- possible effect of location (local conditions) on the colonization pattern and structure of pioneer community on new hard substrate.

Methodology of studies:

Effects of construction works on local benthic communities have been studied by disturbance experiments and added the new hard substrate on the seabottom. In Neugrund project site series of disturbance experiments were carried out in different depth intervals. Here local, hard bottom communities, were disturbed mechanically during different parts of vegetation period and then the recovery/recolonisation was followed on monthly basis. Quantification of the effects was done based on the mapping and spatial modelling of distribution of benthic communities in construction site.

Effects of adding new substrate in depth intervals previously lacking hard substrate were carried out by incubation of artificial substrate in three different area with different environmental and eutrophication level in northern part of Gulf of Riga – Kõiguste, Küdema and Orajõe. The natural rustic granite stones were installed in five depth on the seabed for assessing fouling communities. The experiment period was differ in different areas – experiment time in Kõiguste was 6 month, in Orajõe 7 month and in Sõmeri 11 month. It depended on weather conditions.

Results of studies:

In case of Neugrund project the effect of construction was estimated to be significant in certain depth intervals as the disturbed communities were not recovered during the vegetation period (and also during following vegetation period). The effect was stronger in greater depth (on the limit of photic zone), while communities in shallowest parts restored during one vegetation period.

In incubation experiments of new, artificial substrate incubation timing was identified as an important factor which has a strong impact on the structure of pioneer community. Local surrounding community has great importance in structuring pioneer community of new substrate.

Offshore wind farm has a potential to be a new habitat for marine biota (reef effect!) and causes significant changes in the environment and habitat quality in closest vicinity and possibly can have a cumulative effect over large areas.

Effects on the ecosystem can differ in the different parts of the Sea depending on several local features and large scale gradients.

Eutrophication gradient had significant effect on the colonizing communities.

While most of the environmental effects could be treated as reversible and insignificant, low species diversity, specific physical features, such as ice conditions and extremely low water transparency, should be treated as additional risk factors having magnification effect for any possible impact.

From the result of the experiment we concluded that in the Baltic Sea conditions the detailed experimental studies are needed to be conducted in the framework of EIA studies in each case and simple transfer of knowledge from other similar projects is not enough.

Contact: Liis Rostin & Georg Martin, Estonian Marine Institute, University of Tartu.

France

The French government has set a target of 23% of energetic consumption derived from renewable energy sources for 2020. With more than 11 million km2 of waters under its jurisdiction, France holds a huge natural potential for Marine Renewable Energy (MRE) and its exploitation could represent up to 3.5% of the national energetic consumption. No offshore wind farms have yet been constructed on French coasts in 2015. Nevertheless, France is planning the construction of six offshore wind farms around its metropolitan coasts. Among them, three will be built in the Eastern English Channel at Courseulles-sur-Mer, Fécamp, and Le Tréport. This development of MRE raises many environmental, technical and social issues (conflict of interest within other human activities such as aggregate extractions and fishing). All projects are at an early development stage and Environmental Impact Assessment programmes are not officially adopted yet. In the Channel, we benefited of historical and recent information on the sediment composition, macrobenthos and fish community structure and functioning. These databases should be a precious source for the estimation of reference conditions and the assessment of real impacts of wind farms in such megatidal environments where coarse sand, gravels and pebbles dominated. By anticipation, the Normandie Region has established a multidisciplinary approach and several types of research operations are planned to assess the impact of wind turbines: (i) on the hydrodynamism created around the conjunction foundation/tower, (ii) on the sediment changes, (iii) on the artificial reef effects on benthic and demersal fishes population, (iv) of the airflow change consequences, (v) on the cumulated impacts with other economic activities at sea and (vi) on the social reception and the biogeography of the wind energy. Moreover, Normandy is positioned as a favourite region for the development of renewable marine energy projects. This sparked the edition of a Handbook of Marine Renewable Energy research skill to favour the contact between the industry and the research.

In order to further knowledge on the structure and functioning of the marine ecosystem in response to the installation of those offshore wind farms, two PhD projects began at the M2C and BOREA laboratories at Caen University in late 2014. The PhD thesis of Jean Philippe PEZY will focus on the consequences of anthropological activities on secondary producers and on the trophic network of the eastern part of the English Channel. The PhD of Aurore RAOUX will will focus on modelling the impacts of the building and operational phases of the Courseulles-sur-Mer offshore wind farm on the local food web, in a climate change context. These two PhD thesis adopt a functional and holistic view of the ecosystem. Those two projects will be based on food web modelling tools (Ecopath for both and Linear Inverse Model based on a Markov Chain Monte Carlo method for the second one) through the collection of new data on biological compartments (zooplank-

ton, suprabenthos, benthos with isotopic analysis, and demersal fishes) and data from the Environmental Impact Assessment. In addition, both theses will contribute to a better understanding of the functioning of the English Channel, within an ecosystem-based management approach.

Contact: Jean-Claude Dauvin, UNICAEN, Université de Caen Basse-Normandie, Caen

Germany

In Germany, the offshore wind farm industry is rapidly growing and consecutively more and more results on the effects of wind farms on the benthal might become obvious. The final results of the 5 years ecological research at alpha ventus, i.e. the evaluation of the standard monitoring was finished in 2013 and presented during the StUKplus conference took place in Berlin. Besides the basic mandatory monitoring that is implicit for offshore wind farm environmental assessments, no further sampling campaigns under research projects on the effects of offshore wind farms on benthic invertebrates and demersal fish are carried out or financed thereafter in the near future. However, over the last eight years, the Alfred Wegener Institute (AWI) has built up a database on benthic invertebrates from environmental impact assessments (EIA) and research projects with >8000 station entries and more than 500 species (taxonomically harmonised). This database has been established in close cooperation with the approval authority, the Federal Maritime and Hydrographic Office (BSH).

Besides the research data, EIA data from approved wind farms are stored in the database. Currently, 32 wind farms are approved in the German exclusive economic zone (EEZ) of which six are already in use and seven are under construction. This means that a minimum of 1680 turbines are approved, 204 of these are already in use. However, in total 94 wind farms projects are currently in the process of approval including 6600 turbines. This would lead to a total number of 8000–9000 turbines in the German exclusive economic zone (EEZ) if all projects would be realised (source: www.offshore-windenergie.net).

The database is used to carry out classical spatial pattern analysis e.g. on endangered (red-list) species and biodiversity, biological traits and benthic community analysis. Besides an extensive spatial coverage, the database contains also AWI data on long-term series (> 30 years). Thus the database serves as a detailed base to estimate species or group specific “natural corridors of variation” to discriminate anthropogenic effects from natural background variability. Functionally sensible areas and important geographic sites that are of public concern regarding ecosystem services and goods are to be identified. This data will be used to provide evaluation criteria for identifying sensible areas in the context of licensing procedures of offshore wind farms and marine spatial planning. Study outcomes (e.g. in terms of maps) are made public via the internet (GeoSeaPortal) in order to provide stakeholders, such as authorities and scientific institutions, with scientific advice. Thus a major focus is the dissemination & communication of the results. First products are already available online via the GeoSeaPortal (www.geoseaportal.de/gdi-bsh-portal/ui). Further information systems with more functions and possibilities of diffent products are planned. AWI and BSH are aiming at a service-oriented, long-term open data service as a base for scientific advice for authorities and policy and a decision basis for stakeholders

Contact: Jennifer Dannheim, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven

Ireland

The Sustainable Energy Authority of Ireland (SEAI- www.seai.ie) is responsible for the development of marine renewables in Ireland. In addition to funding prototype development, the SEAI has also taken responsibility along with other state agencies (incl. The Marine Institute) to identify and apply for renewable test sites along the Irish coast. Currently there is one site licenced and operational for ¼-scale devices in Galway Bay. In addition, an application is in train for a full-scale device test site (County Mayo) which would encompass two locations – at 3 km offshore in 30 m water depth and at 10 km in 100 m water depth. An EIA has been produced; however, further cetacean baseline information has had to be gathered. In addition, planning and scoping is currently underway for the development of a site of the Coast of County Clare which would be a small scale array site for approximately 20 devices generating 10 MW. To facilitate these developments other agencies have prioritised research and survey activities in these areas, e.g. The Marine Institute and the Geological Survey of Ireland under the INFOMAR program to carry out acoustic survey of the seabed in these areas (www.informar.ie).

Contact: Francis O' Beirn, Marine Institute, Rinville, Oranmore, Galway

Poland

Marine renewable energy developments in Poland

In the time of writing that paper, there are no offshore wind farms in Poland. Initial plans for development of offshore wind farms in the country's marine areas assumed, that the capacity of installed wind power is going to be at least 0,5 GW in year 2020 and may reach 6 GW until year 2025. Currently due to ongoing delay in the pre-construction process it is obvious, that these goals will not be achieved and the commissioning of the first wind parks in Polish EEZ has been scheduled for years 2022 and 2026. These two wind parks form only a small part in the plans for offshore wind farms development in Poland. In total 23 sites has been chosen and approved for wind farms construction in three regions: Oder Bank, Słupsk Bank and Middle Bank. Total area of chosen sites comes to 1880 square kilometers. Estimated total capacity of wind farms that may be constructed there reaches 17 GW.

