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Report of the Benthos Ecology Working Group (BEWG)

2–6 May 2011

Fort Pierce, USA

ICES
International Council for the Exploration of the Sea

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Executive summary

The Benthos Ecology Working Group (BEWG) held its 2011 meeting at Fort Pierce (FL, USA). The meeting was attended by 18 members, representing seven countries.

Due to the eruption of the Icelandic Eyjafjallajökull volcano and its consequent impact on the flow and organization of the BEWG 2010 meeting (see BEWG 2010 report), last year's meeting focused on the finalisation of ongoing activities, leaving ample time for discussing the possibilities for future BEWG initiatives. This year's meeting hence focused on plans for future collaboration within (and beyond) BEWG and as such assured the development of a renewed research plan for the BEWG.

This year's meeting was structured along three BEWG core business issues: climate change and benthos, benthos-related environmental quality assessment and marine habitat modelling and mapping. The group further discussed possibilities for future internal and external BEWG collaboration, commented on the report from the ICES Workshop on Marine Biodiversity and made suggestions for contributions to the ICES Marine Strategy Framework Directive Steering Group and the ICES Strategic Initiative on Area Based Science and Management.

Six introductory presentations on the impact of climate change on the marine benthos and an overview of the BEWG contribution to the ICES Viewpoint Paper on Climate Change set the scene for a continued elaboration of the Benthic Ecology Long-Term Series Network (BeLTS-Net), established by the BEWG in 2009. Being a network of long-term data set holders and scientists with a particular interest in long-term data set analysis, the BeLTS-Net aims at facilitating joint analysis of long-term data to further the understanding of temporal changes in marine ecosystems over larger spatial scales. BeLTS-Net specifically does not target data compilation, but stimulates a common analysis of individual long-term series. A first network product consists of a meta database of long-term data series on marine benthos throughout the ICES region and beyond. The North-American delegation volunteered to update this database, now populated with mainly Northeast-Atlantic datasets. Secondly, a state of the art report of the first BeLTS-Net research initiative to identify trends and regime shifts within the macrobenthos was presented and a research plan for further development was agreed upon. Finally, the BEWG was introduced to the work, ongoing under its Study Group on Climate related Benthic processes in the North Sea and focussing on the determination of the extent of the temporal variability with which a key ecosystem function (i.e. bioturbation) varies within and between years. As an extensive promotion of the BeLTS-Net is considered crucial, it was felt needed a BeLTS-Net website to be constructed and launched before the end of 2011.

Based on the lessons learned from seven presentations on recent developments in environmental quality assessment with special attention for North-America, a suite of possible BEWG research topics were listed. The group agreed to focus first on the investigation of species tolerance and its variability along environmental gradients. More specifically, this research project elaborate on the fact that species might exhibit a change in life history strategy and or their autecological requirements and consequently its sensitivity to pressures along distinct environmental gradients. A research plan, including the allocation of responsibilities and guiding principles for data selection, is presented.

After two years of increased BEWG interest in species distribution modelling and mapping (SDM), as demonstrated by six introductory presentations, the BEWG decided to write a review paper on SDM and its relevance for ecosystem management

in a marine realm. As SDM is relatively new to the marine environment, it is of particular importance to highlight possibilities, but also weaknesses and pitfalls when applying SDM to the marine environment and when evaluating its relevance to marine management. A paper drafting plan, including the selection of the main topics to be included, the allocation of responsibilities and time line, is presented. As SDM clearly is an initiative overlapping the expertise of both the BEWG and the ICES Working Group on Marine Habitat Mapping (WGMHM), contact with the WGMHM will assure the inclusion of its expertise in the review paper. Further elaboration of the collaboration between both Working Groups is ongoing as illustrated by the joint Theme Session at the ICES Annual Science Conference 2011, consisting of a 16 oral presentations time slot, completed with twelve poster presentations. The lessons learnt from this Theme Session will be used to further outline the potential for collaboration between both expert groups.

The BEWG further reviewed the report of the "Workshop on Marine Biodiversity (WKMARBIO): furthering ICES engagement in biodiversity issues" and considered its potential contribution to the ICES Steering Group on the Marine Strategy Framework Directive (SGMSFD) and the ICES Strategic Initiative on Area Based Science and Management (SIBAS).

The BEWG found S. Degraer prepared to continue as Chair of the group for an extra year, during which the Chair will (again) actively look for replacement.

