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Executive summary

The Benthos Ecology Working Group (BEWG) held its 2012 meeting at the Marine Station of the University of Reykjavik in Sandgerði, Iceland. The meeting was attended by 26 participants, representing 12 countries.

The meeting was structured along the three BEWG core business issues: long-term series and climate change, benthos-related environmental quality assessment and marine habitat modelling and mapping.

The topic on long-term benthos series and climate change was introduced by six oral presentations, after which BEWG developed its future plans on this topic. This future work will be firmly embedded within the Benthos Long-Term Series network (BeLTS-net), with the aim of fostering collaborative work on long-term benthos data. The BeLTS-net website content and layout was fine tuned during the meeting and the website will be launched in mid-June 2012. The issue of climate change and benthos is also the major focus of the Study Group on Climate-related changes in the Benthos of the North Sea (SGCBNS), currently focusing on two case studies (i.e. seasonal and spatial patterns in bioturbation). BEWG further reviewed the status of a joint review paper on the effects of climate change onto the benthos, to be submitted for publication in September 2012. BEWG decided to take on two challenges for the next year: (1) to report on the link between ecosystem functions and ecosystem services and (2) to review a data compilation on functional diversity of macrobenthos to ecosystem functioning as a basis for future research. Both initiatives will be launched intersessionally and finalised during next year's BEWG meeting.

Benthic indicators, their applicability and development have always received a lot of attention from BEWG. The status of the BEWG manuscript "The myths of indicators: The crux with indicator species" was reviewed and plans for finalisation were agreed upon, aiming at submission in December 2012. Based on eight oral presentations serving as an eye-opener for an elaborated discussion on the indicators of biodiversity that are linked to ecosystem functioning, BEWG decided to add ecosystem functioning as a horizontal theme to its future work. A first step here will be to review and identify indicators that reflect the link between biodiversity and ecosystem functioning, with a focus on benthos. BEWG will finally continue its work on benthic indicators by reviewing and reporting on ecological, environmental and conservation status and on indicators under de WFD, MSFD and Habitats Directive.

No less than five participants shared their work on habitat suitability modelling and mapping with BEWG, demonstrating the high importance of this topic relatively new to BEWG. The manuscript on "Species distribution modelling and mapping in the marine environment and its relevance for ecosystem management" was presented and plans for its finalisation were made. The anticipated date of submission is 30 September 2012. BEWG also planned for future initiatives, which will focus on e.g. reviewing and comparing different quantitative modelling techniques.

This year's other business comprised a review of the key stone species concept, an evaluation of the usefulness of fish stomach data to provide information on spatio-temporal patterns in the benthos and an introduction to BEWG outreach initiatives (e.g. workshops, conferences) from the recent past and future.

The BEWG proposed Steven Degraer to continue as Chair of the group for two more years. Steven Degraer accepted.

1 Opening of the meeting

The Chair, Steven Degraer, opened the meeting at the Marine Station of the University of Reykjavik in Sandgerði, Iceland. S. Degraer welcomed the participants and gave a brief summary on the recent work carried out by the Benthos Ecology Working Group. He introduced the three main themes the BEWG continuously has worked on over the last years: Benthic long-term series and climate change, benthic indicators and the latest topic of species distribution modelling. The agenda structure of the meeting follows these main themes. An ICES SharePoint was made available before and during the meeting. This has as before proved to be a valuable tool to speed up the work and make exchange of information more efficient. Further, practicalities for the meeting and reporting were introduced to all participants. H. Hillewaert was appointed to take the lead as editorial rapporteur. Afterwards, the participants introduced themselves and gave a short review of their scientific activities. 26 participants from 12 countries attended the meeting (Belgium, Canada, Denmark, Germany, Estonia, Iceland, Italy, Norway, Russia, the Netherlands, United Kingdom and the United States), two participants contributed remotely (Spain and the United Kingdom). Finally, the local hosts, R. Sveinsson and H. P. Halldórsson (ISL) welcomed the participants on behalf of the Marine Station, Sandgerði, and J. Svavarsson (University of Iceland) gave an introductory overview on benthos research around Iceland.

2 Adoption of the agenda

The group unanimously adopted the agenda without changes (Annex 2).

3 Long-term series and climate change

3.1 Climate change effects on benthic communities

3.1.1 Reports on recent findings on long-term data series analyses and other climate change-related benthos activities

3.1.1.1 From BIOICE to IceAge – mapping and modelling of benthos in Icelandic waters

J. Svavarsson reported on work by J. Svavarsson, K. Meißner, D. Fiorentino, P. Martinez Arbizu, F. Huettmann, S. Schnurr, S. Brix and S. Holst

Icelandic waters are very important in terms of oceanography and in terms of species distributions. The area is the gate between the North Atlantic proper and the Nordic Seas (the GIN Seas, i.e. the Greenland, Iceland and Norwegian Seas). It is characterized by very strong thermal gradients in shallow waters, and in deeper waters the Greenland-Iceland-Scotland Ridge with maximum saddle depth of 840 m, separates the colder deep Nordic Seas (<0°C at depths >1000 m) from the warmer North Atlantic proper (2–3°C mostly in deeper waters). This area is likely to be influence by global warming.

The area is substantial in its size, i.e. being 758 000 km2. Prior to 1991 the area was fairly poorly known with most of the information on species distribution being gathered during the Danish Ingolf expedition in 1895 and 1896. The international BIOICE project (Benthic invertebrates of Icelandic waters; 1991–2004) was initiated to gather information on the distribution and species composition of benthic invertebrates in Icelandic waters. During the project in all 1390 samples were taken from 579 stations, thereof 1050 biological samples and 340 sediment samples. Lots of information has

been gathered on distributions of species and this data offers excellent possibilities for modelling species distributions. In 2011 the BIOICE project was followed up by the IceAGE project (Icelandic marine animals, genetics and ecology). Sampling occurred in September 2011 on RV Meteor and around 36 stations were taken at various depths all around Iceland. This data is used in connection with the BIOICE data to model species distribution. A variety of models have been used, i.e. the MARS model (Salford SystemsTM), the TreeNet model (Salford SystemsTM) and the MaxEnt model (Maximum entropy modelling). Several predictors were used, such as near-bottom temperature, maximum and minimum temperature, salinity, seasonal variation index, POC, oxygen and others. The modelling seems to be very successful and interesting data is coming out of the modelling process. The IceAGE project is ongoing and further data emerging from the IceAGE project will be used to verify the distribution models.

3.1.1.2 On the outcome of the UNESCO workshop on The Ecological Implications of Climate Change on the Venice Lagoon and its relevance to the BEWG

Paolo Magni reported

In spring 2011, under the auspices and organization of the UNESCO Venice's office, the Institute of Marine Sciences of the Italian National Research Council (CNR-ISMAR), brought together in Venice an international group of experts on lagoons and estuaries to discuss the major ecological implications of Climate Changes on the Lagoon of Venice for the end of this century (Tagliapietra *et al*., 2011). The discussion was based on the available climate change scenarios and on the outputs of a previous UNESCO workshop on Sea Level Rise prospecting (Umgiesser *et al*., 2011). These workshops were aimed at providing a scientific contribution to highlight the relevance of Venice and its lagoon as a worldwide and challenging issue in the Climate Change context.

General effects of climate change on the lagoon functioning (e.g. sea level rise, acidification, temperature raise, biological invasions, phenological and physiological changes) were discussed, with a major focus on the benthic communities. It was concluded that there is a need to strengthen a coordinated and large-scale research effort on the relationship between lagoon metabolism and hydrology and on the related biological patterns. Ad hoc research programs with experimental studies and observational monitoring should be implemented to improve our understanding of ecological responses to Climate Change. This will enable the implementation of adaptive management policies to face proactively the change and to mitigate deleterious effects as much as possible. The rapid adoption of a long-term strategy is needed, including careful economic and territorial planning addressing the reduction of loads and pressures on the lagoon. Climate-related ecological changes that are currently being observed in Mediterranean lagoons are likely to occur in the near future at higher latitudes. A stronger cooperation between scientists and institutions from different biogeographic regions, including the Mediterranean and the North Atlantic seas, is encouraged through the BEWG activities.

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3.1.1.3 Regime shifts in the Limfjord coastal system, Denmark

Grete Dinesen reported

An integrated ecosystem assessment was carried out for the Limfjord for the period from 1984–2008 to describe changes in ecosystem structure.

The fjord system has experienced a six-fold increase in nitrogen and phosphorous loadings over the past century, peaking in the mid-1980s, and nutrient levels are still high. The commercial fin fish fishery declined dramatically in the 1970s, and today, mussel fishery provides the largest harvest yield from the fjord system. With a coastline of 1000 km, a surface area of ~1500 km^2, and a mean depth of 5.5 m, the Limfjord connects with the North Sea to the west and the Kattegat to the east. The catchment area is 7528 km^2, of which 62% is arable land.

The analyses showed that from 1990–1995 the ecosystem structure shifted from dominance by larger, demersal piscivores (eel pout, whiting) and flatfish (flounder, plaice) to that of migratory pelagic species (sprat, herring), small-bodied forage species (black goby, sticklebacks, pipefish), mussel predating common crab and starfish, and planktivore jellyfish and blue mussels. We interpreted this change as a regime shift. This is the first empirically detected regime in a Danish fjord system. The analyses further showed the regime shift to be driven by a combination of anthropogenic pressures and possible interplay with climatic disturbance.

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3.1.1.4 Long-term observation of epibenthic fish in the deep Gulf of Mexico.

Chih-Lin Wei reported on work by Chih-Lin Wei, Gilbert T. Rowe, Richard L. Haedrich & Gregory S. Boland

A total of 172 bottom trawl/skimmer samples (183 to 3655 m depth) from three deep-sea studies, *R/V Alaminos* cruises (1964–1973), Northern Gulf of Mexico Continental

Slope (NGoMCS) study (1983–1985) and Deep Gulf of Mexico Benthos (DGoMB) program (2000 to 2002) were compiled to examine temporal and large-scale changes in epibenthic fish species composition. Based on species percentage shared among samples, homogeneous faunal groups (≥ 10% species shared) consistently reoccurred on the shelf-break (ca. 200 m), upper-slope (ca. 300 to 500 m) and upper-to-mid slope (ca. 500 to 1500 m) depths. These similar depth groups also merged in the pooled analysis, suggesting that there has been no large-scale temporal change in depth zonation on the upper section of the continental margin. Permutational multivariate analysis of variance (PERMANOVA) also confirmed no significant species changes on the limited sites and areas that have been revisited across the studies ($P > 0.05$). At a small scale, the most current data suggested a potential shift in species composition of west central upper-slope assemblages toward resembling lower slope assemblages. Nevertheless, the depth zones on the lower slope or abyssal plain were either derived from the *R/V Alaminos* or DGoMB studies, suggesting that the depth zonation may not be consistent across studies in these areas. Based on the ordination of the species shared among samples, species replacement was continuum along a depth or macrobenthos biomass gradient. The fish species changed more rapidly above 1,000 m depth but the rate of changes was surprisingly slow at the higher end of macrofaunal biomass (> 100 mg C m^{-2}), suggesting that the composition of epibenthic fishes did not respond to the extremely high macrofaunal biomass associated with the Mississippi and De Soto Submarine Canyons. An alternative hypothesis based on biological interaction was provided to explain the pattern of fish species turnover with macrofaunal biomass.

3.1.1.5 Long-term changes in macrozoobenthos in the south-eastern part of the Barents Sea

Igor Manushin reported on benthos studies since the 1920s in the south-eastern part of the Barents Sea. The area was chosen for the long existing data series, the pronounced climate changes, the low anthropogenic impact and absence of noticeable invasive species.

One of the major problems in working with this kind of old datasets concerned the harmonization of the species taxonomy between data sets from different sampling times.

The optimal conditions for benthic communities proved to be stable climatic conditions. The highest biomass was observed in that period. Climate change resulted in macrozoobenthos biomass reduction. This reduction may be caused by structural changes in the community, which make a negative impact on the community functioning.

Biogeographic borders were distinct when climate conditions are stable and uncertain when climatic periods change. Climate change furthermore, produced a different impact on species even within the same biogeographic group.

However, not all obtained results may be accounted for by direct influence of climate on macrozoobenthos.

3.1.1.6 Effects of climate change on long-term response of benthic communities in the Western Gulf of Mexico

Paul Montagna reported

Predicting potential effects of climate change is difficult, but comparing benthic communities living in different climate regimes at the same time can inform how benthic communities might change under differing climate regimes in the future.

There is probably no better place on Earth to compare effects caused by changing climate regimes than the Texas coast, because the major estuarine systems lie in a climatic gradient where runoff decreases 56 fold from the Louisiana border in the northeast to the Mexico border in the southwest. This results in a gradient of four subregions where the inflow balance in estuaries ranges from strongly positive, moderately positive, neutral, to negative. Thus, nature has provided a perfect experimental design to compare estuarine processes that change in relation to freshwater inflow, which is the defining characteristic of estuaries. We only have to assume community change along the climatic gradient is analogous to change over time as a function of climate change.

Four estuaries in South Texas: Lavaca-Colorado (LC), Guadalupe (GE), Nueces (NE) and Laguna Madre Estuaries (LM) lie in a climatic gradient where LC and GE receive more rainfall than NE, and NE receives more rainfall than LM. Consequently inflow and nutrient loading decreases and salinity increases along the gradient. In addition there is year-to-year variation in rain and inflow that results in wet and dry years. Therefore, this combination of the climatic gradient and temporal variability can be used to identify the effects of inflow variability on estuarine secondary production. This current analysis used two long-term datasets to compare these estuaries. The Harte Research Institute (HRI) ecosystems group has been collecting water quality and benthic data quarterly since 1987. The Texas Parks and Wildlife Department has been collecting fisheries independent data monthly since 1977.

There are two direct effects of climate change, which are already observable in the instrumental record: rapid sea-level rise and rising sea temperatures (Montagna *et al.* 2007, 2011). The sea-level rise rates are high because of subsidence, which cause the relative rise to be that much greater. The increasing temperatures are already manifesting indirect changes in habitats and water quality.

Black mangroves, which are sensitive to freezes, are expanding northward. Even more cold sensitive species such as the red mangrove are showing up on the Texas coast. However, rapid sea-level rise with interact with habitat change to alter the trajectory of succession of coastal landscapes. It is not clear exactly what will happen. One possibility is that sea-level rise simply drowns wetland habitats. But as long as plant growth and soil stabilization by plant roots occurs at a rate higher than apparent sea-level rise, then the habitats can simply move with moving shorelines. However, there is little reason to conclude that shorelines will not change.

Water quality change may be the most pernicious change of all even though this is an indirect change driven by the lower solubility of oxygen in warmer water. The potential for hypoxia, which are low dissolved oxygen conditions, is very great and increasing. Coined "dead zones" by the media, hypoxic areas are known to be large and expanding in number, extent, and duration. Hypoxia is known to be very destructive to coastal ecosystems, and leads to lower biomass, productivity, diversity, and can alter food webs such that desirable species can no longer be produced in an area. Whereas hypoxia is known to be caused by excess loading of nutrients from watersheds to coastal waters, it is clear that physical processes also play a role in lowering dissolved oxygen concentrations.