Previous and ongoing research

Natural hard bottom is very rare in the southern part of the Baltic Sea. Therefore, artificial structures such as offshore wind farms should be concerned as a significant interference in the local marine environment. Large-scale studies on soft sediment benthos were carried out in the past but current Polish monitoring stations are situated far away from the areas planned for wind farms construction.

As there are no offshore wind farms in Polish EEZ yet, the research in the area is limited to other artificial hard substrates such as shipwrecks and inactive offshore structures left after the World War II. Experimental hard substrates such as settlement plates are also used during the studies.

In year 2012 a pilot study on benthic fauna associated with the artificial hard substrata was carried out in the southern part of the Baltic Sea. Both long-term and short term communities were investigated. An inactive World War II torpedo testing facility in the Gulf of Gdansk served as a site for sampling long-term communities while short-term communities were sampled using settlement panels and PVC cylinders. Panels were deployed at the torpedo testing facility for 5 months. PVC cylinders were deployed for 3 months in the Polish Exclusive Economic Zone. Twenty six faunal taxa, including 11 crustacean taxa, were identified during the research. Mytilus edulis and Amphibalanus improvisus were the most abundant invertebrates at sampled surfaces. Five non-indigenous species were detected. For the first time adult individuals of Mytilopsis leucopheaeta were detected in Polish Marine Areas proving, that it is possible for this non-indigenous species to reproduce in this region. The details about the study are going to be published in Hydrobiological an Oceanological Studies.

Ongoing studies focus further on fouling communities but also on macrobenthic assemblages associated with sandy bottom in the vicinity of the artificial structures. We are planning to investigate an enrichment of soft sediment macrobenthos around offshore manmade structures in the Gulf of Gdańsk, southern Baltic Sea. The research is going to be conducted in similar manner as described by Coates *et al.* (2012) in WinMon Report. Samples are going to be collected around 60-years old foundations of offshore World War II watchtower, which will allow us to study fully-developed benthic communities. We also plan to collect the samples several times a year in order to describe seasonal changes.

Plans for research in upcoming years include a study focused on the role of artificial substrates in facilitating an expansion of non-indigenous species in the southern part of the Baltic Sea.

Contact: Urszula Janas & Radek Brzana, Institute of Oceanography, University of Gdańsk, Gdynia

Scotland

2013

(1) Project licencing research with main focus for informing offshore energy project plans and project licencing being marine mammals, seabirds, fish and fisheries; no research specifically targeting benthic ecology at this time.

Contact: Mike Robertson, Marine Scotland Science, Aberdeen.

(2) Studies on effects of tidal flow on benthic species, habitats and on intertidal bio-films. Theoretical and numerical studies of the probability of interactions between migratory fish and structures for marine renewable energy.

Contact: Angus Jackson, Environmental Research Institute, North Highland College – UHI, University of the Highlands and Islands, Thurso.

(3) Summary on current research on the effects of offshore renewable energy on benthos carried out at SAMS: four PhD thesis, several publication (in prep.) and two large projects are currently undertaken (NERC, EU).

2014

In September 2012, the University of Exeter, Cornwall campus, hosted a workshop on environmental impact of tidal energy devices. Following this workshop, a manuscript titled "Towards resolving fundamental issues in environmental impact assessment of marine renewable energy installations" has now been submitted to the Journal of Applied Ecology. The conference of "Environmental Interactions of Marine Renewables" (EIMR 2014) will run in Stornoway, UK at the end of April 2014. Many of the topics and presentations will be of relevance to our WG. The outputs of a project ("A review of the potential impacts of wave and tidal energy development on Scotland's marine environment") for the Scottish Government is now available online. This consists of 1) a written report (**www.scotland.gov.uk/Resource/0039/00391880.pdf**) and 2) an online tool giving preliminary assessments of likely impacts associated with deployment of 10 MW arrays of wave or tidal energy devices in Scotland. The tool allows you to choose any realistic combination of device technology, mooring method and species (including benthos) or habitat. The tool is available at www.scotland.gov.uk/Topics/marine/Licensing/marine/tool. The information system is in the process of being updated which should be available later in the year.

Contact: Angus Jackson, Cornwall College Newquay, Cornwall Plymouth University

Mike Robertson (Marine Scotland Science), on behalf of Finlay Bennet chair of Working Group on Marine Renewable Energy (WGMRE), delivered a short presentation describing the ToRs to be applied to the inaugural meeting of the WGMRE. These topics were discussed in plenary by all members of the WGMBRED.
Mike also briefly described the current status of marine renewable developments, wind, wave and tidal, in Scottish waters. Many sites have now been identified and leased while biological and environmental survey work is either ongoing or has also been compelled. Government (ministerial) approval to develop has been granted for two sites in the Moray Firth and has been applied for at major sites off the Firth of Forth.
In addition, Mike demonstrated seabed survey work carried out by MSS over the last few years in support of offshore renewables and the Scottish Marine Protected Area (MPA) project. Details of further survey work planned for 2014 were also presented.

Contact: Mike Robertson, Marine Scotland Science, Aberdeen

2015

The offshore renewable resource is considerable in Scotland and optimising the exploitation of this resource remains a high priority for the Scottish government http://www.gov.scot/Topics/marine/marineenergy.

The Pentland Firth, which lies between the north coast of Scotland and the Orkney Isles, is a major tidal energy resource. MayGen ltd (http://www.meygen.com/) have gained consent for Phase 1 of a multi-device deployment in the Pentland Firth. Other tidal projects are in the proposal stage, for example, DP Energy are, in partnership with the Scottish Association for Marine Science (SAMS), characterising the benthic and pelagic environments off Fair Head, Northern Ireland (http://www.fairheadtidal.com/). This site assessment /characterisation phase is being complemented by a research phase which is studying the basis of the current monitoring programmes, particularly in relation to the benthos and fish, and developing methods for assessing their ecological and societal relevance. This innovative research is being complemented elsewhere in Scotland, under the Marine Alliance for Science and Technology (MASTS) pooling initiative

(http://www.masts.ac.uk/). In relation to the benthos, MASTS is actively involved in strategic and joined up approaches across academic, statutory and industry partners to assist in targeted multidisciplinary research (http://www.masts.ac.uk/research/research-forums/marine-energy-forum/). This is evidenced by, for example, the Cumulative Impact Assessment workshop which followed on from the international 'Interactions of Marine Renewables' conference that was held in Stornoway (May 2014). Within SAMS there is a large benthic –renewables-interactions research programme. Current areas of investigation include the effects of man-made structures on sediment oxygenation (Wilding, 2014), the communication between man-made structures and colonising organisms (in relation to non-native species spread; Adams, Miller, Aleynik, & Burrows, 2014), research into the effect of tide, location and deployment duration on biofouling composition on offshore structures (Macleod *et al.*, papers in preparation), the effect of smothering on benthic communities (Hutchison *et al.*, papers in preparation) and assessing benthic productivity on offshore structures (Rouse *et al.*, papers in preparation). SAMS is also a partner in the MARIKA project (Marine Energy Research Innovation and Knowledge Accelerator, FP7 project 2014–2017) which aims to link all aspects (social, engineering and ecological) of the process of developing the renewables sector (https://merikafp7.wordpress.com/). Within Scotland there is a growing consensus that an ecosystem approach to assessing change should be adopted, and a growing awareness that the benthic habitat is a critical component of this ecosystem.

Contact: Tom Wilding, SAMS, Scottish Marine Institute

Sweden

Swedish offshore wind farms currently amount to 81 turbines and a total capacity of 180 MW. The largest one is still the Lillgrund wind farm in Öresund, with was connected in 2007 and has a capacity of 110 MW. Another 2450 MW have per-mission but are not (yet) constructed, and 5000 MW is undergoing consenting pro-cess.

The final report from the environmental monitoring of the Lillgrund wind farm that was published in Swedish in 2013 is now also available in English (translated version): https://www.havochvatten.se/en/swam/our-organization/publications/swam-publications/2015-04-08-study-of-the-fish-communities-at-lillgrund-wind-farm-report-201319.html

A summary of the current state of wind farm development in 2015 is given in the figure below. Some additional information relating to the content of the figure (https://www.havochvatten.se/hav/funktioner/sok/sok.html?query=vindkraft):

- Kattegatt Offshore: The Swedish agency for water and marine management has supported the application for permission, with the particular condition that noise levels during construction and operation are kept below a threshold value, as the area is important for harbour porpoises and a recruitment ground for local cod populations.
- Södra Midsjöbanken: The Swedish agency for water and marine management has opposed the application for permission, as the area is considered of specific importance for harbour porpoise in the Baltic Sea.
- Current experimental research is focussing on the effects of underwater sound of off-shore wind farm development on fish larvae and juveniles and on be-

havioural aspects of marine mammals. Field monitoring is currently limited to a monitoring programs at Amalia Wind Farm.