The next meeting of BEWG will take place in Sandgerði (Iceland), 7–11 May 2011.

1 Opening of the meeting

The Chair, S. Degraer, opened the meeting at the Dockside Inn meeting room in Fort Pierce, Florida (USA) welcoming the participants with an introduction to the working of ICES and the Benthos Ecology Working Group. An ICES SharePoint site 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. Local host Bjorn Tunberg welcomed the group on behalf of the Smithsonian Institution followed up by relaying some housekeeping information. The participants then introduced themselves and gave a short review of their scientific activities. 18 participants (Annex 1) from seven countries attended the meeting (Belgium, Germany, Italy, Norway, Sweden, United Kingdom and United States). H. Hillewaert was appointed Editorial Rapporteur.

2 Adoption of the agenda

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

3 Benthos and climate change

3.1 Climate change effects on benthic communities

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

3.1.1.1 On the impact of ocean acidification on the benthos

S. Birchenough disseminated the national UKOARP research initiative and overview of the goals for the work. SB also provided details of work package 3.1 for sediment environments. The hypothesis for this work package is to test if *Future high CO_2 scenarios will have no significant impact on the functioning of sediment habitats.*

This work is in working progress and will integrate previous understanding gained from high CO_2 environments, field and lab experiments results from other work packages to provide an overview of the effect of OA on sediment functions. These data will be used to develop and test site specific or regional impact models of OA against baseline sediment functions. Site specific and regional knowledge of assemblage distributions, combined with site specific or experimental impact / sensitivity models will allow predictions of OA regional effects within a shelf sea area such as the North Sea and provide greater understanding of overall impact of OA on benthic assemblages and sediment nutrient / carbon cycling.

Datasets available from this, previous and aligned studies (Transacid, BIOACID, EPOCA) will be collated and synthesized via meta-analysis to derive empirical or logic based synthesis and models of the effects of OA on faunal species and sediment function.

3.1.1.2 Long-term dynamics of zooplankton, benthos, and nekton in a high salinity Southeastern US estuary

Presented by D. M. Allen

North Inlet, a high salinity, salt marsh dominated, barrier island built estuary on the northern coast of South Carolina, has been the site of continuous measurements of more than 100 physical, chemical, and biological variables for more than 25 years.

Because nearly all of the watershed surrounding the estuary is in its natural forested state and 40–50% of the water volume is exchanged with the coastal ocean with each tide, water and habitat quality are excellent. Without local impacts, long-term changes in conditions within the estuary can be interpreted as reflecting broader forcing functions, especially climate change and variability.

A significant positive increasing trend was documented for water temperature from 1979–2010 with an estimated change of about 0.9°C. The estimated change in winter water temperature has been about 1.7°C, which is about a 15% increase over levels in the 1980s. The long-term mean salinity was 32, but periods of depressed salinity occurred during El Nino events which bring increased rainfall in winter and spring. Two size fractions of zooplankton were collected biweekly from 1981–2008 and each showed a different long-term pattern. Large mesozooplankton were collected biweekly with a 365 μ mesh epibenthic sled in a subtidal channel. No long-term trend was observed, but decreases in abundance reflected decreases in salinity when it was lowered by ENSO events during the cool season or lowered by higher than average local rain and tropical storms in summer- fall. The high frequency and magnitude of these events from 1991–2005 changed the channel bottom habitat (loss of sessile high salinity invertebrate "live bottom"), which corresponded to lower densities of peracarid crustaceans, larval decapods, and larval fishes. However, an increasing trend in the 365 μ assemblage has been observed since the last major El Nino event in 2005. Oblique collections with a 153 μ mesh net at the same time and location revealed a significant long-term decrease with about 35% fewer organisms (a reduction from about 18 000 to 11 000 m^{-3}) occurring in the water column in recent years. The decline in 16 of 17 major taxa in this copepod dominated assemblage was not correlated with temperature or salinity, but a significant positive relationship was observed with water column chlorophyll, for which a significant long-term decrease has occurred over the past 28 years. Decreasing chlorophyll was correlated with reduced discharge by the largest river supplying nutrients to the adjacent coastal ocean. No long-term change was observed in total macrobenthos and most constituent taxa (cores from muddy shallow subtidal site, sieved with 500 μ mesh) since 1984, but a significant negative correlation with chlorophyll was determined. This could reflect the inverse relationship between water column and microphytobenthos chlorophyll, benthic algae being more important food sources for most infauna taxa. Macrobenthos abundance peaked in the winter and was grazed down considerably each spring with the arrival of small benthivorous fishes from the ocean and the increase in resident predator consumption of benthos within the estuary. Significant positive relationships between water temperature and the timing of the larval ingress of certain shrimps and fishes, and the timing of first, peak and/or last occurrence of larval production by some resident species, indicate phenological responses to climate change. Although major changes in the composition of the zooplankton, benthos, and nekton assemblages have not occurred over the past 25 years, the demonstrated sensitivity of at least some key taxa to factors that can be influenced by changing climate suggests that changes in abundance, composition, and food web structure can be expected.