Long-term trends of benthic macrofauna to hydrological conditions were examined in the Lavaca-Colorado Estuary, Texas (Pollack *et al*. 2011). The relationship between climate variability and local salinity patterns and benthic populations was investigated using the Oceanic Niño Index (ONI), North Atlantic Oscillation (NAO), and North Pacific Index (NPI). Mean salinity declined during the 20 year study period.

Observed changes in salinity were related to river discharge and the ONI because there were more El Niño events in the first half of the study period relative to the second half. Benthic macrofaunal abundance was significantly correlated with salinity, the ONI and the NAO, indicating that global climate variability and the resulting effects on local salinity patterns (Tolan 2007) are important factors shaping benthic macrofaunal communities. While drivers other than physical hydrological factors can obviously affect benthic macrofaunal communities, strong connections between global climate signals, precipitation, and local salinity patterns provided the most plausible mechanistic connection between climatic variability and benthic macrofaunal response in the estuary. An increasingly unstable climate may lead to potentially strong effects in estuarine ecosystems because stability is known to affect diversity and productivity.

An ecological model was used to predict system-wide secondary production for two trophic groups of benthic organisms in response to different freshwater inflow regimes that result from the climatic ecotone along the Texas coast (Kim and Montagna 2012). The bioenergetic model was calibrated using an 11-year dataset (from 1988 to 1999) and validated with a 20-year data (from 1988 to 2008) from four estuaries in South Texas: Lavaca-Colorado (LC), Guadalupe (GE), Nueces (NE) and Laguna Madre Estuaries (LM). The estuaries lie in a climatic gradient where LC and GE receive more rainfall than NE, and NE receives more rainfall than LM. Consequently inflow and nutrient loading decreases and salinity increases along the gradient. In addition there is year-to-year variation in rain and inflow that results in wet and dry years. Therefore, this combination of the climatic gradient and temporal variability can be used to identify the effects of inflow variability on estuarine secondary production. Among Texas estuaries, increased salinity (and thus decreased inflow) benefited deposit feeders, while suspension feeders were reduced; thus there is a decrease in functional diversity when salinity is increased because of loss of a trophic guild. Within estuaries, the upstream benthic community is reduced by reduced inflow, whereas, the downstream community increases with reduced inflow and higher salinities. This is because lower salinity regimes are required to support food production for suspension feeders, and polyhaline deposit feeding species increase during marine conditions. This study demonstrates that freshwater inflow is important to maintain secondary productivity and functional diversity in estuaries, which is required to maintain estuarine health and sustainability.

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3.1.2 Update, plans and further development of the Benthic Long-Term Series Network (BELTS-net)

J. Craeymeersch reported on the status of the Benthic Ecology Long-Term Series Network (BELTS-net)

BELTSnet was established by the BEWG in 2009 to foster collaborative work on long-term data series. The BELTSnet aims at facilitating joint analysis of long-term data to further the understanding of temporal changes in marine ecosystems over larger spatial scales. BELTSnet specifically does not target data compilation, but stimulates a common analysis of individual long-term series. The group agreed that this initiative will enable to establish an open informal network to promote exchange of observed phenomena on existing and additional long-term series. In the following years the initiative was further developed.

As an extensive promotion of the BELTSnet was considered crucial, it was felt a BELTSnet website needed to be constructed and launched before the end of 2011. The group therefore decided at their meeting in 2011 to add an update of the BELTSnet initiatives to the ToR list of the SGCBNS meeting in October 2011. At the SGCBNS meeting, J. Craeymeersch was appointed as a new chair. The text was finalised, and requirements and possible approaches to disseminate the initiative were discussed. See report of the SGCBNS (SGCBNS 2011).

The Institute for Agricultural and Fisheries Research (ILVO) in Oostende, Belgium agreed to host the website and H. Hillewaert agreed to support the technical development of the web. In the months afterwards, a logo was designed and the website layout was set up. A final release of the website was yet not done. H. Hillewaert presented the layout structure.

Members of the BEWG had no major remarks on the finalised text, but stressed the fact that it must be very manifest on the main page of the website that the initiative is not yet another data collection initiative.

BELTSnet is currently focused on series from the north-east Atlantic but coverage of more regions (including all north Atlantic or even worldwide) is desirable, with implied flexibility about geographical focus. The aim is to facilitate collaboration, bringing together people interested in common research questions, so there should be no geographic restrictions on collaboration. Because B. Tunberg could not attend the 2012 meeting, the update of the long term series with North-American data series could not be done as yet and remains an action point.

Current requirements include appointing project management, finalizing website design and content.

3.1.3 Website development and promotion

H. Hillewaert presented a sneak preview of a possible layout of the BELTSnet website.

Figure 1. Screenshot of the BELTSnet homepage.

A meta-database structure, based on EML (Ecological Metadata Language) was suggested to avoid difficulties with different file formats.

Additionally a news-ticker was suggested on new relevant publications to make monitoring programs more visible (e.g. with link to the journal).

References

EML at http://knb.ecoinformatics.org/software/eml/

3.1.4 BEWG manuscript on benthos and climate change to be submitted for publication to the WIRES journal Climate Change

Silvana Birchenough introduced the state-of-the-art of the BEWG manuscript on benthos and climate change, to be submitted as an advanced review for publication in the WIRES journal. The paper draws upon the BEWG contribution to the ICES Position Paper on Climate Change (Birchenough *et al.*, 2011), but elaborates on future prospects and future research needs. The manuscript is anticipated to be submitted in September 2011.

It was noted that the UNESCO will publish a similar lagoon focused report. Finding some good links between the two documents may be interesting and appropriate.

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3.2 Update on the work of the Study Group on Climate related Benthic processes in the North Sea

Henning Reiss reported on the progress on two case studies focused on benthic processes affected by climate change.

First case study aims to look at patterns of seasonal variation of bioturbation potential, species specifically responsible for variation, and their environmental drivers. The other study is focused on spatial patterns of bioturbation potential and attempts to extract regions where there are many or few species in charge to investigate potential vulnerability. A method to calculate the mean individual body mass that is required for estimates is defined.

Effects of climate change cannot always be detached from effects of other drivers of changes (e.g. fishing pressure in heavily fished area).

It was questioned if there should be more interaction with long-term series study groups (e.g. Working Group on Plankton Ecology) or even a joined theme session — because so far this issue is only based on those two case studies.

It was noted that it must be interesting to link bioturbation with functional processes, requiring however for someone to take charge.

Abundance and biomass correlation were mentioned to be used to derive mean body mass. Although this shows a seasonal variability, and it can be a drawback for accuracy its use is needed where only abundance data is available as biomass is required to calculate bioturbation potential.

It was suggested to separate analysis of data that is based on measurements of derived biomass.

3.3 Update of the BEWG research plan on climate change, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area

BEWG explored the possibilities to contribute to the ongoing debate on ecosystem functioning (EF). Two actions were planned:

BEWG noticed that both concepts of EF and ecosystem services (ES) are used in a confusing manner in recent literature. BEWG recognises that there is a link between EF and ES, and aims at delineating the definition of both concepts, and highlighting the links between both concepts to be wrapped up in a position paper. BEWG further recognises that input from other fields of expertise are required, and will look for input from socio-economists and/or lawyers. BEWG will identify those scientists that could provide input. An electronic meeting will be organised in October 2012, to further divide tasks and arrange an outline for the paper. This paper will be finalised at the next BEWG meeting.

This action will result in a ToR for next BEWG:

- To finalise the paper on the link between ecosystem functions and ecosystem services

During the recent years, the relation between macrofaunal functional diversity and benthic ecosystem functioning (expressed as e.g. sediment oxygen consumption or nutrient cycling) became a topic of increased interest, resulting in a number of indi-

vidual investigations and papers, reporting on the effect of selected species/functional traits on ecosystem functioning. BEWG identified the need for integration of these results and an attempt to upscale the individual results to more general knowledge. As this can only be done through the collaborative analyses of integrated data, BEWG will attempt to compile a database of existing results so far. This will be done by a core group consisting of BEWG members, possibly extended to external scientists. The core members will be contacted by email before summer 2012. Data compilation will be ongoing until BEWG 2013, and will be the base for scoping for future research.

The ToR for next BEWG will be:

- To review the data compilation on functional diversity of macrobenthos in relation to ecosystem functioning, and to scope for further research

4 Benthos-related quality assessment

4.1 Reports on recent developments in environmental quality assessment covering phytobenthic and zoobenthic topics

4.1.1 An ecological quality status assessment procedure for soft-sediment benthic habitats: weighing alternative approaches

Gert Van Hoey reported

An assessment procedure for determining the ecological quality status of soft-sediment benthic habitats includes the following aspects: (1) the selection of indicator tools to assess the relative quality status (indicator approach), (2) habitat assignation of the samples (habitat approach), (3) reference or target conditions for the benthic parameters (reference approach). For all these aspects, different approaches exist, of which the reference and indicator selection approaches already received lots of attention. The aspect of the habitat approach however is sometimes neglected, but is essential in determining the reference or target conditions per habitat type. Benthic habitats differ in structure and function, and as such will show wide variation in statistics or measures between habitats. A major problem, mainly in coastal soft-bottom systems, is to distinguish between the different benthic habitat types. An objective assessment of reference conditions is a challenge in areas lacking pristine or minimally disturbed sites, and areas for which historic data is not available. In this study, the strengths and weaknesses of different habitats, reference settings and indicator approaches on the ecological quality status assessment of soft-sediment benthic habitats were investigated. This study is based on a large benthic dataset of the Belgian part of the North Sea (1977–2009).

The take home messages from this exercise were:

- Benthic indicators are useful, but it is advised to integrate several indicators as different indicators each provide additional information on the ecosystem's quality.
- Habitat suitability maps are good tools to assign samples to habitat type, but are heavily relying on the amount and quality of input data.
- Although habitat types are well-defined entities, gradual transitions exist between them. To avoid bias in habitat type-specific quality assessments, ideally samples belonging to the transitions between the habitat types should be avoided in the quality assessment.

- In areas, lacking real reference data, percentile values rather than the extremes, give a reliable estimate of the high quality status.
- The exclusion of data from areas subjected to high human pressures can be useful in optimizing reference or target values.
- Natural disturbance (e.g. cold winters) of the benthic characteristics are mostly detected by any indicator and difficult to exclude in assessments.

4.1.2 Intercalibration of transitional water macroinvertebrates within the NEA-GIG

G. Van Hoey presented A. Borja's work

The intercalibration (IC) of methods used by European Member States in assessing the ecological status, based upon macroinvertebrates, is a mandate of the Water Framework Directive. This IC ensures similar levels of accuracy in the quality assessment across different countries. In the case of the North East Atlantic, 9 countries (Portugal, Spain, France, Belgium, Netherlands, Germany, United Kingdom, Ireland and Sweden) participated in the IC in transitional waters, with 11 different methods. The first work was to select estuarine types to be IC, and we identified 6 types: (A) Lagoons; (B) Freshwater-oligohaline medium river flow; (C) Mesotidal estuary with irregular river flow; (D) Large Estuaries; (E) Small-medium estuary with >50% intertidal area; and (F) Small-medium estuary with <50% intertidal area. After collating data, types C and D merged and finally we worked with types D, E and F.

From 59 estuaries a total of 9337 samples were collated (6795 in type D, 638 in type E and 1904 in type F). Biological data was standardized and harmonized to make them comparable across the countries. Then, main metrics were calculated and each country determined the Ecological Quality Ratios (EQR) for the samples available. Then, information on pressure data, in a comparable way was collated for each country and as much water bodies as possible. Using this common dataset, the response of each method to the pressure data was not very good, due to the mixture of data. However, each country provided examples of the response from each method to different human pressures.

A first approach for IC was used and the results were accepted by each country, but not by the Commission, because the guidelines approved for IC were not used. Hence, in a second approach some new analyses, following the guidelines, were done only for type D. A method from Andalusia (Spain) was rejected since the slope of the regression was too weak in relation to the common metric. Therefore the High/Good boundary was impossible to adjust. In other cases (UK and Ireland method) needed to change the Good/Moderate and High/Good boundaries and the Portuguese method for Good/moderate. The remainder methods did not need adjustment. However, some countries disagree in the approach and finally it was not possible to achieve a complete consensus in the group.

The question whether the intercalibration exercise will be continued could not be answered. It remains unclear to what extend a continuation of the intercalibration would be useful. The need for a better understanding of the underlying ecological processes and causal relationship was highlighted.

4.1.3 Presentation on Estonian coastal water quality assessment scheme based on phytobenthos and zoobenthos

G. Martin reported on work done by himself and K. Torn

The water quality assessment system of Estonian coastal sea areas using submerged aquatic vegetation and invertebrate fauna according to the Water Framework Directive of the European Community is described. Estonian coastal waters are divided into six national types of coastal waterbodies covering 16 waterbodies. The assessment system is based on three monitoring areas for each waterbody. The three metrics that are used for water quality classification system based on phytobenthos are:

1) the depth distribution of phytobenthos as the deepest occurrence of single attached specimen;

2) the maximum depth distribution of Fucus vesiculosus as the deepest occurrence of singe plant specimens;

3) proportion of perennial plant species in the observed community based on dry biomass of attached erect vegetation.

To set the quality assessment system for the invertebrate fauna from the Estonian coastal sea, the composition of current zoobenthic communities was compared to the communities from the 1950s to 1960s. Sensitivity values for benthic taxa were determined, and the macrozoobenthic community index ZKI and boundaries for the classification system were developed. The ZKI index was further validated against nutrient loads and the spatial location relative to pressure, represented by the Baltic Sea Pressure Index (BSPI). High variability in Ecological Quality Ratio assessment results were found for both the ZKI and the brackish water benthic index (BBI) based assessments. However, in the study area, ZKI assessments fluctuated to a smaller extent and displayed a better correlation with the BSPI than the BBI assessments. Both metrics are intercalibrated in the framework of the Baltic GIG intercalibration exercise and are used in official monitoring and assessment systems. Both technical descriptions of the metrics and documentation on the relations with pressures are published.

4.1.4 New developments within the project WISER (Water bodies in Europe: integrative systems to assess ecological status and recovery)

A. Borja (by correspondence)

The WISER (www.wiser.eu) project was divided into several Modules and Work Packages (WP), regarding the implementation of the Water Framework Directive (WFD), and has been functioning from 2009 to 2012. Module 4, on marine topics, had four WPs, including two on macroalgae-seagrasses and macroinvertebrates. The main results can be consulted in the above webpage.

The main findings from this project are available at www.wiser.eu (deliverables section) and in the paper: Borja, A., M. Elliott, P. Henriksen, N. Marbà (accepted). Transitional and coastal waters ecological status assessment: advances and challenges resulting from implementing the European Water Framework Directive. *Hydrobiologia*.

An overview of the project is given in Annex 6.