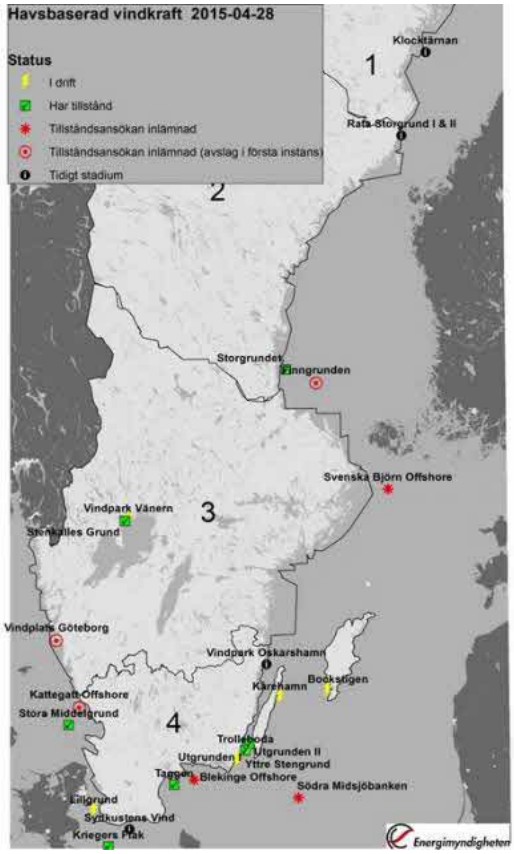

Figure 3. Legend coding: Yellow-operational, Green – permission in place but not constructed yet, Red asterisk- application for permission has been submitted but not yet received a response, Red circle-applicaton for permission has been submitted but denied at first submission, Black – Early stage of prospecting.(from www.energimyndigheten.se/Press/Pressmeddelanden/Stod-till-havsbaserad-vindkraft-har-utretts/.)

With regard to wave energy, a wave power demo farm of Sweden is being constructed at Smögen on the west coast of Sweden since 2013. The wave farm will consist of 420 wave power transformers with an output of 10 MW and 25 GWh per year, and will be the world's largest wave power farm.

A number of studies and doctoral theses have recently been published on the environmental effects of off shore renewables, such as:

Hammar L, Eggertsen L, Andersson S, Ehnberg J, Arvidsson R, Gullström M, *et al.* 2015. A Probabilistic Model for Hydrokinetic Turbine Collision Risks: Exploring Impacts on Fish. PLoS ONE 10(3): e0117756. doi:10.1371

Haikonen,K. 2014. Underwater radiated noise from Point Absorbing Wave Energy Converters : Noise Characteristics and Possible Environmental Effects. Doctoral thesis. Uppsala University.

Bergström L, Kautsky L, Malm T, Rosenberg R, Wahlberg M, Åstrand Capetillo N, Wilhelms-son D. *et al.* (2014). Effects of offshore wind farms on marine wildlife – a generalised impact assessment. Environmental Research Letters 9 034012

Hammar, L. 2014.Power from the brave new ocean. Doctoral thesis. Chalmers University of Technology. ISBN 978-91-7385-994-3.

Wilhelmsson D & Langhamer O (2014). The Influence of Fisheries Exclusion and Addition of Hard Substrata on Fish and Crustaceans. In: Shields M. A. & Payne. Marine Renewable Energy Technology and Environmental Interactions. Springer. 176 pp

Hammar L, Wikström A and Molander S (2014) Assessing ecological risks of offshore wind power on Kattegat cod. Renew. Energy 66 414–24

Summaries of the following papers were presented:

Hammar L, Andersson S, Eggertsen L, Haglund J, Gullström M, *et al.* (2013) Hydrokinetic Turbine Effects on Fish Swimming Behaviour. PLoS ONE 8(12): e84141. doi:10.1371

Bergström L, Sundqvist F., Bergström U (2013) Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community Mar. Ecol. Prog. Ser. 485: 199–210

Contact: Lena Bergström, Swedish University of Agricultural Sciences, Öregrund; Dan Wilhelmsson, Swedish Secretariat for Environmental Earth System Science (SSEESS), Royal Swedish Academy of Science, Stockholm

The Netherlands

In the period from 2013 to 2015, the Netherlands have been active in planning, monitoring and research on (the ecological effects of) offshore wind farms (OWF).

The spatial planning of offshore wind farms has been the emphasis of the last years, and recently that has led to the start of the construction of two new OWF, 'Luchterduin' to the west, and 'Gemini' to the north of the Netherlands. Moreover, a new round of tendering for two established OWF planning sites have started, 'Borssele' on the southwest, and 'Holland Coast' to the west of the Netherlands.

Monitoring and research has been followed up from the Masterplan that was established in 2010 (Boon *et al.* 2010), and led to research programs focusing on the underwater noise effects of construction on marine mammals (e.g. Kastelein *et al.* 2013) and on the survival of fish larvae (Bolle *et al.* 2012). Also, the monitoring around OWF OWEZ was finished, and was carried out around the operational OWF 'Amalia' (second OWF built in the Netherlands) and started around the new OWF mentioned above. Recently, desk studies were finished on the cumulative effects of underwater noise on harbour porpoise and of collision risk on birds.

Furthermore, Ph.D. research has started in 2012 on the effects of artificial reefs (such as oil and gas platforms and OWF) to model the species distribution of a number of reef species present on artificial and natural reefs (Coolen *et al.* 2015).

Coolen JWP, Bos OG, Glorius S, *et al.* (2015) Reefs, sand and reef-like sand: A comparison of the benthic biodiversity of habitats in the Dutch Borkum Reef Grounds. J Sea Res. doi: 10.1016/j.seares.2015.06.010

Bolle LJ, Jong C a F de, Bierman SM, Beek PJG van, Keeken O a van, Wessels PW, Damme CJG van, Winter H V, Haan D de, Dekeling RP a (2012) Common sole larvae survive high levels of pile-driving sound in controlled exposure experiments. PLoS One 7:e33052.

Boon AR, Hofstede R, Klok C, Leopold M, Blacquiere G, Kastelein RA, Camphuysen CJ (2010) Monitoring and researching ecological effects of Dutch offshore wind farms - Masterplan. Deltares report 1207076-000, Delft, The Netherlands, pp. 157.

Kastelein RA, Gransier R, Hoek L (2013) Comparative temporary threshold shifts in a harbor porpoise and harbor seal, and severe shift in a seal. J Acoust Soc Am 134:13–16.

United Kingdom

2013

Ongoing mesocosm study analysis of fish response to EMF and pile driving noise. New development at field site installing modular wave power device for multiple benthic related research projects. Also tidal device development at field site in South of England.

Contact: Andrew Gill, Cranfield University.

Presentation on the development and application of a 'flying array' with HD video camera from Plymouth University

Contact: Emma Sheehan, Plymouth University

2014

Emma Sheehan reported on Wave hub, a test site for Marine Renewable Energy located 10 miles north of SW UK. Wave hub was connected to the grid in 2010 and the first device to be tested at Wave hub will be deployed in summer 2014. Annual benthic monitoring surveys were done by Plymouth University Marine Institute of the Wave hub site and the associated cable route. Funding is required to repeat the annual survey of the Wave Hub site for device developers to use for impact assessment. Funding is also needed to repeat the impact study of the cable route to inform on recovery of the cable and to use as a baseline for future comparison with the potential impact of EMF when the cable becomes live.

Contact: Emma Sheehan, Plymouth University

Andrew Gill gave an update on activities that he and Cranfield University were particularly involved in. He had hoped to report that the field site in western Scotland would be up and running with a wave device (provided by a small Scottish company) and a set of research studies ongoing. However significant problems with the Crown Estate lease meant that it was not possible to allow the project to de-ploy a wave device at the present time. Other options are now being considered to see how research projects can be moved forward. On a more positive note Andrew reported on a new flagship EU project named MaRVEN – Marine Renewable Energy Vibration, EMF and Noise that was awarded to a consortium of nine organisations across seven countries. The project is 18 months long and will critically review the noise, vibration and EMF aspects of marine renewable energy devices (across the technologies – wind, wave and tidal) taking particular note of gaps in knowledge. These gaps will be filled by a field measurement campaign. The data collection covers important aspects of relevance to the benthic ecosystem, such as particle motion component of noise, vibration within sediments and EMF emissions.

Contact: Andrew Gill, Cranfield University, Cranfield, UK

2015

Scientists within Plymouth University's Marine Institute are to be part of a new EUR 17 million EU Horizon 2020 funded research project that will test a new energy converter at Wave Hub, off the north coast of Cornwall.

The five-year Clean Energy From Ocean Waves (CEFOW) project is being coordinated by Nordic company Fortum and will involve a new design of convertor called 'The Penguin' – designed by Finnish firm Wello.

Dr Emma Sheehan, a Research Fellow in the Marine Institute, will lead a team of Plymouth scientists, in conjunction with academics from the University of Exeter, and the University of Uppsala to assess how this device interacts with the marine ecosystem.

Heli Antila, Chief Technology Officer at Fortum, said: "Wave power may play an important role in the future as an emissions-free energy production form, and that is why Fortum is participating in the research and development efforts. By this project we are expecting to increase our capabilities and skills in the field of wave power. We believe that the funding from the European Commission and the experienced collaboration partners create excellent conditions for making great strides forward in commercializing Wello's wave power technology. On a global scale, this project is at the vanguard of wave power research.

The partnership also includes Mojo Maritime Ltd, Wave Hub Limited, Green Marine (UK) Ltd, and Uppsala University.

Dr Sheehan said: "This is a hugely exciting research and development project, and it's tremendous recognition once again of the expertise that we have, not just here in Plymouth, but across the South West, that we're an integral part of the impact study. We will be working with local fishermen during the course of the research, using our flying array to assess how the device interacts with the marine ecosystem."