4.2 BEWG paper on "The myths of benthic indicators: The crux with indicator species"

M. Zettler and A. Darr reported on this initiative which is an outcome of last year's BEWG meeting in Fort Pierce, Florida

The initiative on the *Myths of indicator species* was introduced and the rationale behind the study was explained and defined with the following key points:

1) The use of sensitivity/tolerance lists of macrozoobenthic species in assessment tools is common practice. These lists are generally useful tools and were improved in the last decade by addition of worldwide species and an improved understanding of the autecology of many taxa.

2) Caution is however required as sensitivity to anthropogenic impacts may change along environmental gradients. Natural variables may act similar as human stressors.

3) Indiscriminate use of static species lists for determining presence or dominance of bioindicators may as such be a problematic procedure.

In this study the differences in the response will be tested based on selected species along an environmental gradient. Data contributors were asked to provide abundance and biomass data of selected species, accompanied by environmental data such as temperature, salinity, median grain size and organic content. These datasets should also include "zero" values (where the species was not found, but environmental data are available). Areas where data are meagre so far are the North Sea, Skagerrak and Kattegat.

All above mentioned data are essential to carry out the analyses. For the organic content, LOI (loss on ignition) will be the variable of choice, but TOC (total organic carbon) data can be converted into LOI. Mud content as a proxy for organic matter cannot be used. Additional data providers and the timeline for the submission of data will be identified in the subgroup meeting of this initiative.

The new timeline for the paper is:

- Data delivery: 2012/06/15
- Analysis: 2012/08/15
- Manuscript (draft): 2012/10/15
- Final Version: 2012/12/15

The template for data contribution is available on the BEWG 2012 SharePoint.

4.3 Review and report on existing indicators of biodiversity that are linked to predictable changes in ecosystem function and/or to develop, assess and report on the feasibility and performance of such indicators

4.3.1 Biological Trait Approach and indicators of biodiversity

M. Zettler introduced the topic

The main tasks are:

a) We will test the controversial hypothesis that a loss of biodiversity threatens ecosystem's functioning.

b) Complementary datasets and accounting activities of key macrofauna species are prerequisite for a better understanding of the role of biodiversity and of their ecological services in sediments.

c) Therefore different functional properties of benthic macrofauna assemblages will be studied.

The first step is predicting the distribution of the biomass of relevant (key) species in relevant areas as a function of selected environmental variables (e.g. salinity, substrate, water depth). In the next step the quantification of the function of invertebrate species and communities will be done. The single functional approach connects distribution maps gathered during step 1 to simple equation displaying function as a response to individual biomass (e.g. filtration rates). The full functional approach couples holistic functional information (e.g. Biological Traits Analysis or BTA) with environmental parameter using classification techniques (e.g. CART). The following two presentation from M. Gogina and A. Darr will illustrate the Biological Trait Analysis (BTA) approach in an exemplarily way.

4.3.1.1 BTA approach to assess consequences of hypoxia events for benthic ecosystem functioning in the south-western Baltic Sea

M. Gogina reported on a case study by M. Gogina, A. Darr and M. L. Zettler

The study aims to assess structure and changes of functional diversity in the western Baltic over the last two decades (1990–2010) and to investigate patterns of response to hypoxia in the functional traits pool of different habitats. Data from four long-term monitoring stations located along the steep salinity gradient (two muddy stations in Fehmarnbelt and Mecklenburg Bight and two sandy stations in Darss Rise and Pomerania Bay) are used in the analysis. Fuzzy coding was used to affiliated 139 taxa (observed quantitatively) to 47 modalities of 13 traits. These traits that directly describe ecological functionality or are relevant as indicators, characterise species role in modifying the environment, their behavioural strategies, morphology and life history. Methods such as fuzzy correspondence analysis (FCA) and co-inertia (COI) analysis were applied. Clear differences in structure of prevailing biological (functional) traits between four stations were evidenced. Response to episodic hypoxia and subsequent recovery are observed in relative composition of biological traits for muddy stations close to the Baltic Sea entrance. Planktonic larvae and short longevity being characteristic for the oxygen-rich years while benthic larvae (i.e. slow dispersion) and longevity over 10 years being typical for the second (oxygen-poor) group years – due to dominance of hypoxia tolerant *Arctica islandica.* No similar trends related to decreased oxygen concentration were found for "inner" sandy stations. For both eastern sandy stations years before the inflow are most dissimilar to all others and characterised by reduced number of species that partly might be explained by the lack of recruitment sources, i.e. no inflows, or the unfavourable conditions at source of recruitment. Planktonic larvae are more dominant in abundance-driven structure.

Problematic issues that were faced included subjectivity of scored traits information. Complexity of results interpretation due to multidimensionality of traits space lessen dimensionality suggests the need to look at distinct traits and their responses separately. Traits information should constantly be edited when new data appear in order to increase accuracy and justify application for various problems.

During the discussion it became clear that some results are largely driven by specific dominant species. For example, *A. islandica* is surviving anoxic conditions, which resulted in an affinity of e.g. the trait 'long living species' to anoxic conditions.

4.3.1.2 Linking environmental information (e.g. benthos, abiotic parameters) and ecosystem functioning.

A. Darr presented

Using functional traits (BTA) was shown to be a useful tool for identification of functional changes in benthic community structure over time in relation to environmental changes at several monitoring station in south-western Baltic Sea. Based on this, we tested the general ability of the BTA-approach to show spatial pattern in benthic functioning and its correlation with environmental parameters.

Within the first case-study, the usually very tight correlation of community structure on a taxonomy-based approach with driving parameters such as salinity, water depth and sediment characteristics was much weaker using the functional approach.

We consider that amongst others, the static use of the fuzzy coding weakens the functional response to the environmental gradients as the communities in transitional waters are usually dominated by ubiquitous species. Their changes in behaviour along specific gradients are not reflected in the BTA-approach.

During the subsequent discussion it was mentioned that the functional role of some species is changing along environmental gradients e.g. sediments. The reduction of feeding traits on a few essential ones (maybe only two) might be a solution. Ecosystem functioning can only be partly addressed with BTA, since the analysis does not distinguish between different levels of processes. For example, differences in the filtration rate of bivalves cannot be covered by BTA approaches, which treats all filter feeders the same. These issues need to be solved for future applications.

4.3.2 Other introductory presentations

4.3.2.1 Lessons learnt from the Marine Strategy Framework Directive (MSFD) implementation in the Basque Country (northern Spain)

Angel Borja (by correspondence)

In the case of Spain, the Basque Country has proposed an integrative assessment within the MSFD (Borja *et al*., 2011), from which this report is extracted. The indicators used in the assessment, for each of the 11 qualitative descriptors (i.e. biodiversity, sea-floor integrity, eutrophication, etc.), where those recommended by the European Commission (2010) and Rice *et al*. (2012). For this Issue 2C, I have only considered two of the descriptors: biodiversity and sea-floor integrity.

Regarding biodiversity, Borja *et al*. (2011) propose using integrative tools, such as the biodiversity valuation approach, in assessing biodiversity within the MSFD. The valuation of biodiversity is in response to the continuing requests of policy-makers and marine managers for reliable and meaningful biological baseline maps, to be able to make well-deliberated selections, concerning the sustainable use and conservation of the marine environments. Biodiversity valuation maps aim the compilation of all available biological and ecological information for a selected study area and allocate an integrated intrinsic biological value to the subzones (Derous, 2007; Derous *et al*., 2007).

For the Basque Country, data on zooplankton, macroalgae, macroinvertebrates, demersal fishes, sea mammals and seabirds, for the period 2003–2009, and over the whole of the Basque continental shelf, were collated. The integrative biodiversity value of the Basque continental shelf is based upon Pascual *et al*. (2011, 2012) valuation, from which it is possible to integrate the biodiversity valuation into a unique

value for the whole of the Basque continental shelf (Borja *et al*., 2011); this is a similar approach to the Ecological Quality Ratio (EQR), within the Water Framework Directive (WFD). In this particular case, reference conditions for high values do not exist; as such environmental targets, as demanded by the MSFD, rather than reference conditions, can be used (see Borja *et al*., 2012). Such targets can guide progress towards achieving good environmental status; for biodiversity, those for 'high' value can be adopted.

Regarding sea-floor integrity, from the human pressures determined within the area, the extent of the seabed affected significantly by human activities was established at 245.4 km^2 (240 km^2 affected by fish trawling; 3.3 km^2 by sediment disposal areas; and 2.1 km^2 by cables and pipelines). This surface represents 2.3% of the area studied (from the baseline, to the Exclusive Economic Zone), or 13%, considering only the continental shelf (hence, EQR: 0.87). The impact over these areas can be considered as 'moderate' (sensu the WFD), when assessing the benthic ecological status using the index M-AMBI (multivariate AMBI (AZTI's Marine Biotic Index) Borja *et al*., 2004; Muxika *et al*., 2007). This index incorporates a measure of richness, diversity and the proportion of sensitive/opportunistic species, as required by some indicators within this descriptor. The remainder of the area presents a quality status lying between 'good' and 'high', with a mean EQR value of 0.83 (standard deviation 0.14, n: 176 samples), which represents 'high' status in the WFD.

AMBI values in the area range between 0.22 and 3.41, showing that the benthic communities within this area are dominated by sensitive species, with opportunistic species being present in low percentages. Only 1.13% of the samples showed AMBI values above 3.3, which are considered as being moderately disturbed, by the presence of opportunistic species (Borja *et al*., 2000). Hence, the presence of sensitive species indicates an EQR of 0.98.

The evolution of M-AMBI, since 2002, was studied in 3 stations of the continental shelf. In general, the status is 'high' and sometimes 'good', with stability in a station and a progressive increase in quality in two stations.

As demonstrated by Borja *et al*. (2011), many of the methods, tools, indicators and targets implemented in the WFD could be used within the MSFD; this, in turn, provides an easier and reliable way to implement this complex directive. Finally, as commented upon for the WFD (Borja *et al*., 2004), the use of different monitoring surveys, assessment methodologies, data integration, etc., should be based upon affordable indicators and pragmatic approaches, both from a managerial and ecological point of view.

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4.3.2.2 The effect of biodiversity, seasonality and sediment type on marine benthic ecosystem functioning on the Belgian part of the North Sea

J. Vanaverbeke reported on work done by J. Vanaverbeke, U. Braeckman and M. Vincx

This presentation reports on how macrobenthic functional diversity affects benthic ecosystem functioning in different types of sediment, and in different seasons. Ecosystem functioning here is considered as sediment community oxygen consumption (SCOC) and nutrient cycling, as proxies for benthic ecosystem functioning. It showed that functional diversity is important for bioturbation (mixing of particles), SCOC and the nutrient cycle. It was shown that bio-irrigation is very important for the nitrogen cycle, and it was stressed that this functional trait is not included in many functional indices.

At the moment, an attempt is made to upscale the results of the single-species treatment results described above, to the field situation. To do so, 10 stations on the Belgian Part of the North Sea are sampled monthly, fluxes are measured and modelled, and they will be related to the macrofauna being present. As such, the aim is to increase our understanding of how macrofaunal functional diversity affects the benthic ecosystem functioning.

4.3.3 Discussion and conclusion

The discussion concentrated on the need to include several important issues in the report: how feasible is it to link indicators of biodiversity to changes in ecosystem function; what indicators have a link between biodiversity and ecosystem function; how changes in ecosystem function could be reflected in visible changes in biodiversity and what functional traits could be used as proxy values for biodiversity e.g. bioturbation. Concerns were also raised such as: do we have the data to support these links (long-term series are essential); are biodiversity indicators sensitive enough to show fine scale changes in biodiversity that could affect function; and that BEWG does not have expertise in biogeochemistry that would be a useful addition to the paper. It was also noted that long term monitoring is important to detect changes in ecosystem functioning. After the discussion around the Biodiversity/Ecosystem func-

tioning topic the group focused on discussing J. Vanaverbeke's presentation on bioturbation as a potential ecosystem function that could be considered as a proxy for biodiversity. A more general discussion on biodiversity followed that included the importance of biodiversity to resistance, resilience and recovery in ecosystem's structure and function. This could have an influence on regime shifts- would regime shifts happen if an ecosystem was more diverse? It was also suggested that diversity could be defined by the number of functional niches represented.

This topic concerns a rather theoretical, overarching question, which can be filled in from different viewpoints. How can existing biodiversity indicators be used to link changes in ecosystem functioning?

Most indicators on biodiversity, do not reflect on ecosystem functioning and cannot assess it, as they are 'state' indicators not aimed at the functioning of the ecosystem. A compilation of information on the development of functional indicators, and their possible relation with state indicators needs to be initiated.

Therefore, the BEWG wants to focus on the following question: How is biodiversity linked to ecosystem functioning and do we have indicators to reflect the link between both aspects? Four main papers will form the start of a literature search, as a basis for an elaboration on this topic during next year's BEWG meeting:

Bolam SG, Fernandes T, Huxham M (2002) Diversity, biomass, and ecosystem processes in the marine benthos. Ecological Monographs 72:599-615

Covich AP, Austen MC, Bärlocher F, Chauvet E, Cardinale BJ, Biles CL, Inchausti P, Dangles O, Solan M, Gessner MO (2004) The role of biodiversity in the functioning of freshwater and marine benthic ecosystems. BioScience 54:767-775

O Gessner M, Inchausti P, Persson L, G Raffaelli D, S Giller P (2004) Biodiversity effects on ecosystem functioning: insights from aquatic systems. Oikos 104:419-422

Wilsey BJ, Potvin C (2000) Biodiversity and ecosystem functioning: importance of species evenness in an old field. Ecology 81:887-892

A compilation table will be constructed through those literature searches which will yield an overview of:

- the function considered;
- the link with biodiversity;
- indicator tool available.

This will be provided and discussed during the next meeting.

A new ToR follows from this discussion:

- Disentangling the link between biodiversity and ecosystem functioning: to review and identify indicators to reflect the link between both aspects.

4.4 Update BEWG's research plan on benthic indicators, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area (ToR f, in part)

The group expressed concerns regarding the status and progress of the intercalibration within the Water Framework Directive (WFD) (e.g. NEA-GIG benthos intercalibration, Estonia-Finish intercalibration) and discussed about an appropriate continuation of the BEWG work on benthic indicators. BEWG acknowledged that benthic indicators are not only relevant to the WFD, which received our major attention during the last couple of years, but also to other EU directives. Within the

framework of the Marine Strategy Framework Directive (MSFD) for example, every country has to deliver its GES description, environmental targets and indicators to the EU in the summer of 2012. The year 2013 is also a deadline for reporting on achievements in the framework of the Habitat Directive. Therefore, BEWG considers contributing to the integration of knowledge and ongoing work on indicators and the aforementioned EU directives and look for synergy.

A new ToR follows from this discussion:

- To review the use of benthic indicators and targets within WFD, MSFD and Habitats Directive: Compatibility and complementarity.

5 Marine habitat modelling and mapping

5.1 Report on recent initiatives on habitat suitability modelling and mapping: introductory presentations

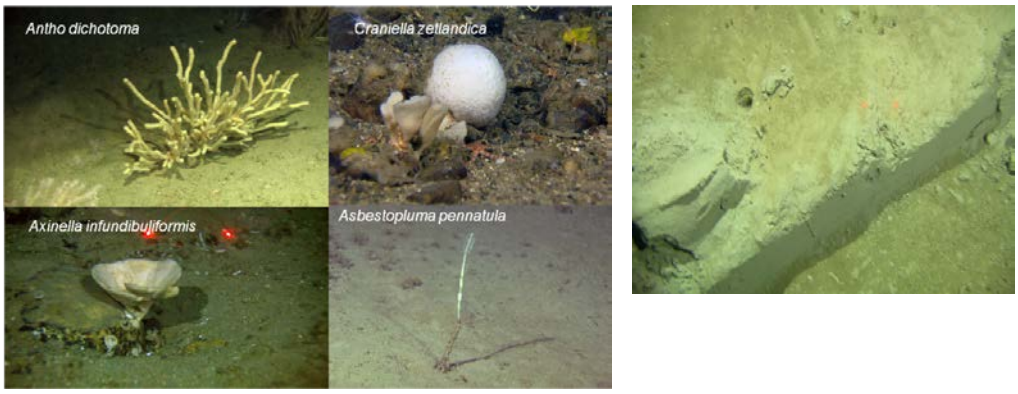
5.1.1 New information from MAREANO on the effect of trawling on megafauna: Trawling impact on habitat-forming organisms in the Barents Sea: indication of resilience and implications for sustainable management

L. Buhl-Mortensen presented work done by L. Buhl-Mortensen, K.E. Ellingsen, P. Buhl-Mortensen and K. Skaar

What is the relationship between bottom trawling activity and the status of habitat forming bottom fauna? To answer this question Results from video-mapping of megafauna conducted by the MAREANO program was compared with trawling activity.

Based on the mean number of VMS-registrations per year, in a 5 × 5 km grid cell, eight groups of fisheries intensity (FI) was defined. The fauna material consisted of 154 video-transects from 50 to 400 m depth in the Barents Sea. The density and composition of megafauna was compared for areas with differed FI. Density and diversity was significantly lower in areas with high FI and the response was logarithmic indicating that low trawling frequency has a clear negative effect. Of 134 taxa 100 showed a negative trend with increased FI, nine of these revealed a significant ($p < 0.05$) response and five of these were sponges. Four taxa with particularly low resilience were: *Antho dichotoma*, *Craniella zetlandica*, and *Phakellia/Axinella*. A few taxa responded positively to increase in FI of these scavenging large gastropods showed the strongest response. Interestingly *Sebastes* that are often found amongst boulders and sponges showed a strong negative relation to FI while the opposite was observed for cod. A clear connection between presence of trawl marks and soft bottom was documented rather than FI.

The results are particularly relevant to two descriptors of GES in the MSFD: Biological diversity and Seafloor integrity, with the relevant criteria: the distribution, extent and condition of habitats, ecosystem structure, physical damage and physical loss.



Marks from trawl door

5.1.2 Standing Stocks and Body Size of Deep-Sea Macrofauna: Predicting the Baseline of 2010 *Deepwater Horizon* Oil Spill in the Northern Gulf of Mexico

Chih-Lin Wei reported on work by Gilbert T. Rowe, Elva Escobar-Briones, Clifton Nunnally, Yousria Soliman & Nick Ellis

A composite database encompassing 6 benthic surveys from years 1983 to 2003 was constructed to evaluate the distribution of macrofaunal biomass in the deep Gulf of Mexico (GoM) prior to the *Deepwater Horizon* oil spill. Predictive models based on optimal scaling of ocean colour data and high resolution bathymetry were employed to map the benthic biomass in the vicinity of spill site because no previous sampling had been conducted at that exact location. The predicted biomass declines with water and mixed layer depth and is an increasing function of surface primary production and temporal variation of sea surface temperature. The decline of animal size with depth, however, was a function of a shift of dominant abundance from large to small taxa. At a local scale, high benthic biomass in the N GoM was associated with the enhanced productivity by the nutrient-laden Mississippi River outflows, offshore transport of the river plumes, and upwelling along the northern edge of the Loop Current. The apparent biomass enhancement at the Mississippi and De Soto Canyon and deep sediment fan was presumably related to lateral down-slope advection of organic carbon from the surrounding continental margin. Except for the Campeche Bank, the meagre biomass of the Mexican margin may reflect the characteristic low-productivity Caribbean water that enters the GoM through Yucatan Strait. Benthic biomass in the N GoM was not statistically different between comprehensive surveys in the years 1983 to 1985 and 2000 to 2002. The stock assessment and biomass predictions from 669 cores at 170 locations throughout the deep GoM provide an important baseline of the sediment-dwelling fauna that may be subjected to immediate or long-term impacts from the oil spill or from climate change.

5.1.3 Mapping larger infauna and epifauna distribution in the Dutch part of the North Sea

M. Lavaleye reported on work done by M. Lavaleye, R. Witbaard, M. Bergman and G. Duineveld

The macrobenthos of the whole NCP was sampled for the first time quantitatively (boxcorer) in 1986 during the ICES - Synoptic Mapping. Since 1991 the Netherlands have a yearly monitoring (BIOMON) of the macro-infauna of the NCP; the first years only at 25 stations, but later on at 100 stations. However, boxcore samples will not produce good quantitative data for the large long living infaunal species. In EU-projects in 1996/1997 NIOZ developed a special dredge, the Triple-D, with which the infauna to 20 cm sediment depth can be sampled quantitatively. During one haul it is

normally set to sample 20 m², which is equivalent to about the sampled surface of 300 boxcores. In 1997 the first map of the distribution of this large in- and epifauna for the NCP was publish, based on 60 stations sampled with the Triple-D. In 2006 NIOZ started an initiative to sample the whole NCP again with the Triple-D, but this time with a much denser grid (about 400 stations). During several cruises in the years 2006–2008, most of the NCP was sampled and the database was finalised and a preliminary atlas with maps of the density and biomass distribution of the different species was made. Besides some areas that could not be sampled by the dredge because of gravel and stones (Cleaver Bank) or coarse sands (Southern part of NCP), there were still some gaps which needed to be filled in. Finally 2011 presented the opportunity to fill in these gaps by sampling another 50 stations. The database is now almost finalised, and the publishing of the final atlas of the larger infauna (and epifauna) is planned in early 2013.

5.1.4 Benthic habitat mapping conducted in Estonian coastal waters and EEZ

G. Martin reported on work by himself and K. Herkül

Estonian marine waters compose approx. 36 000 km² of territorial waters and EEZ in the north-east corner of the Baltic Sea. Until recent time the information on the distribution and structure of benthic habitats and species was very fragmented due to lack of large scale systematic investigations and inventories. Since 2005 series of large scale inventories and mapping projects have been conducted mainly triggered by the need of nature conservation (establishment of Natura 2000 network) and investigations for large scale economic development projects (offshore windparks, bridges and harbours, fish farms). The methods used in the current activities are based on grid sampling using both quantitative and semi-quantitative methods combining traditional sampling with under-water video sampling and SCUBA. Using comparable methods almost one third of the marine areas is mapped presenting a distribution of key species and habitats. Habitat information is presented both using the EU Habitat Directive Annex I habitat types and a developed habitat classification system comparable with EUNIS system. Recent attempts have included also spatial modelling of distribution of key species covering the whole sea area under Estonian jurisdiction. Modelling was based on the historical and present data and environmental information available from national databases (bathymetry, bottom substrate, exposure, bottom slope declination, transparency depth, oxygen). Modelling was performed using different statistical methods (GLM, GAM, MARS). As a result estimation of distribution of different habitats is available. Future work includes additional sampling for validation of modelling results as well as development and using of new techniques including remote sensing to improve precision of the mapping results.

5.1.5 Habitat suitability studies and mapping within the Basque Country (northern Spain)

Angel Borja (by correspondence)

In recent years, an important effort has been done within the Basque Country (northern Spain) to map habitats, using different methods (i.e. Ecological-Niche Factor Analysis (ENFA), process-driven habitat modelling) and tools (i.e. multibeam, LiDAR, bathymetric LiDAR, submarine imaging). The applications and methodologies can be seen in the references below. Additionally, two European projects, dealing with these issues, are being undertaken in this region:

- MeshAtlantic project (Mapping European Seabed Habitat Maps in the Atlantic area; InterReg Atlantic Area Transnational Programme of the Euro-

pean Regional Development Fund). This project has organized a workshop in San Sebastian (23rd and 24th April, 2012), which will focus upon the experience of different countries and case studies, using the EUNIS (the European Nature Information Service) habitat classification.

- MESMA- Monitoring and Evaluation of Spatially Managed Areas" Project number: 226661. Seventh Framework Programme. 2009-2013, which deals also with habitat mapping and other issues.

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5.2 Finalise the BEWG review paper on "Species distribution modelling and mapping (SDM) in the marine environment and its relevance for ecosystem management"

During the 2011 BEWG meeting an initiative was started with the aim to write a review publication on the use of species distribution models (SDM; or Habitat suitability models, niche models) within an ecosystem management context. The main objective of this review is to provide (i) an overview of distribution modelling tech-

niques and (ii) to discuss their prospects and limitations as a tool within marine ecosystem management.

A first draft of the review was distributed among the participants prior to the meeting, compiling the contributions of 16 BEWG members from 9 countries.

Within a subgroup during the meeting, the draft was reviewed and suggestions for the improvement of the manuscript were discussed and compiled. The main general points raised during the meeting were (i) to reduce the length and level of detail of some chapters of the draft, (ii) to focus the manuscript more thoroughly on possible SDM applications for management purposes and (iii) to visualise the main messages with additional tables and figures. Accordingly, lists of suggested changes were given in the manuscript and the updated version was distributed among the contributors. The finalisation of the second draft is scheduled for the 29 June followed by a final WebEx meeting on 13 July. The compiled draft will be distributed prior the WebEx meeting (6 July). The group is aiming for a submission of the manuscript to the *ICES Journal of Marine Science* by 30 September 2012.

5.3 Update BEWG's research plan on species distribution modelling and mapping, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area

The recommendations of the review paper (see 5.2) were used to outline the future work within the BEWG on distribution modelling methods. The following topics were discussed in the subgroup:

Quantitative models

Developing a methodological case study on comparing different quantitative models and their performance (e.g. GLM, GAM, MARS, RF, quantile regression). The mini-review from M. Goggina about different quantitative modelling approaches will be incorporated here.

Case study 1 – Quantitative distribution models - lead by A. Darr and M. Goggina.

Trends / Climate change / incorporation of time-series

The possibilities of using data sets from different periods were discussed and the need for the application of dynamic models was highlighted, which would include interspecific interactions. External expertise would be needed here.

Case study 2 - long-term changes of species distribution by including different time periods in distribution models (p/a vs. quantitative method).

Other possible initiatives

Several burning issues in the field of species distribution modelling were discussed, such as modelling of distribution of populations, the identification of dispersion boundaries, modelling of functional traits and changes in ecosystem functioning and the spatial scale dependency of model performance.

It was concluded that these topics should be followed up in the upcoming meeting but no action will be taken at this stage. Additional expertise would be needed to address some of the above mentioned issues (e.g. population level modelling).

Finally it was decided to start with planning case study 1 about the quantitative modelling methods with the following schedule: identification of "ready to use" data-sets by 15.12.2012. One data set for both studies (case study 1 and 2) is preferred. Information should be sent to A. Darr.

Prior to next year's meeting a selection of possible descriptors, target species and available quantitative methods will be collated and summarised in a 'proposal' for both case studies (priority on case study 1).

6 Other business

6.1 Identify and report on functional characteristics that could lead to species being defined as 'keystone'

6.1.1 Defining keystone species

A search using Google Scholar for the term "keystone species" returned about 65 200 results (10 May 2012). So, clearly the term "keystone species" has been incorporated into the lexicon of science and ecosystem management and it is often used. The term "keystone species" was coined by Paine (1969b) to narrowly define how community composition can be greatly modified by a species high in the food web on rocky shores. The predator can have a large controlling effect on the diversity of a prey group, even though they may not actually consume a large amount of this prey item, or be important in controlling rates of carbon flow. It was hypothesized that "Local species diversity is directly related to the efficiency with which predators prevent monopolization of the major environmental requisites by one species" (Paine 1966). Therefore, as top predators control competitive interactions, higher diversity results because there is no competitive exclusion among prey species. The concept was later refined to mean a "focus on the entire assemblage and the recognition that one species can have a disproportionate effect on many associates" (Paine 1995). So, the simplest definition of a keystone species is: "A species that is disproportionately important in the maintenance of community integrity and without which drastic alteration of the community would occur" (Nybakken 1988).

One problem is the word "keystone" itself, which many find attractive to use while not necessarily understanding the ecological definition of the word. Keystone is often used to mean "important" or "charismatic" species, or for any predator or species high in the food chain. When this definition is used almost any predators, parasites, or diseases could be incorrectly labelled keystone species.

Adding to the problem of defining the term "keystone species" is that the term is often shortened to "key" species. A key species can be any species classified as important for any reason. Thus the term "key" should not be used instead of "keystone" and inversely, a key species should not be referred to as a keystone species.

There are several kinds of additional terms used by ecologists that express other complex and important relationships within communities. These terms are used in ecology to denote focal species with special attributes (Jordan 2009). Examples are: foundation species or ecosystem engineers (which form habitats such as corals and oysters), indicator species (which identify attributes of the environment, such as canaries), and umbrella and flagship species (which are recognizable by the public and attract support for conservation, such as blue whales); (Annex 7). All of these concepts are useful, but the different terms denote different ecological functions within ecosystems.

The vagueness in defining the term is especially problematic for conservation and management (Mills *et al*. 1993). In fact, Mills *et al*. (1993) went on to define five different types of keystone species: keystone predator, keystone prey, keystone mutualists, keystone hosts, and keystone modifiers. While there can be both top-down and bottom-up influences, it is the strength of interactions in a community that is important in defining a keystone species. So, despite the attractiveness of the term "keystone" and the obvious connection to selecting sites for protection, it is difficult to use the word keystone for management purposes because of the complexity of ecological interactions and the uncertainty of what the term really means.

The definition of keystone species has also been broadened as the "community importance" concept (Power *et al*. 1996). This definition expands Paine's (1969b) original definition to build on Mills *et al*. (1993) concept of interaction strength. The idea is to quantify the relative contribution of a species trait to a community or ecosystem, where trait refers to productivity, nutrient cycling, species richness, or abundance of functional groups. This broader definition means that the characteristics of keystone species are more difficult to define and so it is more difficult to identify keystone species. Ideally keystone effects would be identified through experimental manipulation or comparative studies. However, it is difficult to choose appropriate spatial and temporal scales for such work. Keystones are usually top predators or high trophic level predators, but all top predators are not necessarily keystone species.