Fortum signed a leasing agreement in February 2014 with the Wave Hub test facility to test wave power solutions off the coast of Cornwall in Great Britain. The agreement offers Fortum a new opportunity to trial run full-scale wave power devices in ocean conditions.)

Contact: Emma Sheehan, Plymouth University

Dr Andrew Gill highlighted the EU MaRVEN project: Environmental impacts of noise, vibration and electromagnetic fields from marine renewable energy. The study has been conducted by nine organisations across seven countries and has focussed on the construction and operational phases of MREDs. A specific target has been to understand if we have the information needed before we start looking at biological relevance of underwater noise. For example, only some species are sensitive to sound pressure, others only to particle motion but no one is measuring this. Hence the study has used bespoke equipment to measure unknown factors such as pile-driving and EMF emissions associated with wind, wave and tidal developments and looked to close knowledge gaps and hence reduce uncertainty for the decision makers.

Another project that has just started is linked to subsea cables, in USA, to learn about migrating species response to HVDC cables. There are suggested plans for extensive cable networks along the US coast to access the planned renewable energy developments and

export energy to other countries so understanding the impact of EMF is more important than ever.

There is a new EPSRC doctoral training programme run by Cranfield and Oxford universities, named REMS – Renewable energy marine structures. Centre for doctoral training – lots of Phds available looking at interface between engineering and environment. Dr Andy Gill has 2 new PhDs – Cumulative environment effects assessment and assessment of energy structures and environment.

Contact: Andrew Gill, Cranfield University, Cranfield, UK

5.3 Identified important topics besides the terms of references

During the three years of work in WGMBRED, some issues and questions occurred regularly when discussion the ecological relevance regarding the effects of MREDs on the benthal. These were questions on (a) defining relevant scales, i.e. if and when an effect matters to the system and if it is of ecological relevance, (b) considering not only of MRED effects but also other anthropogenic impacts on the system, (c) comparability of methods and habitats and (d) the ecological relevance of impacts versus effects and if these can be regarded as positive and negative.

Scale issues

Scales are an important aspect to assess interactions between benthos and offshore renewables. They differ from local, single device testing to commercial deployment, this will have important consequences to how the benthos responds and also how we determine the level of change and ultimately whether there are any impacts. The scale of change is already happening for offshore wind as plans for much larger developments and more developments in adjacent areas of the sea are in place with construction already occurring (e.g. southern North Sea). The cumulative effects on the benthos are much related to the scale aspect. Near-field effects are going to occur and we have the knowledge with which to determine the changes but are changes at this scale relevant? Devices are usually part of an array, London Array is 100 km2, but an effect at 50m distance, is small compared to total footprint. We need to think from single devices to arrays to superstructures: clusters of OWF such as 100–500 wind farms in an area. The question is what might happen looking at this larger scale. Here, we also need to consider linked questions such as what about invasive species at this scale, important for distribution.

Further, other human activities should be considered (i.e. MREDs as part of coastal modification): shipping, aquaculture, fishing. Here, scale-based connectivity and gradients are visible, as are temporal scale aspects such as seasonal, annual and long-term variability. Further, national boundaries prevent to carry out large scale investigations. All these things are part of the EIA, consistent guidance on scale related and cumulative effects, as well as 'significant thresholds identified' are lacking. Decision makers use the term 'reasonable foreseeable future' which is impossible to define. We need identification of relevant receptors, however there is currently no consideration for benthos except for designated features such as Sabelleria reefs.

Hence, the question is why benthos is important for society and at which scales act those societally relevant ecosystem services and goods. Some receptors are protected (e.g. Sabellaria, Lophelia, Modiolus), but we need to understand what scale these receptors op-

erate at. Thus, in relation to benthos, important issues can be raised such as questioning whether we are able to define a population, reproductive dispersal strategy, rarity, critical mass or baselines for general evaluation. Further, environmental positives and negatives are not weighted such as connectivity and habitat restorations/constructions etc. For the society, the issues biodiversity, biogeochemical cycling and food production are key functions of the benthos. Thus scales are relevant for both, ecosystem structure and functioning. Researcher need a strategy to make these steps relevant and scale plays a crucial role here.

MREDs are not placed randomly so more local scale effects may need to be considered on a site by site basis. However, the scale of the deployment footprint in relation to the benthic habitats within the jurisdiction of the country making the decision to deploy is relevant. Ecologists lack knowledge to understand relevant scales, but the society lacks even more. Choosing the right receptor is important if effects should be identified on different scales. Scale issues should always be in one's mind as they are the most relevant aspects that benthic ecologists need to consider when looking at the interactions between the benthos and MREDs in the future.

Cumulative impacts

Cumulative effects (CE) from single or multiple activities have moved to the top of the priorities for Marine Spatial Planning (MSP). CE by definition is considered as the combined impacts of a single activity or multiple activities. The individual impacts from a single development may not be significant on their own but when combined with other impacts, those effects could become significant. For example the combined effects of wind farms, climate change and loss of biodiversity can be considered as CE.

One of the main challenges facing offshore wind farm developers, regulators and environmental practitioners is how to best assess the CE or impacts of major offshore developments. At present there are several methods which offer the possibility of predicting cumulative effects, on biological receptors in response to cumulative effects of multiple interacting human activities. UK has developed a conceptual framework based on the DPSIR approach for documenting cumulative effects for UK offshore wind farms. This framework was then used to describe the main steps necessary for assessing cumulative impacts within the context of MSP (for example issues related to activities, scales and considering different levels of effects).

This work presents an initial assessment on the utility of various GIS modelling approaches to investigate cumulative impacts on marine biota and seeks to develop a consensus when developing CEA methodologies. Additionally some of the outputs from regional climate models (e.g. UKCP09) as well as data layers of current and future human activities have been considered to identify regions where multiple pressures are likely to interact to impact marine organisms in the future. Other countries (e.g. Belgium, Germany and the Netherlands) are facing similar challenges when assessing CEA and transboundary exchanges on suitable methodologies for assessing CEA will help managers and regulators to integrate and harmonise knowledge from current and future OWF developments. Such complex issues require collaboration between groups with dissenting interests over short and long term.

Cross-cutting topics

WGMBRED identified a number of scientifically relevant cross-cutting themes that are not completely covered by the Terms of References.

Comparability of methods and habitats

An important issue is the comparability of techniques / methodology in offshore wind park/marine renewable energy monitoring sampling. The development of common sampling design is important to observe long-term changes of offshore intertidal and subtidal fauna and flora and hard-bottom benthic communities from marine renewable energy developments (autochthonous and exotic species) to establish a European observatory link to climatic changes.

An interesting hypothesis would be if devices and subsurface structures are surrogates for natural hard substrata, i.e. if natural and artificial hard substratum ecosystems are different in structure function and ecosystem services. Further, it is important to assess how the type of environment that the marine renewable technology is deployed within will have implications for benthal ecosystem.

Ecological relevance of positive/negative effects and impacts

An important issue in the research of MRED effects on the benthos are the consideration of the definition of effects (i.e. something that is happening to the organisms, or a response) versus impacts (i.e. something where an effect causes significant change to either a species population or a community and the dynamics and whether it is regarded as positive or negative). In this context, addressing the question if arrays of MRED might function as sources for populations and have spill-over effects to the surrounding, i.e. the source-sink hypothesis, is of high ecological relevance. Further, determining methods to address the question of whether these new renewable energy structures in the environment can be regarded as positive or negative ecologically, including the spatial scale issue to consider the relevant scale of benthic ecological functioning (species, community, ecosystem) versus the societal magnitude of the impact (cf. context setting) is of great importance. As a first step, changes in ecological functioning might be evaluated using biological traits. Similar to fishery impact studies, changes in biological traits might be more significant than changes in species composition, e.g. transnational analysis of benthos in different wind farms.

5.4 Knowledge theme, summary of three years work (2013–2015)

Renewable energy developments, in particular wind farms, will most likely become one of the most important and large-scale anthropogenic pressures and will affect benthic communities over various spatial and temporal scales within coastal and offshore ecosystems over the next decades. Benthic organisms have a fundamental place in marine ecosystems and deliver numerous ecosystem goods and services (such as marine biodiversity, long-term carbon storage and natural resources), which are intimately linked to the benthic system. Extensive renewable energy developments have the potential to initiate processes which are expected to affect benthic communities in numerous ways. The identification and analysis of these processes is the prerequisite for an efficient,

hypothesis-driven approach towards the understanding of the various effects of marine energy developments on the marine benthos as well as on the whole ecosystem.

WGMBRED developed a set of hypothesis-driven pathways based on the schematic presentations of cause–effect-relationships (see ICES 2012) to subsequently provide a list of prioritized hypotheses (Multi-annual ToR A) and evaluated what and how much knowledge on related topics (e.g. artificial reefs) contribute to the issue of effects of renewable energy constructions (Multi-annual ToR E).

The output of this work will be a review paper (working title: 'Benthic effects of offshore renewables: prioritizing the known unknowns') that is relevant to managers, policy-makers and developers of offshore renewables, highlighting current knowledge gaps and suggest prioritization of the known unknowns. The review paper is due end 2015.