6.1.2 Keystone species and BEWG initiatives

The implications of the keystone species concept is profound for ecosystem-based management because we must be concerned about the loss of a species that can alter systems, and be aware that introduced (or invasive) species could act like keystone species in unanticipated ways. Biodiversity studies should include identification of keystone species, although this may be difficult (Power *et al*. 1996). The keystone species concept is important because it is a theoretical framework to explain diversity patterns and how the loss of certain species can have reverberating effects throughout the ecosystem. The main issue is that much of the world's biodiversity is not well understood at a theoretical level. Therefore studies are needed that focus on the elucidation of ecological theory needed to explain biodiversity patterns. For example, the BEWG currently has initiatives on sea floor mapping, environmental quality indicators (especially diversity as an indicator of quality), and relationships between biodiversity and functioning of marine environments. All of these initiatives are important to provide an understanding of the broader issue of coastal and ocean productivity.

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6.2 Consider whether stomach data could provide information on the spatial and temporal changes in abundance of species or species groups difficult to sample with traditional gear types, and if the answer to this is affirmative, consider whether there would be interest in cooperating with WGSAM, IBTSWG and WGBIFS on planning and conducting future stomach sampling programmes

H. Reiss gave an introductory presentation on diet composition of meso-predatory demersal fish species in the North Sea, work done by S. Schückel

The diet composition of meso-predatory demersal fish species were studied in different regions of the North Sea. In the southern North Sea small demersal fish species are dominating together with commercially exploited flatfish species, whereas in the northern North Sea haddock is the dominating demersal meso-predator. Stomach content of the different fish species and the benthic communities in the field were analysed regarding diet composition, prey selection, diet overlap and food competition. In total 121 species were found in the haddock stomachs in the regions of the northern North Sea, whereas 64 and 58 species were found in the diet of the two dominating small flatfish species in the southern North Sea solenette and scaldfish, respectively. Most species were feeding opportunistically on the most dominant benthic prey, but a few dominant prey species were avoided. The potential use of stomach content data for gaining information on benthos species distribution is limited, but they may provide useful data for regions with unsuitable habitats for quantitative benthos sampling. Furthermore, diet analyses on a high taxonomic resolution require excellent knowledge and experience on benthic species determination. However, detailed studies on the diet of demersal fish can provide valuable information about food web structure and predator prey interactions.

Discussion

The BEWG considered the role of stomach content data as useful information on benthic species or species groups. In particular, the combination of macro-zoobenthic data and stomach contents of fish would provide valuable information on the trophic transfer in benthic systems. In this context, food web analysis of macro-zoobenthos could be obtained by stable isotope ratios or fatty acid analysis, but these methods provide only information on the relative position of an animal within the trophic hierarchy or insufficient/relative information on prey composition. Combining the consumption part by fish species could deliver information on a) prey items of benthos and b) productivity of benthos. Such food web analyses are of particular interest for the Marine Strategy Framework Directive, too.

Stomach contents might provide valuable information on rare species, as fish can be selective in predation. In vulnerable marine ecosystems and areas that are difficult to sample by traditional gears (grabs, trawls), i.e. hard-bottom substrates such as coral reefs (e.g. cold water reefs in Norway, see www.mareano.no, Buhl-Mortensen *et al*. 2012) or seamounts (e.g. BioIce-project in Iceland, chapter 3.1.1.1.), stomach contents

of fish could deliver a non-destructive sampling method for qualitative information on species composition. Fish stomach contents also could provide information of yearly and seasonal variation by spatial and temporal predation pressure changes on the benthos. However, it has to be kept in mind that these changes might also be caused by fish behaviour and not by changes in the benthic community, i.e. "multi-choice" consumers can switch between different prey items and thus diminish prey population oscillations and prevent one single species from becoming dominant (Post *et al*., 2000; McCann *et al*., 2005).

The BEWG members discussed some concerns/limitations and raised some issues that one should be aware of if stomach contents are to be used to provide information on species and species groups abundances. A high level of taxonomic skill is needed to analyse stomach data to species level, often requiring thorough knowledge of the local fauna. However, genetic assay could assist with this analysis. Scale is an important issue, as fish are mobile and therefore feed over larger scales, data on benthos will be integrated over different scales. Hence, information on fish behaviour, mobility and distribution should be taken into account. Stomach data may be biased due to the specific diets of demersal fish. Quantitatively, stomach data is also influenced by different residence times in the stomach, which requires knowledge about digestion times for predators as well as prey items. Further, obtaining stomach data is time consuming and high resolution can prove to be quite costly. Last but not least, stomach content data delivers presence only data, however, for species distribution modelling, for example, there are presence-only data techniques.

Some projects in this field of research, i.e. linking stomach contents and benthic communities, are already ongoing in the BEWG (e.g. Schückel *et al*., 2011; Schröder *et al*., 2008; Fraser, 2008; Reilly *et al*., in process).

Overall, the BEWG members agreed that stomach content data can provide valuable information on the spatial and temporal changes in abundance of species and species groups. The BEWG sees more possibilities beyond spatial or temporal distribution: food web analysis and trophic links within the benthic trophic net, which would include fish predation pressure on benthos and information of trophic energy transfer by linking benthos and fish, quantifying the function of a habitat (as feeding ground) and possibly linking predator species to specific habitats. Hence other expert groups might be involved in this topic as well.

Silvana Birchenough and John Pinnegar (Cefas) also mentioned (by correspondence) some progress on looking at stomach content data (from ICES data and DAPSTOM data sets) for assessing the consumption by fish on specific benthic invertebrate species that are thought to be vulnerable to ocean acidification. This information is deemed important for 'scaling-up' the effects of ocean acidification on higher trophic groups. This work is ongoing as part of the UK Ocean Acidification project.

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6.3 A digitalized map of average benthos production and biomass

The request by WGSAM to produce a digitalized map of benthos production and biomass by quarter and area for the North Sea, was only briefly discussed. BEWG itself does not have the appropriate data for producing such maps, but WGSAM is directed to the outcomes of the FP7 project MAFCONS (http://www.mafcons.org/), in which maps on benthos productivity and biomass were produced based on data available till the early nillies. To our knowledge this is the best information available at this moment.

There is also available published work for macrofaunal production across the UK continental shelf (see Bolam *et al.*, 2010)

Bolam, S.G., Barrio-Frojan, C.R.S., Eggleton, J.D. 2010.Macrofaunal production along the UK continental shelf. Journal of Sea Research 64 (2010) 166–179

6.4 BEWG Strategic planning

6.4.1 Feasibility and efficiency of intersessional work

Intersessional work largely contributes to a timely finalisation of BEWG initiatives and helps to free up time for conceptual and strategic thinking and discussion during the annual meetings. BEWG however identified a couple of drawbacks on the feasibility and efficiency of intersessional work and the possible solutions to it.

The annual BEWG meetings always create a momentum for continued scientific contributions to BEWG initiatives. It however proves difficult to keep the momentum intersessionally. Agreed deadlines for intermediate deliverables seem difficult to hold. Intersessional work can be quite time consuming, especially when it comes to analysing data for example. As a solution, intermediate WebEx meetings, linked to crucial deadlines, were proposed for a regular re-establishment of the momentum.

Re-opening the discussion on the objective of BEWG initiatives intersessionally hampers a swift execution of the working plan, in which case there is a serious risk of failure. The group recognised the need for limiting the discussions once an initiative is started and its focus established. Working with a clearly confined group, strict deadlines and well-defined targets was deemed a productive path to take for such tasks.

6.4.2 Draft a format for a future intensified collaboration between BEWG, WGMHM and WGEXT

BEWG, WGMHM and WGEXT share an overlap in interest and expertise. Unofficial contacts between the chairs and members of the three groups repetitively highlighted the need for a strengthened collaboration between the three groups. While some collaboration between BEWG and WGMHM exist (see 5.2 and 6.5.1), such interactions with WGMHM are missing. Back-to-back meetings to promote interaction seem logic. However, BEWG identified the need to first identify the scope for interaction and to initiate shared initiatives on the basis of which physical meetings should be organised.

BEWG therefore proposed a new joint BEWG–WGMHM initiative to produce a viewpoint paper on "What habitat mapping is needed for ecosystem based management with focus on benthos". This proposal was added to the WGMHM 2012 meeting agenda for further elaboration.

6.5 BEWG conference contributions & workshop organisation

6.5.1 ASC 2011 Theme Session "Habitat mapping for better assessment and monitoring of our seas"

BEWG and WGMHM jointly organized a theme session at the ICES Annual Science Conference 2011. Conveners were R. Coggan (UK), J. Populus (France), S. Degraer (Belgium). The session led to following conclusions:

There has been an increasing demand for habitat maps to improve our spatial awareness of the marine environment and so support the decision making process in marine management and spatial planning. Habitat Mapping can take two forms, mapping the distribution of habitat/biotope classes defined *a priori* in some classification scheme (e.g. the marine section of EUNIS, the European Nature Information System habitat classification) or mapping the geographical distribution of biodiversity assets (e.g. species or communities) of interest. Both forms of mapping are amenable to direct or predictive mapping. Where direct mapping plots actual observations, predictive mapping shows where habitats or species are likely to occur based on our knowledge of the 'preference' that a habitat or a species has for a given set of environmental conditions; so-called 'habitat suitability modelling'. Predictive mapping is being pushed to the fore as a consequence of limited resources for observational mapping and the immediacy of the need for information to underpin management decisions. This session looked across the range of these approaches, to highlight areas of difficulty, innovation or new knowledge that would improve our ability to assess and monitor the benthic environment.

Three papers (G:03, G:05 and G:16) focused on the EUNIS habitat classification scheme. Concerns were raised that internal inconsistencies in the hierarchical structure of the scheme lead to internally inconsistent maps that can mislead and misinform the uninitiated end-user. Furthermore there is mounting evidence that the original partitioning of sediment types into four broad EUNIS classes (coarse, sand, mud and mixed sediment) is not as ecologically meaningful as was first anticipated and that some revision is needed so that the biotope classes defined in the scheme better reflect the observations made in the field. The USA uses a different classification scheme, NOAA's Coastal and Marine Ecological Classification Standard (CMECS) and work is underway to investigate how this, and habitat suitability modelling, could be merged with the Habitat Template approach to broadscale mapping (G:15).

Habitat suitability modelling was clearly in widespread use. Some applications were driven by the need to identify habitats and localities used at critical stages in the life cycle of commercially valuable marine species (G:01, G:02), whereas others used it to predict the distribution of ecologically important habitats recognised for their biological and functional diversity (G:07, G:13, G:06). Many different models are available for use in habitat suitability modelling and produced largely similar outputs when tested on the same data set (G:14). Hence it is not the case that one model should be preferred over all others; rather the model should be chosen that best fits the circumstances of the study. Substrate characterisation was fundamental to all habitat mapping initiatives and good sediment maps were considered to be highly important, but were lacking in some countries (G:08). Sediment mapping remains a major objective of modern surveys (G:04) but it was also demonstrated that historical data can be used to produce modelled raster maps of sediment type and that the technique of Kriging with external drift (KED) significantly improved their quality (G:11). These raster maps had the advantage of recording the % gravel, % sand and % mud for each map pixel, so enabling classification according to the needs of the end user, rather than imposing an *a priori* classification (e.g. the Folk sediment classification) that may not suit the needs of every end-user.

Pressure mapping is a further key element in effective spatial management of the marine environment and two papers addressed the problems of mapping the most widespread anthropogenic impact on the seabed, that of demersal fishing. In order to assess the 'significance' of such disturbance (*sensu* Marine Strategy Framework Directive, MSFD) methods are needed that help us appreciate the magnitude of anthropogenic disturbance in relation to that of natural disturbance (G:10), and to provide quantitative evidence of the change that trawl/dredge impacts make to the benthic communities that structure benthic habitat (G:12).

In discussion there appeared to be a consensus view that those who commissioned habitat maps found it difficult to specify precisely what they wanted from the map. Our increasing ability to provide bespoke maps suggests that there should be a greater dialogue between map users and map producers as to the desired information content of maps, and the undesirable limitations that can be imposed by adopting some *a priori* classification schemes.

It was common experience that managers were found to be reluctant to use gradient/graduated maps as these placed an interpretive burden on them to decide the significant points along the gradient. Instead they preferred interpreted maps, with hardclass outputs giving clearly defined (not fuzzy) boundaries. Time and again we appeared to be 'dumbing-down' the information content of our maps to make then 'simple enough for managers to use'. Greater liaison between map producers and map users might help to educate both sides as to what is actually needed and what can actually be achieved. The scientific body should still aim to make the 'best' maps they can, as this provides the greatest flexibility in providing simplified, bespoke maps to a range of end users.

As a conclusion, bringing together people with a common interest in describing and monitoring the seabed through habitat mapping was deemed a relevant initiative, as testified by the success of this session: the session, comprising 15 oral and 12 poster presentations, was well attended by 40–50 people during all three time slots of the session. The knowledge we gathered is equally important for benthos and fish ecology and underpins several Good Environmental Status descriptors of the MSFD. The fact that more knowledge – notably in map form – was called for by both SCICOM

meetings held at the conference reinforce our belief that there is quite some scope for progress on this topic.

ICES can be instrumental in this respect through collaborative actions of its relevant working groups, such as the Working Group on Marine Habitat Mapping and the Benthos Ecology Working Group who initiated this Theme Session, but also the groups concerned with Marine Spatial Planning and the ICES Data Centre.

6.5.2 Effects of offshore wind farms on marine benthos - Facilitating a closer international collaboration throughout the North Atlantic region

J. Dannheim and S. Degraer reported on the ICES workshop "Effects of offshore wind farms on marine benthos - Facilitating a closer international collaboration throughout the North Atlantic region" (WKEOMB) which took place 27–29 March 2012 at the Alfred Wegener Institute of Polar and Marine Research in Bremerhaven, Germany. The WKEOMB was well received by the participants (19 experts from 7 countries, 4 experts from 3 additional countries contributed remotely) with concrete plans for future work.

The workshop aimed at bringing experts working in the field of offshore wind farms – benthos together for the first time in order to get an overview on the state of the art. This was achieved by an extended poster session. The second issue of WKEOMB was to identify knowledge gaps and evaluating monitoring strategies. This issue was evaluated by disentangling the cause-effect relationships affected by the pressures of the activities during the construction and operation phase of offshore wind farms. All cause-effect relationships were summarized in a schematic presentation. The identification and a comprehensive overview of cause-effect relationships is a prerequisite for an efficient, hypothesis driven approach towards the disentanglement of the various effects of offshore wind farms on the marine benthos as well as on the whole ecosystem. Further, manifold cause-effect relationships were prioritized based on three main research themes, biological resources – biogeochemical reactions – biodiversity, disentangled by the participants as relevant.

An important outcome of the workshop is that benthos receives by far too little attention compared to other ecosystem components (e.g. seabirds, marine mammals), although it contributes to a great extent to marine ecosystem services and goods, e.g. biodiversity, long-term carbon storage and trophic supply for higher trophic-level species. A second main outcome of WKEOMB was that legal baseline monitoring merely allows for net-effect descriptions but not for identifying and understanding the underlying processes. Key processes should be, thus, identified and become subject to hypotheses-based target monitoring and/or experimental studies.