Analytical strategy

Step 1. WGMBRED first developed a set of hypothesis-driven pathways from a conceptual scheme of cause–effect relationships as developed during the Workshop on the Effects of Offshore Wind Farms on Marine Benthos, WKEOMB (ICES, 2012) and evaluated how knowledge of related topics (e.g. artificial reefs) can contribute to the issue of effects of renewable energy constructions. The disentanglement of the conceptual scheme began with consideration of societally relevant issues, i.e. the benthal being (1) a 'biogeochemical reactor', (2) a source of biodiversity and (3) a source of food resources for higher trophic levels. This work was conducted during the WGMBRED 2013 and finalised intersessionally between the WGMBRED 2014 and 2015 meetings.

Step 2. WGMBRED then classified the hypotheses into pressure groups in order to structure the manifold hypotheses. Four overarching pressure groups were defined (after Bergström *et al.*, 2014): (1) mechanical sea-floor disturbance, (2) artificial reef, (3) additional energy (sound, other energy) and (4) fishery cessation & displacement. The categories were used to group and structure the cause-effect-relationships and to discuss the relationships in a thematic context. This work was conducted during the WGMBRED 2014 meeting.

Step 3. WGMBRED then reviewed, evaluated and classified existing knowledge on the effects of offshore renewable constructions and related topics (e.g. artificial reefs) providing information on cause-effect relationships comparable to those of offshore renewables. For each hypothesis, lead authors were identified during the meeting, who steered the review process. This work was conducted intersessionally between the WGMBRED 2014 and 2015 meetings, and finalised during the WGMBRED 2015 meeting.

Step 4. The sensitivity of importance, confidence/certainty (i.e. amount of knowledge available) and consistency (i.e. appliance to all biotopes/habitats/areas) was assessed for each hypothesis. Here, also the concept of Bergström *et al.* (2014) was used as a basis. As there will be differences in the response of the benthic system to the effects of offshore renewable developments, the consistency of the hypothesis was evaluated for different habitats (soft – hard substrate) and different biological components (demersal fish, invertebrates and phytobenthos including benthic algae and microphytobenthos). WGMBRED further considered the importance of different spatial and temporal scales of the effect size caused by renewable energy developments throughout this assessment. This work was prepared for during the WGMBRED 2014 and finalised at the 2015 meeting.

Step 5. Analysis of knowledge gaps to identify and prioritise the known unknowns. This analysis will ultimately lead to the review paper 'Benthic effects of offshore renewables: prioritizing the known unknowns'. This work was prepared for during the WGMBRED 2015 meeting and will be finalised intersessionally before the end of 2015. Given that the work is ongoing at the time of writing, its results are not presented in this report.

Results

Step 1. Conceptual cause-effect schematics

The diagram as developed by WKEOMB (ICES, 2012) was greatly simplified and brief text descriptions of the processes that link the constituent components are provided. Figure 4 shows the simplified scheme of the 'biogeochemical reactor' issue, as an example of the conceptual cause-effect relationships schematics. Each hypothesised cause-effect relationship is symbolised by a coded arrow and was briefly described, e.g. a) the addition of artificial hard structures will change the morphology and increase the complexity of benthic habitats; b) a specific hard bottom assemblage consisting of fouling organisms (fauna and flora) and associated mobile megafauna will colonize the new and complex artificial habitat; c) export of organic matter released by the fouling and megafauna community on the artificial structure provides food for benthic communities in the nearby natural sediments; d) turbidity caused by suspended matter reduces light penetration into the water column thereby reducing the primary production of photosynthetically active phytoplankton; e) suspension-feeding fouling organisms extract plankton and suspended matter from the water column and thereby decreasing turbidity. The end results in this 'biogeochemical reactor' issue will facilitate the identification and assessment of (1) important functions of the benthos such as bioturbation and decomposition changed by the altered benthic assemblage structure, which may substantially affect biogeochemical processes crucial to the functioning of the local marine ecosystem, (2) the pelagic primary production support to benthic biogeochemical processes. Accordingly, altered rates of primary production may affect biogeochemical turnover rates of benthic species. This may substantially affect biogeochemical processes crucial to the functioning of the local marine ecosystem, and (3) the addition of 'new players' (i.e. fouling community on artificial hard substrata) and their specific metabolic activities substantially affecting biogeochemical processes crucial to the functioning of the local marine ecosystem.

Similar hypothetical cause-effect relationships schematics were developed for the benthos as a source of biodiversity and as a source of food resources for higher trophic levels (see ICES, 2013). In total, 19 hypothesised cause effect relationships were identified for the 'biogeochemical reactor' issue, 29 for the 'biodiversity' issue, and 15 for the 'food resources' issue. Note that some hypotheses are shared between two or three issues or are to be considered highly similar, leading to the identification of 26 unique hypothesised cause-effect relationships. This number is to be considered conditional as further scrutinisation is yet to be finalised.

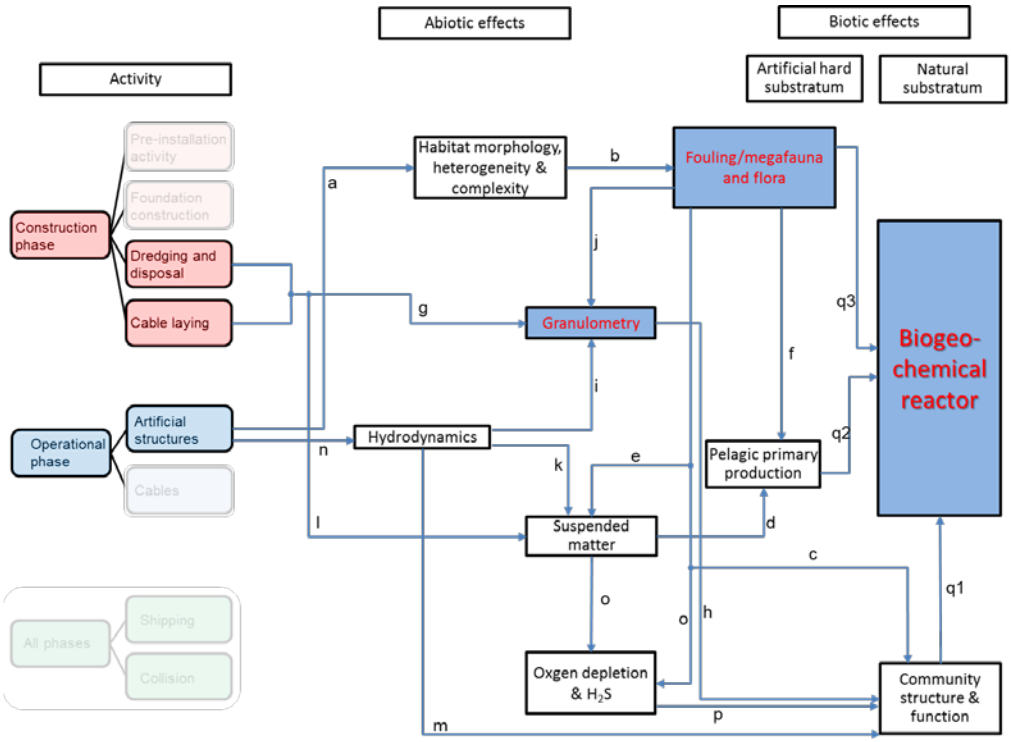

Figure 4. Conceptual presentation of the abiotic and biotic processes linked to biogeochemical reactor-importance of the benthos, altered by activities and the resulting activity pressures during the construction and operational phase of offshore renewable energy constructions. Hypothesised cause-effect relationships are coded by different letters (see text below for a selection). Note: Cause–effect relationships linked to cessation and displacement of fisheries are not considered here.

Step 2. Classifying cause-effect relationships in thematic pressure types

Some hypotheses are shared between two or three issue of the conceptual schematics. And are thus to be considered highly similar. In order to avoid duplication in the explanation of the cause-effect relationships of all three hypothetical schematics, the cause-effect relationships are along the four thematic pressure types following Bergström *et al.* 2014. These are mechanical sea-floor disturbance, artificial reef, fishery cessation & displacement and the introduction of energy effects, additional energy (sound, other energy). Note: Cause–effect relationships linked to cessation and displacement of fisheries are not considered.

Step 3. Existing knowledge review

During the intersessional work, a large literature review was carried out. For each hypothesis, text paragraphs of 5–15 lines were drafted by the WGMBRED lead authors summarising the current knowledge on the targeted cause-effect-relationships. These paragraphs are backed up with approximately 5–15 key references to literature from the offshore renewable energy development impact assessment studies or related studies. An example referring to the 'Biogeochemical reactor' issues, hypothesised cause-effect relationship 'i' (Figure 4), is given in the text box 1.

Text Box 1. Changes in water flow can lead to turbulences that cause resuspension of fine sediment fractions. Increased current speeds around the foundations will cause scour in the surrounding of the artificial structures.

Wind turbines may affect sediment- and morphodynamics particularly in relation to increases in turbidity; scour around the foundations, and erosion around the cables (e.g. Carroll *et al.*, 2010). For example, sediment erosion pits of 2 to 6.5 m were measured around Belgian monopiles (Van den Eynde *et al.*, 2013), while even larger erosion pits were reported from larger monopiles (den Boon *et al.*, 2004). Sediment sorting during erosion differs between sediment types (Law *et al.*, 2008): in non-cohesive sediments, larger grains are eroded progressively with increasing bottom stress; in cohesive silts, preferential erosion of the finer sizes no longer occurs, with all sizes up to medium silts eroding at approximately the same rate. Since most offshore wind farms are constructed in non-cohesive sediments (i.e. fine to coarse sands), granulometry will hence coarsen as a consequence of wind mill scouring. Cooper *et al.* (2011) demonstrated the sensitivity of macrofaunal communities to increase as both the proportion of gravel increased and the level of natural physical disturbance decreased.

References

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den Boon, J.H., Sutherland, J., Whitehouse, R., Soulsby, R., Stam, C.J.M., Verhoeven, K., Høgedal, M., Hald, T., 2004. Scour Behaviour and scour protection for monopile foundations of offshore wind turbines. European Wind Energy Conference & Exibition, 22-25 November 2004, London, 14 pp.

Law, B.A., Hill, P.S., Milligan, T.G., Curran, K.J., Wiberg, P.L., Wheatcroft, R.A., 2008. Size sorting of fine-grained sediments during erosion: Results from the western Gulf of Lions. Continental Shelf Research, 28: 1935-1946. doi: 10.1016/j.csr.2007.11.006.

This literature review produced 35 pages of summary text, covering 26 unique cause-effect relationships and referring to 232 unique scientific papers.

Step 4. Sensitivity, confidence, certainty and consistency assessment.

While preliminary developed during the WGMBRED 2014 and 2015 meetings, further discussion on the appropriateness of the criteria and their corresponding thresholds were held intersessionally after the WGMBRED meeting. Table 1 presents the final consensus on the selection of criteria and thresholds for prioritisation.

Table 1. Consensus selection of criteria and thresholds for hypothesis prioritisation.

Criteria	Score			
Following Bergström *et al.* (2014)				
	1 (low)	2 (moderate)	3 (high)	
Spatial extent	<100 m	<1000 m	>1000 m	
Temporal extent	<2 y (mainly construction effect)	<30 y (operation effect)	>30 y, beyond MRED life time (permanent)	
Sensitivity (quality of impact, extent of change)	Minor or no effects on abiotic and biotic processes	Effects on abiotic and biotic processes, no cascading effects	Effects on abiotic and biotic processes, cascading effects	
Consistency	Applicable to specific biotope/ecosystem components/effect size	Applicable to numerous biotopes/ecosystem components/effect size	Applicable to all biotopes/ecosystem components/effect size	
Following the evidence ranking of Marlin (www.marlin.ac.uk/evidenceranking.php)				
	1 (very low)	2 (low)	3 (moderate)	4 (high)
Confidence	information by "informed judgement" where very little or no information is present at all on the species	information has been derived from sources that only cover comparable studies or effects or from a general understanding of the cause-effect relationship. No information is present regarding the specific cause-effect relationship	information has been derived from sources that consider comparable effects of a particular cause-effect relationship (e.g. such as artificial reef studies)	information has been derived from sources that specifically deal with the cause-effect relationship of MREDs. Experimental or field work has been done to investigate the specific cause-effect relationship

The spatial and temporal scale extent scores, as well as the sensivity and the certainty scores were taken from Bergström *et al.* (2014).

The scale extent was chosen pragmatic rather then ecological reasons. The low score (<100 m) include very local effects, e.g. around one wind turbine, the moderate score (<1000 m) include e.g. all effects around an (wind farm) array, and the high score reflects effects that act on wider levels. The spatical scales was hence not chosen from a benthic perspective, as most of the benthic species have a far narrower activity range, but from an ecosystem perspective.

The temporal scale reflects the different phases of marine renwable energy developments, i.e. the effects of the construction of a structure, of its operation and effect of the marine renwable energy developments on the benthic systems that last longer than the marine renwable energy development's life time.

The sensitivity describes the quantity of an effect or the extent of a change. Low scores mean that the benthic system is nearly not afffected, medium scores reflect a direct impact on the benthic system without cascading effects, while high scores include unforseeable and cascading effects that might occur from the introduction and operation of marine renwable energy developments.

The consistency of the cause-effect relationships describes the appliance of the effect size to all biotopes, ecosystem components and effect sizes.

The confidence was scored on four categories following the evidence scoring of Marlin (www.marlin.ac.uk/evidenceranking.php), i.e. a very low score if there is limited or no documentation on the cause-effect relationship is available until extensive documentation of MRED studies by field or experimental work on a specific cause-effect relationship with a common agreement on the effect.

Table 2 presents an example of cause-effect relationship scoring as presented in Text box 1.

cause-effect relationship	spatial extent	temporal extent	sensitivity	confidence	consistency
Biogeochemical reactor, hypothesis "i" (see Text box 1)	1	2	2	3	1

The matrix constitutes the base for scientifically justification of the cause-effect relationships and thus to identify knowledge gaps and prioritise the known unknowns.

Step 5. Identifying knowledge gaps and priority known unknowns.

Currently ongoing. The group aims at submitting the manuscript until the end of the three years cycle (end of 2015).

References

Bergström, L., L. Kautsky, T. Malm, R. Rosenberg, M. Wahlberg, N. A. Capetillo and D. Wilhelmsson. 2014. Effects of offshore wind farms on marine wildlife-a generalized impact assessment. Environmental Research Letters 9(3). 12 pp.

ICES. 2012. Report of the Workshop on Effects of Offshore Windfarms on Marine Benthos - Facilitating a closer international collaboration throughout the North Atlantic Region (WKEOMB), 27–30 March 2012, Bremerhaven, Germany. ICES CM 2012/SSGEF:13. 57 pp.

ICES. 2013. Report of the Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED), 19-22 March 2013, Caen, France. ICES CM 2013/SSGEF:17. 23 pp.

5.5 Monitoring theme – summary of three years cycling, final conclusions and products to ICES

The ICES WGMBRED has met three times since its inception in 2012/13. The meetings occurred in Caen, France (March 2013), Tallinn, Estonia (March 2014) and Oban, Scotland, UK (April, 2015).

This report is structured chronologically and summarises the progress, conclusions and outputs from the Monitoring sub-group in relation to each meeting.

Caen, 2013

During the inaugural of the WGMBRED (Caen, 2013) the Monitoring Group was established to "review and evaluate sampling techniques the scientific efficiency of ongoing monitoring programmes of offshore renewable construction projects by identifying knowledge gaps and simplifying future standardised research". During the Caen meeting it was acknowledged that much of the current 'monitoring', as occurring around offshore renewable devices, did not serve a useful purpose in terms of better understanding the ecological processes affected by such developments. It was agreed that a fresh look at the main purpose and function of monitoring was required. During the Caen meeting the main issues in relation to monitoring were identified. These issues were:

1) The monitoring should not set out to assess whether change is occurring because change is inevitable - null hypothesis significance testing is not a useful paradigm in monitoring situations.
2) Given that change is inevitable, a major challenge before embarking on monitoring is to determine what change is important and how much change should be considered permissible (i.e. thresholds should be set).
3) Any 'threshold' setting exercise has to consider what are relevant scales in time and space. This means that local acute effects might be irrelevant (even if easy to monitor).
4) Given the inevitable limitation to resource, the group agreed that the focus of monitoring should be on determining change in relation to ecosystem services (e.g. fisheries) that had real meaning to society.

Following the identification of the issues identified during the Caen meeting it was decided that a scientific review paper should be written, drawing on the broad international experience represented in the ICES WG, to produce a synthesis. This paper would highlight and explain current deficiencies and propose a rationalised approach to monitoring that was fit for purpose. Given the current developmental stage of the sector as a whole it was decided that offshore wind should form the main focus of the review paper. A paper content was agreed (in broad terms) and tasks were assigned to member of the sub-group to initiate the paper writing phase with the objective of discussing the content and structure during the next meeting (Tallin, 2014). The objective of publishing a 'Monitoring review paper' was set.

Tallinn, 2014

In relation to the Monitoring sub-group the purpose of the Tallinn meeting was to coordinate the various inputs to the Monitoring review paper, rationalise the content and consider publication direction and options. It was agreed that the paper should focus on:

1) Consider current monitoring practices
2) Consider how to identify appropriate scales in time and space.
3) Consider what is required in terms of baseline studies/ background information

Given the lack of understanding about some of the fundamental aspects of inferential statistics (i.e. asking relevant questions and interpreting the resultant data) and the issues with the regulation of activities where the boundaries of impact were diffuse and where impacts are likely to be difficult to detect, it was agreed that the Monitoring paper review should be written for policy makers and regulators. Following discussion it was agreed that a potential journal could be the 'Journal of Applied Ecology'.

During the Tallinn meeting the Monitoring Review paper was re-structured and further (inter-sessional) writing tasks assigned with a view to finalising the paper during the following meeting.