Finally, the way forward, i.e. the perspectives and collaboration opportunities with regard to identified knowledge gaps, was discussed. The participants agreed that there is an urgent need for future scientific collaborations, particularly in the scientific research field of cumulative impact assessments when expert knowledge, scientific results from projects and potentially data are shared among scientists across frontiers. Several action points were made which will be listed in the WKEOMB report. The participants decided that there is a certain need for regular meetings in order to bring the raised issues forward. This will be best tackled by initiating an ICES Expert Group on the effects of renewable energy constructions on the marine benthos which will be chaired by J. Dannheim, Germany and A. B. Gill, United Kingdom. A recommendation for this initiation was forwarded to the BEWG.

The new expert group WGMBRED (Working group on Marine Benthal and Renewable Energy Developments) should aim at the specification of cause-effect-relationships resulting from such constructions and at developing a strategy how to proceed in terms of researching the processes and cause-effect relationships. The understanding of the processes and changes initiated by renewable energy constructions in the benthic system is important in the context of marine ecosystem services and goods such as biodiversity, the biogeochemical systems (e.g. long-term carbon storage) and the biological resources/food supply for higher trophic levels. The outputs of the group will also be set within the context of marine spatial planning strategies and future ecosystem-based management approaches.

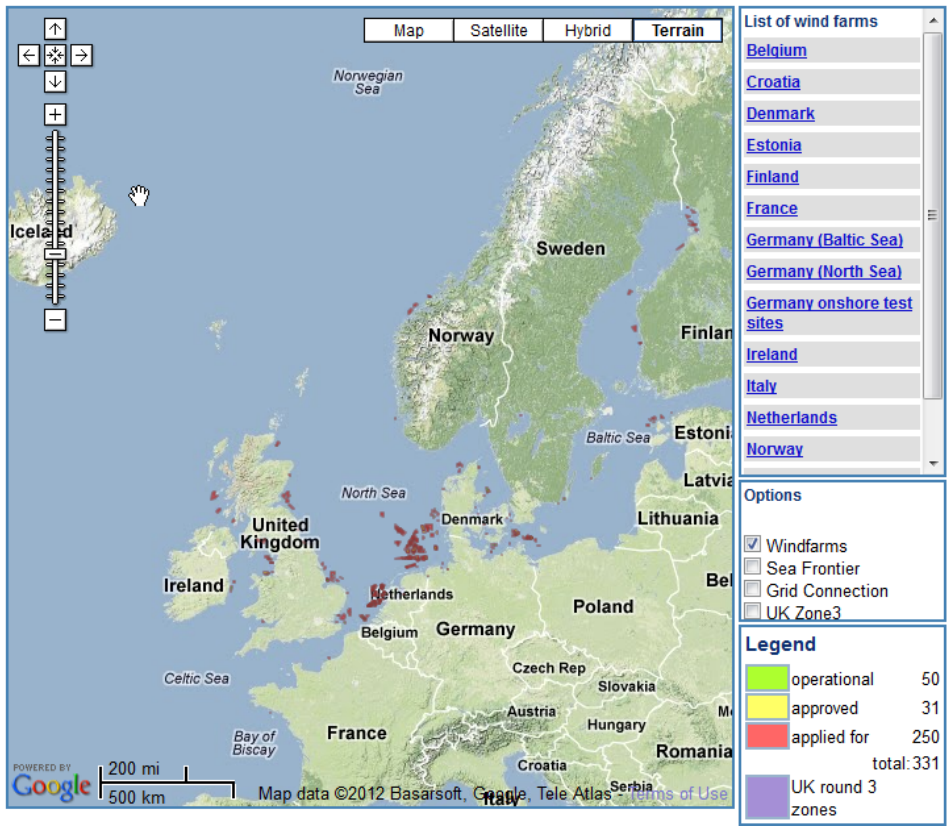

Figure 2. Current (May 2012) operational, approved and applied for wind farms (RAVE).

6.5.3 ASC 2012 Theme Session "How does renewable energy production affect aquatic life?"

E. Winter (Netherlands), A. Maltby (UK), S. Degraer (Belgium) and B. Tunberg (USA) will host the following theme session at the ICES Annual Science Conference 2012

Understanding the ecological effects of renewable energy installations is a high priority issue and there is a demand for greater understanding for the environmental assessment and spatial planning of new infrastructure. The renewables industry is growing at high speed due to policy drivers and financial instruments to reduce reliance on fossil fuels. The result is a renewed interest in old principles of river-based hydropower based on new technology, and proposals for large energy-producing tidal barrages across important estuaries and deltas. Furthermore, the marine environment is increasingly being proposed as a publically acceptable location for large-scale wind farms, and in the development of new technology for exploiting tidal movement and wave power. These technologies and physical installations have the

potential to affect aquatic ecosystems during their construction, and throughout their operational life. Effects could range from severe negative impacts (e.g. high mortality rates for entrained species, or altered benthic communities), to potentially positive effects (e.g. foundations for offshore wind turbines that may serve as artificial reefs, or new habitats for benthos). Studies that target direct or indirect impacts on higher trophic levels e.g. fish, seabirds and marine mammals, have increased, but knowledge on many areas is still dominated by speculation. Over the last decade, knowledge of local effects on benthic communities through changes in biogeochemistry or food web interactions, particularly of offshore wind farms, has increased. Current research is focusing on large-scale effects on the functioning of the marine and estuarine ecosystem. This session aims at sharing knowledge and research ideas on the ecological effects of renewable energy production.

6.5.4 ICES sponsored conference on fisheries impact on bottom and bottom fauna (June 2014 in Tromsø, Norway)

Conveners: Lene Buhl-Mortensen, Carsten Hvingel and Børge Holte (Norway), Francis Neat (Scotland) and Mariano Koen-Alonso (Canada)

Understanding and reducing fishing impacts to the seafloor represents a key challenge to the implementation of a sustainable management of marine resources. Maintaining the economic value of fish stocks, while ensuring ecological sustainability requires the implementation of a ecosystem-based approach to marine resource management. Any bottom-contact fishing will impact the sea floor to a greater or lesser extent depending on the seabed type and the gear type used. At one extreme, substantial damage to coral, sponge and sea pens communities caused by bottom trawling has been widely documented. On the other hand some shallow sandy habitats have been beach-seined for centuries without obvious change. We know little about how fishing impacts ecosystem function, biodiversity, productivity, vulnerability and resilience. Longer term ecosystem responses to fisheries discards are hardly understood at all. We are at a very early stage in developing indicators of ecological status and performance and we generally lack predictive models of recovery time for most ecosystems. Technical solutions aimed at minimizing fishing impacts are starting to appear, but their efficacy remains to be tested in many ecosystems. This symposium will review the state of the art of this important developing area that lies at the core of ecosystem based management.

Papers and posters are welcome on the following topics:

- Instantaneous and physical (?)changes to the benthic ecosystem caused by fisheries
- Change in the extent of habitats impacted by bottom trawling – how big is the problem?
- Effects of fishing on marine faunal biodiversity
- Effects of fishing on nutrient recycling and benthic-pelagic coupling
- Effects of fisheries discards on the benthic ecosystem
- Effects of seabed protection measures; total or partial fishing gear substitution and techincal conservation measures.
- Development of indicators of ecological change

The symposium is small (150–300 participants) to allow for close contact and discussions between the participating scientists. It should function as a forum for presenting state of the art in the field and allow for exchange of views and results. There will

be no parallel sessions to create an environment that allows for good communication. The proceedings are planned to be published in the Marine Biological Research.

6.5.5 ASLO 2013 Aquatic Sciences Meeting. Theme session "Ecosystem-based Marine Spatial Planning for better management of our oceans", 17–22 February 2013 (New Orleans, Louisiana, USA)

Conveners: Angel Borja (Spain), Steven Degraer (Belgium) and Tundi Agardy (USA)

In recent times, human pressures and subsequent impacts on marine ecosystems have increased dramatically. This is due both to traditional activities (e.g. fishing, resource extraction, pollutant discharges and maritime transport) and more recent uses (e.g. offshore aquaculture and marine renewable energy exploitation), which may well increase impacts. Many countries have developed new legislation to address these challenges (e.g. the US Marine Policy, Canada's Oceans Act, and the E.U. Marine Strategy Framework Directive). These regulations seek to safeguard marine ecosystems, through an integrative ecosystem-based approach encompassing all ecosystem components in order to allow sustainable use of marine goods and services. Marine spatial planning is the best framework to consider present and future human activities and systematically plan and achieve better management of our oceans. The main objective of this session will be to showcase approaches undertaken in different countries to implement such plans and to draw lessons for an improved marine spatial planning process ensuring a proper implementation of the ecosystem-based approach.

The deadline for abstract submission is 23:59 U.S. Central Time on 5 October 2012.

6.5.6 To explore possibilities of a joint theme session on long-term changes of benthos and climate change effects during the ASC 2013

Long-term datasets are key to the exploration of the effects of climate change. While such long-term series are (being) identified for the benthos through BeLTS-net, such precious series are also available and explored as such for other ecosystem components. BEWG will therefore take the initiative to propose a Theme Session to be organised at the Annual Science Conference 2013, during which experiences and major findings of long-term series analyses in a context of climate change will be shared.

Theme session conveners: S. Birchenough (UK), H. Reiss (Norway) and J. Craeymeersch (the Netherlands).

6.6 Any other business

6.6.1 Election of BEWG chair

S. Degraer was unanimously re-nominated as Chair of the Working Group for the coming two years.

6.6.2 Selection of next year's meeting place and date

Three possible venues were proposed by members: Askö (Sweden), Bergen (Norway) and A Coruña (Spain). The group chose to meet on 22–26 April 2013 in A Coruña, Spain.

6.6.3 Acknowledging H. Rumohr's retirement

Former Chairman and long-term member retired and his many contributions to the BEWG were acknowledged.

Annex 1: List of participants

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Annex 2: Agenda and Meeting Structure

Terms of Reference and Expert Group Recommendations for this meeting

Terms of References

a) Update, plan and further develop the Benthic Long-Term Series Network (BeLTS-net) activities, based on the intersessional BEWG work on long-term data series analyses with special attention to climate change;

b) Recommend future actions for the Study Group on Climate-Related Processes (SGCBNS) within the Benthos of the North Sea based on the SG's 2010/2011 work;

c) Finalise the BEWG paper on "The myths of benthic indicators";

d) Finalise the BEWG review paper on "Species distribution modelling and mapping (SDM) in the marine environment and its relevance for ecosystem management";

e) Draft a format for a future intensified collaboration between BEWG, WGMHM and WGEXT;

f) Update the BEWG's research plan on species distribution modelling, benthic indicators and climate change, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area;

g) Review and report on existing indicators of biodiversity that are linked to predictable changes in ecosystem function and/or to develop, assess and report on the feasibility and performance of such indicators; [1]

h) Identify and report on functional characteristics that could lead to species being defined as 'keystone'. [1]

Recommendations

i) from Working Group on Multispecies Assessment Methods (WGSAM): Produce a digitalized map of average benthos production and biomass by quarter and area for the North Sea.[2]

j) from WGSAM: Consider whether stomach data could provide information on the spatial and temporal changes in abundance of species or species groups difficult to sample with traditional gear types, and if the answer to this is affirmative, consider

[1] These ToRs have been requested by the Strategic Initiative on Biodiversity Science and Advice to support the development of biodiversity science in ICES.

[2] Benthic food plays a large role in the diet of several North Sea predators. Among these are haddock and grey gurnard, two species which are important predators of sandeel (haddock), cod and whiting (grey gurnard). Unfortunately, the Working Group on Multispecies Assessment Methods (WGSAM) does not have any information on the yearly variation in benthos production and biomass and is therefore forced to assume these as constant. However, future developments of the SMS will likely be able to include spatial differences in biomass and production of prey and the BEWG should be able to describe these to WGSAM. With these data, the model can take account of whether e.g. northern areas differ from southern in the amount of benthos present.

whether there would be interest in cooperating with WGSAM, IBTSWG and WGBIFS on planning and conducting future stomach sampling programmes.[3]

k) from SGCBNS: To develop further the existing text, website and facilitate analysis in connection with BeLTS-net.

l) from SGCBNS: To explore possibilities of a joint theme session on long-term changes of benthos and climate change effects during the ASC 2013.

Meeting structure

THEME 1: LONG-TERM SERIES AND CLIMATE CHANGE

- **ISSUE 1.A**: Climate change effects on benthic communities
    - 1.A.1 Report on recent findings on long-term data series analyses and other climate change-related benthos activities.
    - 1.A.2 Update, plan and further develop the Benthic Long-Term Series Network (BeLTS-net) activities, based on the intersessional BEWG work on long-term data series analyses with special attention to climate change (ToR a), including a further elaboration of existing text, website and facilitation of analysis in connection with BeLTS-net (Rec. k, SGCBNS)
    - 1.A.3 BEWG manuscript on benthos and climate change to be submitted for publication to the WIRES journal Climate Change
- **ISSUE 1.B**: Review activities of the Study Group on Climate-related changes in the Benthos of the North Sea (SGCBNS). Recommend future actions for SGCBNS, based on the SG's 2010/2011 work (ToR b)
- **ISSUE 1.C**: Update BEWG's research plan on climate change, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area (ToR f, *in part*)

THEME 2: BENTHOS-RELATED QUALITY ASSESSMENT

- **ISSUE 2.A**: Report on recent developments in environmental quality assessment covering phytobenthic and zoobenthic topics
- **ISSUE 2.B**: Finalise the BEWG paper on "The myths of benthic indicators: The crux with indicator species" (ToR c)
- **ISSUE 2.C**: Review and report on existing indicators of biodiversity that are linked to predictable changes in ecosystem function and/or to develop, assess and report on the feasibility and performance of such indicators (ToR g)
- **ISSUE 2.D**: Update BEWG's research plan on benthic indicators, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area (ToR f, *in part*)

THEME 3: MARINE HABITAT MODELLING AND MAPPING

- **ISSUE 3.A**: Report on recent initiatives on habitat suitability modelling and mapping
- **ISSUE 3.B**: Finalise the BEWG review paper on "Species distribution modelling and mapping (SDM) in the marine environment and its relevance for ecosystem management" (ToR d)

[3] Benthic food plays a large role in the diet of several North Sea predators and in future sampling programmes, information on the diet of these predators may be of value to BEWG though it does not improve estimates of the amount of fish consumed. WGSAM therefore asks BEWG to consider whether determining benthos in stomach contents to species or species groups would provide a significant value to BEWG.