Oban, 2015

In relation to the Monitoring sub-group the main focus of the meeting was to finalise the Review paper. Considerable work had gone into restructuring the review following the Tallinn meeting. Finlay Bennet (chair of the ICES WG on Marine Renewable Energy and part of the Marine Science Scotland's consenting team for offshore renewables) joined the group for a lively discussion about the concepts the paper was addressing. The review is split into two main parts: 1. asking logical questions, gathering data, understanding confidence in data and making decisions and 2. Determining relevant scales for monitoring and strategies for monitoring at those scales. The review paper challenges the current methodologies by questioning whether monitoring programmes that are not spatially delimited and linked to thresholds deliver value for money. We argue that a collaborative approach to determining the nature of significant changes that are attributable to offshore renewables is optimal, that sampling effort should be focussed quantifying changes in ecosystem services (e.g. fisheries) and that any sampling programme should be focussed on societally relevant metrics and be designed following a logical consideration of impact pathways and mechanisms of change.

The paper's draft title and structure is:

Title: Turning off the DRIP ('Data-rich, information-poor') - assessing relevant environmental impacts associated with offshore renewable energy developments

Contents

The main product from the Monitoring Group will be the publication of the review paper outlined above. This paper is in the final stages of drafting and will be submitted by September.

5.6 Metadatabase group

To address the ToRs c and d, it was agreed within the group that rather than reinvent the wheel on this we would assess the availability of existing metadatabases. We then chose to align our activities with the best international metadatabase access resource, the Tethys Annex IV, which is supported by the USA Department of Energy and the International Energy Association; existing knowledge is available and ready to be access by those looking for advice. Each member of WGMBRED is now a signed up member of the Tethys community and is able to add his/her expertise and outputs to the metadatabase. Also the outputs of the WGMBRED have been arranged to be available via the Tethys metadatabase to enable wider outreach via a linked webpage that we would align with Tethys.

5.7 Opportunities for collaboration and funding

Collaboration opportunities and cross-fostering research has been an important and continuous topic on the agenda of WGMBRED. The group regularly explored possible funding opportunities and collaboration perspectives ranging from workshops to tackle specific scientific questions in manuscript writing (e.g. joint data analysis on wind farm effects on benthos) to research projects at the EU level. Among these were:

- ICES science fund that has the aim to strengthen collaboration and support innovation (www.ices.dk/community/icessciencefund/Pages/default.aspx),
- COST fund which supports networking activities such as meetings (e.g. travel, subsistence, local organiser support), conferences, workshops, short-term scientific exchanges, training schools, publications and dissemination activities (www.cost.eu),
- European Science Foundation (ESF) has had regular calls for research networking programmes (www.esf.org/coordinating-research/research-networking-programmes.html),
- EU which is looking for ideas to develop the Horizon 2020 - Blue Growth focus area. Blue Growth aims at a long-term strategy to support sustainable growth in the seas and ocean. The Blue Growth Strategy recognises that the European seas and oceans are central to economy and has a large potential for innovation, economic growth and job creation.

- INTERREG programme which is an important tool for European regional development supporting cross-border, transnational and inter-regional cooperation of various entities, institutions and companies on relevant matters.
- ERA-NET (European Research Area Network) scheme which supports cooperation, nework activities and coordination of research activities carried out at national or regional level, including member and associated states.
- JPI Oceans which follows the concept of joint programming and was initiated to implement the European Research Area (ERA). It aims at solving challenges that cannot be solved at a national level and funds member states and associated countries to participate in joint initiatives for a common planning, implementing and evaluating national research programmes. JPI Oceans is a platform where applied research questions e.g. monitoring concepts and strategies in OWF research field might be funded.

WGMBRED has and will keep track on any upcoming calls that allows for funding opportunities on international level to strengthen research on MBRED effects on the benthos.

Besides funding opportunities, WGMBRED itself brought scientists together by experts working together in research projects, charging conference theme sessions etc. and sharing PhD students. Another example is the "Brussels Group" (chair: Roland Krone) was established in 2013, an informal network that aims at the facilitation of a cross-border collaboration on offshore wind farm effect research with a focus on mobile demersal megafauna.

6 Cooperation

WGMBRED has close links to several other ICES WGs, particularly to WGMRE, chaired by Finlay Bennett, and the BEWG, chaired by Steven Degraer and Silvana Birchenough respectively. While WGMBRED is focused on the scientific challenges of MRE monitoring for the benthic ecosystem, WGMRE has a wider remit and is focused on the policy aspects of MREsiting, consenting, licensing and monitoring. Andrew B. Gill represented the work of WGMBRED during the WGMRE meeting. BEWG deals with the ecosystem component in general but does not tackle the effects of MRED on the benthos. Jennifer Dannheim gave regular updates of WGMBRED activities during BEWG meetings. WGMBRED's current position is that it is focused on offshore renewable energy devices (e.g. wind farms, tidal and wave energy installations) but acknowledges that there are other MRE devices. WGMBRED does not currently have the in-house expertise to deal with these. If future scientific questions would show up, WGMBRED will aim at finding the appropriate expertise.

Until now, WGMBRED has no cooperation with advisory structures. However, the group is relatively young (3 years only) and no engagement in giving advice has been requested. In the future, WGMBRED would be open for any request giving advice on the knowledge developed within the group. Besides the group as a whole entity, single experts of the group are involved in national structures giving scientific advice to approval authorities, decision-makers and policy. The same holds true for cooperation with IGOs and national experts of WGMBRED.

7 Summary of Working Group self-evaluation and conclusions

The full Working Group evaluation can be found in annex IV, below is the summary and main conclusions:

- The WG made a significant contribution to the Science plan research priorities: 1.1, 1.3, 2.3 and 2.4.
- The main outcomes and achievements of the WG are:
    - Review paper for managers, policy makers, developers and academics highlighting the knowledge gaps (ToR A & E) in relation to offshore renewable energy devices on the benthic ecosystem. including a
    - Review paper on monitoring (ToR B & F), which has addressed scale aspects and the relevance to monitoring, defining suitable objectives and approaches to determine relevant changes to the benthic ecosystem.
    - Contribution of WGMBRED to the already existing global database Tethys, Annex IV, US DoE that brings together projects, experiments, research and scientists that relate to the effects of marine renewables on the benthal (ToR C & D).
- WGMBRED did not get any requests from ACOM.
- Within the last three years, experts of WGMBRED contributed to a number of conferences and meetings acting as members of scientific advisory committees, keynote presenter, main conference oral presentation and posters and workshop leading and participation.
- During the three years' work of the MBRED working group a slight adaptation of the focus of the ToRs has been conducted. Further, the time schedule was very tight and were a bit behind our schedule. We overestimated the amount of work and topics, as WGMBRED on this topic was just newly established. Change of direction in ToRs. However, no general difficulties to meet the ToRs occurred.

Future plans

- The experts agreed that a continuation of the WG is definitely required. The reasons are the rapidly evolving and changing industry in the sector of renewable energies, as well as the consecutive legislation requirements. The ongoing uncertainty and inconsistent interpretation of legislation between countries calls for an implementation of a common legislative framework. Further, more projects with a wider geographic scope are needed to look at cumulative impacts along coast lines. This calls for stronger international collaboration and knowledge exchange for all types of marine renewable energy technologies, not just wind.
- A stronger integration to other WGs such as WGMRE is important in the future. Several legislative frameworks points towards an ecosystem approach in marine management and sustainable use of marine services and goods. This calls for a stronger focus on the benthal as well, particularly in the context of cumulative impacts and connectivity of marine renewable energy devices.

- We believe that the specific outputs of the ToRs should be used to inform the advisory process as they are directly linked to the marine renewable energy sector and the ecosystem based management that is being promoted across the ICES region and further afield. The outputs of the ToRs form the main conclusions of the journal papers that have been written by the knowledge and monitoring sub-groups and will be submitted over the coming months.
- The WG has centred on making the benthic ecosystem of wider relevance by setting its importance within the ecosystem services context of, biodiversity, biological production and biogeochemical reactor. These three ecosystem services associate with the benthos highlights the fundamental role and importance within our marine ecosystems.
- Further advice would be linked with metadatabase where we have aligned our activities with the best international metadatabase access resource, the Tethys Annex IV which is supported by the USA Department of Energy and the International Energy Association.

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Annex 2: Recommendations

RECOMMENDATION	ADDRESSED TO
1. To continue the expert group on Marine Benthal and Renewable Energy Developments (WGMBRED) (see Annex 3)	SCICOM

Annex 3: WGMBRED draft multi-annual resolution

A **Working Group on Marine Benthal and Renewable Energy Developments** (WGMBRED), co-chaired by Jennifer Dannheim, Germany and Andrew B. Gill, United Kingdom, will meet to work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2016	14–18 March	Delft, the Netherlands	Interim report by 31 May 2016 to SSGEPI	
Year 2017			Interim report by Date Month to SSGXXX	
Year 2018			Final report by Date Month to SSGXXX	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Critically assess relevant temporal and spatial scales in relation to the effects of MREDs on the benthic ecosystem and evaluate the consequences in relation to environmental policy and decision-making.	Based on the first 3 years of WGMBRED the spatio-temporal aspect has risen to the top of the priority list for determining the interaction between the benthic ecosystem and MREDs	14, 25, 31	3 years	Review paper
b	Review progress on filling knowledge gaps relating to the benthic ecosystem including differentiation among MRE technologies using e.g. reports of national activities.	The need to update in light of new knowledge and expansion of MREDs is fundamental to feed into advice and assessment of MREDs in relation to benthos. It also enables the WGMBRED to feed into the identified science plan topics	8, 11, 25, 27	1,2,3 years	Matrices – updated knowledge base
c	Analysis of network and interactions amongst WGMBRED and other relevant groups including regulators,	It is evident that only a coordinated effort to harness the wide international interest and requirement to understand MREDs	15, 26	1,2 years	Collated list -1 Network map -2

	stakeholders, policy makers and scientists, in order to evaluate the impact of MBRED science.	and the benthic ecosystem is needed to then provide the evidence for policy makers			
d	Identifying and operationalising relevant indicators in relation to assessing ecosystem functioning and change in relation to MBRED at scales related to ToR A.	The benthic ecosystem is complex so to convey important changes to the system relating to MREDs suitable indicators are required. This also fits with a number of aspects relating to the science plan topics	5, 6, 8, 9, 11,	3 years	Review Paper