- **ISSUE 3.C**: Produce a digitalized map of average benthos production and biomass by quarter and area for the North Sea (Rec. i, WGSAM)
- **ISSUE 3.D**: Update BEWG's research plan on species distribution modelling and mapping, based on e.g. reports on exciting developments in ongoing phyto- and zoobenthic research in the ICES area (ToR f, *in part*)

THEME 4: OTHER BUSINESS

- **ISSUE 4.A**: Identify and report on functional characteristics that could lead to species being defined as 'keystone' (ToR h).
- **ISSUE 4.B**: BEWG Strategic planning
    - 4.B.1 Update BEWG's research plan (ToR f, *in part*), e.g. feasibility and efficiency of intersessional work
    - 4.B.2 Draft a format for a future intensified collaboration between BEWG, WGMHM and WGEXT (ToR e)
    - 4.B.3 Consider whether stomach data could provide information on the spatial and temporal changes in abundance of species or species groups difficult to sample with traditional gear types, and if the answer to this is affirmative, consider whether there would be interest in cooperating with WGSAM, IBTSWG and WGBIFS on planning and conducting future stomach sampling programmes (Rec. j, WGSAM).
- **ISSUE 4.C**: BEWG Valorization initiatives
- **ISSUE 4.D**: Any other business

Anticipated time schedule

Sandgerði (Iceland), 2012/05/7-11

Monday

09h30 – 10h00	Arrival of participants
10h00 – 11h00	Icelandic welcome, and practicalities (0.5h)
	Icebreaker: Jörundur Svavarsson (University of Iceland) on "BioIce and IceAge" (0.5h)
11h00 – 12h30	Theme 1, Issue 1.A, 1.A.1: Long-term benthic series: Introductory presentations (1h)
	Theme 1, Issue 1.B: Review SGCBNS activities (0.5h)
12h30 – 13h30	Lunch
13h30 – 15h30	Theme 1, Issue 1.A, 1.A.2: BeLTSnet (2h)
15h30 – 16h00	Coffee break
16h00 – 18h00	Theme 1, Issue 1.A, 1.A.3: SoA WIRES paper submission (0.5h)
	Theme 4, Issue 4.B, 4.B.1: Feasibility and efficiency of intersessional work (0.5h)
	Theme 1, Issue 1.C: BEWG's research plan (1h)
18h30 – 20h00	Welcome reception
20h00	Dinner in Sandgerði

Tuesday

09h00 – 10h00	Theme 2, Issue 2.A: Benthic indicators: Introductory presentations (1h)
10h00 – 10h30	Coffee break
10h30 – 12h30	Theme 2, Issue 2.B: Paper "The myths of benthic indicators" (1.5h)
	- possibly extended to break out groups on Thursday
	Theme 2, Issue 2.C: Indicators of biodiversity: Introduction to subgroup work (0.5h)
12h30 – 13h30	Lunch

13h30 – 15h30	Theme 2, Issue 2.D: BEWG's research plan (1h)
	Theme 3, Issue 3.A: Introductory presentations (1h)
15h30 – 16h00	Coffee break
16h00 – 18h00	Theme 3, Issue 3.A: Habitat suitability: Introductory presentations (ctd.) (1h)
	Theme 3, Issue 3.B: Species distribution modelling paper (1h)
	- possibly extended to break out groups on Thursday
19h00	Dinner in Sandgerði

Wednesday

09h00 – 10h30	Theme 3, Issue 3.C: Digitalized map of benthos production and biomass (0.5h)
	- possibly extended to break out groups on Thursday
	Theme 4, Issue 4.B, 4.B.3: Fish stomach data and benthos (1 h)
	- possibly extended to break out groups on Thursday
10h30 – 11h00	Coffee break
11h00 – 12h30	Theme 3, Issue 3.D: BEWG's research plan (1h)
	Theme 4, Issue 4.A: Functional characteristics of 'keystone' species (0.5h)
	- possibly extended to break out groups on Thursday
13h30 – 19h00	Surprise excursion to Iceland's nature treasures
19h00	Dinner in Sandgerði

Thursday

Draft list of break out groups, to be concluded during the first three days of the meeting
BeLTS-net
Species distribution modelling (and mapping) paper
Digitalized map of benthos production and biomass
Fish stomach data and benthos
Functional characteristics of 'keystone' species

09h00 – 09h30	Introduction to the break out group work, phase 1 (0.5h)
09h30 – 12h00	Break out group work, phase 1 (incl. coffee break) (2.5h)
12h00 – 12h30	Plenary feedback, phase 1 (0.5h)
13h30 – 14h00	Introduction to the break out group work, phase 2 (0.5h)
14h00 – 16h30	Break out group work, phase 2 (incl. coffee break) (2.5h)
16h30 – 18h00	Plenary feedback, phase 2 (0.5h)
	Conclusions from break out group work (1h)
19h00	Dinner in Sandgerði

Friday

09h00 – 12h30	Theme 4, Issue 4.B, 4.B.2: Collaboration with BEWG, WGMHM and WGEXT (1h)
10h00 – 10h30	Coffee break
10h30 – 12h30	BEWG valorisation initiatives (2h)
12h30 – 13h30	Lunch
13h30 – 15h30	Theme 4, Issue 4.D: Any other business (2h)
15h30 – 16h00	Coffee break
16h00 – 18h00	Wrap up of BEWG 2012, incl. SoA reporting, action points and ToRs BEWG 2013 (2h)
18h00	Closure of the meeting
19h00	Dinner in Sandgerði

Annex 3: BEWG terms of reference for the next meeting

The **Benthos Ecology Working Group** (BEWG), chaired by Steven Degraer, Belgium, will meet in A Coruña, Spain, 22–26 April 2013 to:

a) Evaluate the progress made within BELTS-net and to identify further actions, taking account of the progress made within SGCBNS;

b) Review and report on the use of benthic indicators and targets within WFD, MSFD and Habitats Directive: Compatibility and complementarity;

c) Compare and report on the performance of different quantitative species distribution modelling techniques;

d) Disentangling the link between biodiversity and ecosystem functioning:

- To review and identify benthic indicators to reflect the link between both aspects.
- To review and report on how ecological function and diversity relates to different parts of the benthic communities at different spatial scales.
- To review the data compilation on functional diversity of macrobenthos in relation to ecosystem functioning, and to scope for further research.
- To finalise the paper on the link between ecosystem functions and ecosystem services.

BEWG will report by 15 June 2013 (via SSGEF) for the attention of the SCICOM.

Supporting Information

Priority	The current activities of BEWG will continue along the three major axes of priority within BEWG: long-term series and climate change, benthic indicators and EU directives, and species distribution modelling. Next year's BEWG work will also accommodate for the exploration of the link between biodiversity and ecosystem functioning, which will cut through BEWG's work as a transversal theme. All issues mentioned fit ICES Science Programme and may hence be considered of high priority.
Scientific justification	**ICES Science Plan, Priority 1 "Understanding ecosystem functioning"** **Research topic "Climate change processes and prediction of impacts"** Term of Reference a) Evaluating the progress made within BELTS-net and identifying further actions within BELTS-net (ToR a) will help identifying major ecosystem regime shifts, including their geographical spread, as starting point for further consideration of the impact of climate change onto the benthos. **Research topic "Biodiversity and the health of marine ecosystems"** Term of Reference d) Disentangling the link between biodiversity and ecosystem functioning is currently considered key to a full understanding of the health of marine ecosystems. This topic hence became a red line through the BEWG 2012 meeting, from which it was decided to identify issues BEWG could substantially

	contribute to. BEWG will therefore review and identify benthic indicators to reflect the link between biodiversity and ecosystem functioning and review how ecological function and diversity relates to different parts of the benthic communities at different spatial scales. BEWG will also scope for research on the functional diversity of macrobenthos in relation to ecosystem functioning, for which a first data compilation will be dealt with intersessionally. From a more conceptual perspective, BEWG will finally investigate the link between ecosystem functioning and ecosystem services. The latter paper will be drafted intersessionally and will be finalised during the BEWG 2013 meeting **ICES Science Plan, Priority 2: "Understanding interactions of human activities with ecosystems"** **Various Research topics** Term of Reference b) A wide suite of benthic quality indicators were developed, intercalibrated and applied within the framework of several international regulations. At present, the most relevant directives within the Northatlantic realm are the Water Framework Directive, the Habitats Directive and the Marine Strategy Framework Directive. BEWG will review the use of benthic indicators and targets within all three EU Directives, with a specific focus on the compatibility and complementarity of the use of benthic indicators. **ICES Science Plan, Priority 3: "Development of options for sustainable use of ecosystems"** **Various Research topics** Terms of Reference c) Species distribution modelling (SDM) helps understanding the distribution of species and communities. As such, it helps elaborating a scientifically-sound management of the marine ecosystem. While qualitative SDM (i.e. modelling the likelihood of occurrence of benthic feature) has been regularly applied, today attention is needed to quantitative modelling techniques (e.g. modelling densities or biomass. This ToR will compare and report on the performance of different quantitative species distribution modelling techniques and will as such contribute to a next phase in SDM.
Resource requirements	No ICES resources are required.
Participants	The Group is normally attended by some 20–30 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are no obvious direct linkages with the Advisory Committee.
Linkages to other committees or groups	There is a very close link to the work of several expert groups within SSG-EF, among which SGCBNS, WGMHM and WGEXT.
Linkages to other organizations	The work of this group is closely aligned with similar work in FAO and in the Census of Marine Life Programme.

Annex 4: Action points

- *J. Craeymeersch*: will take action to realise The BELTSnet that in the next months.
- *H. Hillewaert*: A first online version of the BELTSnet site should be launched by half June (further polishing and addition of features afterwards when needed).
- *J. Vanaverbeke*: will compile a starting table for the ecosystem functioning paper with literature to be reviewed by the volunteers (G. Van Hoey, M. Zettler, ….).
- *P. Montagna*: To investigate the link between Ecosystem Functioning and Ecosystem Services to be wrapped up in a paper to be sumitted before next BEWG meeting.
- *J. Vanaverbeke*: To investigate the possibilities for integrating research on macrofaunal functional diversity in relation to ecosystem functioning
- *L. Buhl-Mortensen*: to contact WGMHM to liaise to draft a structure for a paper on the topic: What habitat mapping is needed for ecosystem based management with focus on benthos.
- *S. Degraer, B. Tunberg & J. Dannheim*: ASC 2012 Theme Session "How does renewable energy production affect aquatic life?"
- *L. Buhl-Mortensen*: ICES sponsored conference will be held June 2014 in Tromsø, Norway, on fisheries impact on bottom and bottom fauna.
- *L. Buhl-Mortensen*: Mareano methodology – workshop is held 17-18 October in Trondheim, Norway. The following topics are treated:
    - Surveyplanning, Analyses of visual observations
    - Habitats and biotopes (classification, prediction and verification)
    - Integration of data from different sampling gears
- *H. Reiss & S. Birchenough*: To explore possibilities of a joint theme session on long-term changes of benthos and climate change effects during the ASC 2013.
- *S. Degraer, A. Borja & T. Agardy*: ASLO 2013 Theme session proposal "Ecosystem-based Marine Spatial Planning for better management of our oceans".
- *B. Tunberg and North-American colleagues*: to update the long term series table with special attention to North-American data series.

Annex 5: Recommendations

RECOMMENDATION	ADRESSED TO
1. To establish a new expert group WGEMBRED (Working group on Marine Benthal and Renewable Energy Developments) to target the cause-effect-relationships resulting from offshore renewable energy installations and to develop a strategy on how to proceed in terms of researching the processes and cause-effect relationships. The outputs of the group should also be set within the context of marine spatial planning strategies and future ecosystem-based management approaches. J. Dannheim, Germany and A. B. Gill, United Kingdom were found prepared to chait this Expert Group.	SSGEF

Annex 6: The WISER Project

The main findings from this project are available at www.wiser.eu (deliverables section) and in the paper: Borja, A., M. Elliott, P. Henriksen, N. Marbà (accepted). Transitional and coastal waters ecological status assessment: advances and challenges resulting from implementing the European Water Framework Directive. Hydrobiologia.

Macroalgae and seagrasses

The main objectives of this WP were:

- Study seagrass indicator potential;
- Study responses of macroalgae and seagrass indicators to drivers of deterioration;
- Study and develop benthic macroflora indicators for coastal waters, including classification;
- Study benthic macroflora indicators for transitional waters, including classification boundaries, definition of reference conditions and uncertainty.

Seagrass indicators

This WP identified 42 on-going monitoring programs of European seagrass meadows aiming at evaluating seagrass health (11 programs), assessing coastal quality (28 programs) or both (3 programs); (Marbà *et al.*, submitted). The monitoring programs span across the four European ecoregions and involve the four European seagrass species (*Zostera nolti, Z. marina, Posidonia oceanica, Cymodocea nodosa*), although *C. nodosa* is the least seagrass species monitored. These programs use 49 seagrass indicators including a total of 51 seagrass metrics used either alone or in various combinations of up to 14 metrics per indicator. Mediterranean monitoring programs include by far the largest diversity of seagrass indicators, followed by those for the North East Atlantic and the Baltic Sea regions, while those of the Black Sea encompass the least diversity of seagrass indicators. The large number of seagrass indicators in use in European monitoring programs reflects the broad interest for documenting seagrass status and highlights the role of seagrasses as "miner's canaries" of European coastal quality. However, the large diversity of indicators applied and their limited overlap across regions limits the possibility to provide pan-European overviews of the status of seagrass ecosystems. Whereas the diversity of indicators can be partially justified by differences in species and associated time scales of responses as well as by differences in habitat conditions and associated community types but also seems to be determined by scientific traditions. The evaluation of the performance of seagrass indicators on the basis of their responses to pressures in space and, particularly, time and their associated uncertainty is highly needed in order to identify the most suitable indicators that should conform the standards of monitoring for specific coastal European eco-regions. The inclusion of functional metrics in seagrass monitoring assessments may help to early detect ecosystem changes.

Responses of macroalgae and seagrass indicators to drivers of deterioration

This WP quantified and compared benthic and pelagic gross primary production (GPP) along nutrient gradients in time and space in a shallow estuary (Krause-Jensen *et al.*, 2012). The estuary experienced a shift from a pristine, seagrass-dominated clear water regime with high total GPP in the early 20th century to a eutrophic, plankton-

dominated regime still with high total GPP in the 1980s when nutrient loadings peaked. Recent reductions in nutrient loadings reduced pelagic GPP as expected, but the water remained unclear and seagrass abundance and GPP did not increase correspondingly. The results suggest that feedback mechanisms, such as increased resuspension of the seafloor and reduced trapping of particles and nutrients, resulting from the loss seagrasses and their associated ecosystem services delay or prevent restoration to a state with seagrass dominance. Ecosystems do not necessarily respond linearly to changes in nutrient loadings and that the response to eutrophication and oligotrophication may follow different trajectories. Reductions in nutrient loadings to levels below those causing the decline in seagrasses may be necessary, along with initiatives to e.g. reduce the disturbance of the seafloor, in order to stimulate a return to a seagrass-dominated state.

Benthic macroflora indicators for coastal waters

Black Sea

A methodology for assessing the quality of coastal waters along the Black sea coasts was developed, based upon Bulgarian coast hard substrate communities (Orfanidis *et al.*, submitted), compliant with the European Water Framework Directive (WFD, 2000/60/EC) and with the intercalibration processes in the Black Sea. The Ecological index is derived from proportion of two main sensitivity groups (ESGI an ESGII-sensitive and tolerant species), which are divided to 7 subgroups. Assessing the pressure-response relationships, good significant correlations were found between some pressures and macrophytobenthic community Ecological index and some structural indicators.