Summary of the Work Plan

Year 1	Begin review paper to start to address ToRs a and d; develop and set out matrix of knowledge gaps for ToR b; gather information on network of experts for topic to address ToR c
Year 2	Continue review paper activity to address ToRs a and d; further develop matrix of knowledge gaps in relation to national and international knowledge for ToR b; use information on network of experts to analyse and produce a network map for ToR c
Year 3	Finalise reivew papers ready for submission for ToRs a and d; finalise matrices and interpret output to address ToR b

Supporting information

Priority	The activities of the working group will lead ICES into issues related to upcoming large-scale ecosystem effects of renewable energy constructions on the marine benthal community (i.e. macroalgae, invertebrates and demersal fish). The objectives addressed here will be highly relevant in the context of future ecosystem-based management approaches, marine spatial planning and required monitoring schemes. Consequently, these activities are considered to have a very high priority.
Resource requirements	No specific resource requirements beyond the need for invited members to prepare for and resource their participation in the meeting.
Participants	These would include scientists working with the effects of marine renewable energy developments on the marine benthal community, including algae, infaunal invertebrates to benthic /demersal fish. Participation is sought from ICES countries and by scientists both from disciplines and scientific circles not normally represented at ICES. The Group is normally attended by some 15–20 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no direct linkages with the ICES advisory services, although the expert group results will have potential here.

Linkages to other committees or groups	There is a very close working relationship with Benthos Ecology Working Group (BEWG) and the Working Group on Marine Renewable Energy (WGMRE) and hence SSGEPI and SSGEPD.
Linkages to other organizations	

Annex 4: Copy of Working Group self-evaluation

1) Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED)

2) Year of appointment: 2013

3) Jennifer Dannheim (Germany) and Andrew B. Gill (United Kingdom)

4) 19–23 March 2013, Caen, France (21 experts)

25–28 March 2014, Tallinn, Estonia (19 experts)

21–25 April 2015, Oban, Scotland/ United Kingdom (15 experts)

WG Evaluation

5) If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

1.1 Climate change processes and predictions of impacts

1.3 The role of coastal zone habitat in population dynamics of exploited species

2.3 Influence of development of renewable energy resources (e.g. wind, hydropower, tidal and waves) on marine habitat and biota

2.4 Population and community level impacts of contaminants, eutrophication, and habitat changes in the coastal zone

6) In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

- Review paper for managers, policy makers, developers and academics highlighting the knowledge gaps (ToR A & E) in relation to offshore renewable energy devices on the benthal including a
    - Matrix/literature review on related topics of hypothesis that are part of the specific cause-effect relationships of effects of offshore energy constructions on the benthal
    - Assessment of sensitivity, certainty and consistency of cause-effect-relationships of the matrix
    - Analysis of knowledge gaps via literature review in order to identify and prioritise the known unknowns.

- Review paper on monitoring (ToR B & F), i.e. addressing scale aspects and the relevance to monitoring, defining suitable objectives and approaches to determine relevant changes to the benthic ecosystem
    - Highlights the current issues related to benthic monitoring, particularly in relation to spatial and temporal scale and biologically relevant size of effect to be monitored
    - Case study to be used to illustrate concepts reviewed and presented in paper.

  - Highlights knowledge gaps and prioritisation

- Contribution of WGMBRED to the already existing global database Tethys, Annex IV, US DoE that brings together projects, experiments, research and scientists that relate to the effects of marine renewables on the benthal (ToR C & D) including a
  - webpage portal entry for WGMBRED with a link to ICES, metadata from members of the WGMBRED and their expertise details were stored in the database
  - Set of relevant reports, metadata and publication notices that expose the work of the WGMBRED to the outside world as the come to experts on the topic.

7) Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

WGMBRED did not get any requests from ACOM.

8) Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

Within the last three years, experts of WGMBRED contributed to the following outreach activities:

- Keynote speaker on the Conference on Wind energy and Wildlife impacts, Berlin, Germany, 2015 (**Andrew B. Gill**)
- WinMon-conference: Environmental impacts of offshore wind farms – learning from the past to optimise future monitoring programmes, Brussels, Belgium, 2013 (Organiser: **Steven Degraer**; members of the scientific conference committee: **Jennifer Dannheim, Andrew B. Gill, Dan Wilhelmsson**; oral contributions: **Silvana Birchenough, Delphine Coates, Jennifer Dannheim, Ilse De Mesel, Francis Kerckhof, Jan Reubens, Roland Krone**)
- Stukplus conference: Five years of Ecological Research at alpha ventus – Challenges, Results, Perspectives, Berlin, Germany, 2013 (oral contributions: **Jennifer Dannheim, Steven Degraer, Lars Gutow, Roland Krone**)
- Hydrobiologia special issue (volume 756, issue 1) on Environmental impacts of offshore wind farms – learning from the past to optimise future monitoring programmes (eds: **Steven Degraer, Jennifer Dannheim, Andrew B. Gill, Han Lindeboom, Dan Wilhelmsson**) (publications of WGMBRED experts: **Delphine Coates, Jennifer Dannheim, Steven Degraer, Andrew B. Gill, Ilse De Mesel, Francis Kerkhof, Jozefien Derweduwen**)

- Publication in Proceedings of the Twenty-third (2013) International Offshore and Polar Engineering Benthic Interactions with Renewable Energy Installations in a Temperate Ecosystem. **Emma V Sheehan**, Matthew J Witt, Sophie L Cousens, Sarah C Gall, Martin J Attrill. Conference on International Offshore and Polar Engineering, Anchorage, Alaska, USA, June 30–July 5, 2013. Copyright © 2013 by the International Society of Offshore and Polar Engineers (ISOPE) ISBN 978-1-880653-99–9 (Set); ISSN 1098-6189 (Set)
- Workshop leader – **Tom Wilding**. 2nd International Conference on the Environmental Interactions of Marine Renewables (EIMR - II). Theme: Interactions with devices.
    - Presentation 1: Offshore renewables and impacts: who cares, how much and why? **Thomas A. Wilding** and L. Greenhill
    - Presentation 2: Development of a spatio-temporal risk assessment methodology applicable to the marine environment. **Andrew B Gill**, H L Perotto-Baldivieso, M Castillo Garcia, M Moore, G Prpich, C Maulshagen, A Queen, **Silvana Birchenough** + & S Jude

9) Please indicate what difficulties, if any, have been encountered in achieving the workplan.

During the three years' work of the MBRED working group a slight adaptation of the focus of the ToRs has been conducted. Further, the time schedule was very tight and were a bit behind our schedule. We overestimated the amount of work and topics, as WGMBRED on this topic was just newly established. Change of direction in ToRs. However, no general difficulties to meet the ToRs occurred.

Future plans

10) Does the group think that a continuation of the WG beyond its current term is required?

Yes. The experts agreed that a continuation of the WG is definitely required. The reasons are the rapidly evolving and changing industry in the sector of renewable energies, as well as the consecutive legislation requirements. The ongoing uncertainty and inconsistent interpretation of legislation between countries calls for an implementation of a common legislative framework. Further, more projects with a wider geographic scope are needed to look at cumulative impacts along coast lines. This calls for stronger international collaboration and knowledge exchange. A stronger inclusion of other devices than only wind farm turbines is needed and thus a stronger integration to other WG such as WGMRE is important in the future. Several legislative frameworks points towards an ecosystem approach in marine management and sustainable use of marine services and goods. This calls for a stronger focus on the benthal as well, particularly in the context of cumulative impacts and connectivity of marine renewable energy devices.

11) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

No, please see the new category 2 draft for WGMBRED continuation.

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

None.

13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used?

We believe that the specific outputs of the ToRs should be used to inform the advisory process as they are directly linked to the marine renewable energy sector and the ecosystem based management that is being promoted across the ICES region and further afield. The outputs of the ToRs form the main conclusions of the journal papers that have been written by the knowledge and monitoring sub-groups. The papers have yet to be submitted as they are in the final stages of work with the main authors prior to final submission. However they are covered in the WGMBRED reports to ICES and centre on making the benthic ecosystem of wider relevance by setting their importance within the ecosystem services context of, biodiversity, biological production and biogeochemical reactor. These three ecosystem services associate with the benthos highlights the fundamental role and importance within our marine ecosystems. Further advice would be linked with metadatabase where we aligned our activities with the best international metadatabase access resource, the Tethys Annex IV which is supported by the USA Department of Energy and the International Energy Association; existing knowledge is available and ready to be access by those looking for advice. The outputs of the WGMBRED are linked to the Tethys metadatabase and will be kept updated as long as the WG continues.