Bay of Biscay

Within this WP a new method for assessing the quality of coastal waters along the Atlantic Iberian coasts was developed, based upon Basque coast rocky intertidal assemblages (Díez *et al.*, 2012), compliant with the European Water Framework Directive (WFD, 2000/60/EC). Biological data collected over a 20-year period, during the gradual introduction of a sewerage plan, are compared to several reference stations in order to differentiate various degrees of community alteration. A quality index (RICQI: Rocky Intertidal Community Quality Index) is drawn up, on the basis of: indicator species abundance; morphologically complex algae cover; species richness; and faunal cover (herbivore and suspensivore cover, proportion of fauna with respect to the whole assemblage). An independent dataset collected in Plentzia Bay (Basque coast, N. Spain), before and after the set-up of a wastewater treatment plant, is used in order to validate RICQI. A conceptual model based on our results is proposed, which describes successional stages of assemblages along a gradient of increasing environmental disturbance and associated values of the metrics included in the index. The performance of this new approach is compared with that of the quality of rocky bottoms index, used presently as the official method for assessing the ecological status of rocky assemblages in the Atlantic coastal waters of Spain. Both indices respond to changes in community structure, associated with pollution removal. However, the RICQI index shows a more accurate response, identifying different degrees of disturbance.

Portugal

Neto *et al.* (2012, submitted) have developed and tested metrics to use in the assessment of ecological quality. Although this fact, for MarMAT and SQI, several steps

were missing for a complete validation of the methods in the WFD intercalibration exercise. During WISER some crucial improvements were done, the methodologies were concluded, their responses tested against pressure, and studied the uncertainty for the SQI. IMAR was also involved in defining a protocol to quantify the anthropogenic pressures affecting TW and CW (in harmony with WFD) to check the response of assessment methods against the pressure levels present in those systems. These developments allowed fulfilling important requirements from WFD in terms of the methods' validation (e.g., response of methods against pressure, definition of reference conditions).

Uncertainty analyses

This WP has performed different uncertainty analyses of classification using different macrophyte indicators/indices in use in the WFD. The main results are (Balsby *et al.*, submitted; Bennett *et al.*, 2011; Mascaró *et al.*, in press, submitted):

- For the POMI classification system we analysed five factors (zones within site, sites within water body, depth, years and surveyors) that potentially generate classification uncertainty. Of these, depth was a major source of uncertainty, while all the remaining spatial and temporal factors displayed low variability.
- For the POMI classification system we found that the variability of EQR scores of meadows within a water body is higher when water bodies are classified in moderate/poor status than when they are in good/high status. This can be attributed to the effects of human pressures, which are not uniformly distributed across the entire water body and widen the natural range of variability among meadows. Thus, local human pressures influence the ecological status classification of coastal water bodies, potentially raising the risk of misclassification associated to the quality status classification of water bodies.
- When applied to different classification methods based on macrophytes, uncertainty analyses revealed that the factors related to the spatial scale of sampling (both horizontal and vertical) are the main source of uncertainty when classifying the ecological status of water bodies, probably due to the high horizontal and vertical heterogeneity of macrophyte communities. On the contrary, the uncertainty associated to both temporal variability and surveyor is very low.

Macroinvertebrates

The main objectives of this WP were:

- Identify pressure-response relationships of coastal and transitional benthic invertebrates based on existing data and new data obtained during the joint field sampling survey, using seven case-study sites across Europe;
- Develop indicators for hard-bottom substrate fauna;
- Refine numerical models linking the biological and environmental aspects to define reference conditions in transitional waters (lagoons and estuaries);
- Define reference conditions, particularly concerning the role of single and complex habitats, in ecological status assessment of transitional waters;
- Determine the risk of misclassification for different indicators and scales.

Response of metrics to human pressures

This was published by Borja *et al.* (2011). Additionally, we developed, tested and validated a multimetric index of size spectra sensitivity (hereafter, ISS), which integrates size structure metrics with metrics describing the sensitivity of size classes to anthropogenic disturbance and species richness measures (Basset *et al.*, 2012). The ISS was developed using benthic macroinvertebrates data of 12 Mediterranean and Black Sea lagoons. They included micro and non-tidal lagoons, saltpans and oligohaline coastal wetlands, which differed in terms of their physiographic, hydrological and physico-chemical characteristics and the degree of anthropogenic disturbance. The selected lagoons were classified as either "disturbed" or "undisturbed" ecosystems based on expert quantitative analysis, evaluation of anthropogenic pressures in the catchment area and their current protection and conservation status. Data from a thirteenth Mediterranean lagoon (Margherita di Savoia), characterised by a very strong abiotic stress gradient, were used for validation purposes. The ISS was computed in accordance with the formula:

$$ISS_{benthos} = \sum p(CL_i) \times \omega_i \times s$$

where $p(CL_i)$ is the proportion of individuals in the i_{th} size class; ω_i is the assigned sensitivity value for the i_{th} size class; s is a discrete correction factor for the number of taxa (Barbone *et al.*, 2012). For the ISS calculation the macroinvertebrate size spectra were divided into 6 classes (CL1–CL6) by clustering the original abundance octaves into groups of three. We used this approach in order to achieve a large enough size ratio between neighbouring size classes (8:1) to be able to assign each class a different value for sensitivity to anthropogenic disturbance. Detailed information on description of the new index is reported elsewhere (Basset *et al.*, 2012).

The size spectra index showed high discrimination between disturbed and undisturbed sites and it presented significantly higher values at undisturbed than disturbed sites.

Reference conditions in lagoons

The ecological status classification of aquatic ecosystems requires a number of steps, including the description and standardisation of the assessment tools' natural variability. We have addressed this point with reference to selected Mediterranean and Black Sea lagoons and of proposed lagoon typologies in order to: (i) explore the influence of potential sources of natural variability on four multimetric assessment tools (BAT, BITS, ISS and M-AMBI); (ii) evaluate type and metric specific reference conditions and related classification boundaries; (iii) test the accuracy of both type-aspecific and type specific classification boundaries to evaluate the lagoon ecological status.

Surface area, tidal range, confinement and water salinity, which are the drivers of the lagoon typologies proposed in the literature, were found to be significant sources of assessment tool variability. On the basis of these findings, type-specific reference conditions and classification boundaries were defined, improving the accuracy of ecological status assessment. At the lagoon level, accuracy increased by 100% for the more complex typological schemes and by 83% in a validation test performed on an independent set of highly disturbed sites (expected ecological status from moderate to bad). Nevertheless, a certain degree of uncertainty was still found to affect classification at the study site level, with up to 38% of reference sites classified as moderate to bad. The definition of type specific reference conditions is an important contribu-

tion to the implementation of the WFD in the Mediterranean Ecoregion. Anyway, a strong effort is actually required in order to develop procedures minimising the risk of misclassification.

Reference conditions in estuaries:

The description of biotic Reference Conditions (RC) is essential to measure the level of impairment observed in a system (see information in Borja *et al.,* 2012). But for estuaries RC are difficult to define, since these systems are 'constantly variable' and the characteristics of estuarine biocenosis usually mimic those due to anthropogenic stress, the so-called "estuarine quality paradox". In addition, these ecosystems have been historically preferential sites for human occupancy. There are few, if any, estuaries in Europe that have not been explored, occupied, transformed or polluted, and the extent of such alterations is difficult to quantify. Since many factors operate in estuaries it is often difficult to relate biotic responses to explanatory variables, and a major challenge in estuarine ecology is therefore to deal with multiple and limiting factors (both natural and anthropogenic). Quantile regression (QR) approaches present great potential for the definition of reference values for biotic metrics used in ecological assessments. Its properties allow modelling the potential upper (or lower, depending on the parameter modelled) limits of the ecological indices distribution in function of limiting factors for benthic invertebrates (e.g. habitat predictors such as salinity or sediment grain size) across different levels of those factors.

Moreover, in estuaries due to the difficulty in measuring the level of disturbance present and, therefore, distinguishing affected from non-affected communities, QR adds yet another advantage by coping with the effect of unmeasured limiting factors acting simultaneously, without compromising the results of the regression analysis. In this deliverable the patterns of ecological indices commonly applied to assess benthic invertebrate condition in marine and transitional ecosystems were explored across distinct spatial scales, taking into account the longitudinal gradients of 19 estuarine systems across the Northeast Atlantic geographical region. The aims of the study were to:

a) quantify the response of ecological indices to environmental factors widely recognized as crucial in structuring benthic habitats, using QR and to evaluate this statistical approach for multi-gradient analysis;

b) to test if the estuarine diversity paradigms hold across bio-geographical scales comprising relatively similar hydrodynamic systems, as are the northern hemisphere temperate estuaries;

c) use the identified patterns to propose a framework for establishing RC for estuaries across the studied scales to support the WFD implementation in Transitional Waters.

Hard-bottom assessment:

Bayesian models were built for predicting the status of macroalgae, macrofauna, and macroalgae + macrofauna, within hard-bottom substrata of the Basque coast (Bay of Biscay, north Atlantic), at different shore levels. All the analyses carried out were based upon the biomass data (dry weight per square meter of each taxon). The taxonomy of data was verified by means of the WoRMS (World Register of Marine Species, www.marinespecies.org) and ERMS (European Register of Marine Species; http://www.marbef.org/data/erms.php). A total of 288 samples were taken into account. Data was classified in the following shore levels: (i) Supralittoral zone (intertidal area, only covered by water in high tides); (ii) Midlittoral zone (intertidal area,

subjected to daily tides); (iii) Infralittoral zone (intertidal area, only discovered in very low tides); (iv) Subtidal zone depth 5-15 m; and (v) Subtidal zone depth >15m. However, from the supralittoral zone a low number (9) of samples was available and therefore this data was excluded. As an example of the work done, we include here the Bayesian model based upon macroalgae and macrofauna, within the midlittoral zone.

The response variable (status) included two classes: 'high-good', 'moderate-poor' status. The selected variables (i.e., those variables that better predict the status) were:

- H' [Plantae]
- Average taxonomic distinctness (Presence/Absence) [Plantae, Bacteria and Chromista]
- Total Phylogenetic diversity [Arthropoda]
- Total taxonomic distinctness (Presence/Absence) [Plantae]
- Average taxonomic distinctness (Presence/Absence) [Mollusca]
- Total taxonomic distinctness (Presence/Absence) [Mollusca]
- Variation in taxonomic distinctness (Presence/Absence) [Rhodophyta]

Regarding to the performance of the model, the accuracy was of 73.9 ± 2.1 and the Brier score was of 0.10 ('excellent' performance).

Uncertainty analysis

Data from the Basque monitoring network was used for an uncertainty analysis of methods used in the assessment. The dataset included M-AMBI values calculated from soft-bottom macroinvertebrate data from 1995 to 2011. Using 683 data from 48 sampling stations, 4 coastal water bodies and 14 transitional water bodies were assessed. Uncertainty associated to spatial and temporal variability was assessed, focusing on between stations variance within water bodies and between years variance within assessment period (samples were taken annually, but ecological status was assessed every three years). The total variance and variance components associated to each factor were estimated for all indices using a linear mixed effects model in the nlme package of R (Version 3.1-103, R Core Team, 2012), treating "Year" and "Station" as random factors. Variance components were determined by calculating the proportion of the total variance explained by each individual factor. Then, the uncertainty in ecological status classification was estimated using WISERBUGS (WISER Bioassessment Uncertainty Guidance Software®). The results show that the main source of uncertainty is the between stations variance (98%). Variances were included in WISERBUGS in order to test the uncertainty associated to different sampling strategies, varying the number of stations per water body (from one to six) and the number of sampling years per assessment period (from one to three).

Other studies

WISER has developed other studies, including the recovery of a variety of estuarine and coastal ecosystem components (Borja *et al.*, 2010).

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Annex 7: Other species terms in ecology related to Keystone Species

Excerpted Verbatim From Wikipedia [http://wikipedia.org/wiki/]

Keystone species: Some species, called a *keystone species*, form a central supporting hub in the ecosystem. The loss of such a species results in a collapse in ecosystem function, as well as the loss of coexisting species. The importance of a keystone species was shown by the extinction of the Steller's Sea Cow (*Hydrodamalis gigas*) through its interaction with sea otters, sea urchins, and kelp. Kelp beds grow and form nurseries in shallow waters to shelter creatures that support the food chain. Sea urchins feed on kelp, while sea otters feed on sea urchins. With the rapid decline of sea otters due to overhunting, sea urchin populations grazed unrestricted on the kelp beds and the ecosystem collapsed. Left unchecked, the urchins destroyed the shallow water kelp communities that supported the Steller's Sea Cow's diet and hastened their demise. The sea otter is a keystone species because the coexistence of many ecological associates in the kelp beds relied upon otters for their survival.

Ecosystem engineers: Any organism that creates or modifies habitats. Jones *et al.* (1994) identified two different types of ecosystem engineers:

Allogenic engineers modify the environment by mechanically changing materials from one form to another. Beavers are archetypal ecosystem engineers; in the process of clearcutting and damming, beavers alter their ecosystem extensively. Different types and numbers of other organisms will thrive in the region of a beaver dam than would in a non-dammed region. Caterpillars that create shelters from leaves are also creating shelters for other organisms which may occupy them either simultaneously or subsequently.

Autogenic engineers modify the environment by modifying themselves. As trees grow, their trunks and branches create habitats for other living things. In the tropics, lianas connect trees, which allow many animals to travel exclusively through the forest canopy.

Humans are very significant allogenic engineers, though this interaction is more studied in the field of human ecology.

Foundation species: In ecology, a foundation species is a dominant primary producer in an ecosystem both in terms of abundance and influence. Examples include kelp in kelp forests and corals in coral reefs.

Indicator species: An *indicator species* has a narrow set of ecological requirements, therefore they become useful targets for observing the health of an ecosystem. Some animals, such as amphibians with their semi-permeable skin and linkages to wetlands, have an acute sensitivity to environmental harm and thus may serve as a *miner's canary*. Indicator species are monitored in an effort to capture environmental degradation through pollution or some other link to proximate human activities.[5] Monitoring an indicator species is a measure to determine if there is a significant environmental impact that can serve to advise or modify practice, such as through different forest silviculture treatments and management scenarios, or to measure the degree of harm that a pesticide may impact on the health of an ecosystem.

Government regulators, consultants, or NGOs regularly monitor indicator species, however, there are limitations coupled with many practical considerations that must be followed for the approach to be effective. It is generally recommended that multiple indicators (genes, populations, species, communities, and landscape) be moni-

tored for effective conservation measurement that prevents harm to the complex, and oftentimes unpredictable, response from ecosystem dynamics.

Umbrella and flagship species: An example of an *umbrella species* is the Monarch butterfly, because of its lengthy migrations and aesthetic value. The Monarch migrates across North America, covering multiple ecosystems and so requires a large area to exist. Any protections afforded to the Monarch butterfly will at the same time umbrella many other species and habitats. An umbrella species is often used as *flagship species*, which are species, such as the Giant Panda, the Blue Whale, the tiger, the mountain gorilla and the Monarch butterfly, that capture the public's attention and attract support for conservation measures.