3.1.1.3 Detecting climate change effects using long-term benthic data along the Texas Coast

P. A. Montagna reported

Climate change will affect terrestrial and aquatic systems differently. On the land side we can expect precipitation change, which will drive change in sediment discharge and hydrological flows. This in turn will affect basins, geo-environments, salinity, and habitats. On the coastal ocean side, we can expect sea-level rise, hydrodynamic change, habitat change, temporal dynamics of water quality change, and interactions with salinity, temperature, and acidification. There is already evidence of change in the instrumental record for: temperature, precipitation, water quantity, water quality, sea-level rise, flooding, habitats, diversity, and productivity (Tolan 2007).

The Texas coast is likely to experience severe climate change impacts because of a synergy between the regional climate regime and the coastal geology (Montagna *et al*. 2007). Lying between about 26° and 30° N latitude, the Texas coast is already in a relatively warm climate zone and subject to very high rates of evaporation. Thus, potential changes in rainfall or temperature will have great impacts on the Texas coastal hydro-cycle. The Texas coastal plain is relatively flat and low-lying, and the Texas coast has one of the highest rates of subsidence in the world (Anderson 2005). Thus, changes in sea-level will be exacerbated on the Texas coast because the land is relatively flat and it is rapidly sinking. The combined effects of these changes can affect the physical and biological characteristics of the Texas coast dramatically.

In one of the earliest discussions of the potential impacts of climate change along the Texas coast, Longley (1995) focused on potential changes in habitat area that might result from changes in precipitation and concomitant changes in freshwater inflow to bays and estuaries. Other authors have focused on sea-level rise (Zimmerman *et al.* 1991) or temperature change (Applebaum *et al*. 2005). In addition, Twilley *et al*. (2001) provided a comprehensive assessment of climate drivers, such as changes in temperature, rainfall, freshwater resources, and sea-level rise, and the consequences of human activities as they act in concert with climate change effects.

If the Texas coast is indeed exceptionally susceptible to climate change effects, then there must be both physical and biological indicators of change. Temperature change itself, is an obvious indicator. Salinity is an indicator of changes in the fresh water cycle, because it dilutes sea water when it flows to the coast. It is also possible for indirect changes of water quality to occur because oxygen is less soluble in hotter, saltier water. Thus, the temporal dynamics of water quality change is also an indicator. Species that are sensitive to changes in any one or more of these physical factors, or reside at the edge of their distribution range are indicator species.

In the context of climate change, the indicator species are sensitive to either temperature, salinity, or elevation changes. One potential indicator species is the black mangrove (*Avicennia germinans*), because its distribution and survival in Texas is limited by winter temperature (Sherrod and McMillan 1981). Other indirect effects include explicit links between temperature and water quality and change in biotic responses. The earlier habitat change analysis conducted by Longley (1995) assumed only inflow rates will change, but rising sea levels may obliterate these effects. Therefore attention to effects of sea-level rise is critical. In the current study, focus is on identifying changes in the instrumental record (for both water and habitats) to determine if there are trends in recent long-term records of water temperature and quality, mangrove habitat cover, and sea level rise.

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 may 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.

While earlier studies focused on how rainfall and consequent freshwater inflow changes might alter systems, there is no evidence in the recent instrumental record that salinities are changing along the Texas coast. Focus should be placed on adaptation to hydrological changes in climate. This would include better coastal planning so that human activities account for changing coastlines and habitats, and more concern about nutrient reductions. If climate change drives down dissolved oxygen concentrations, then the only recourse to adapt to this condition will be to put further controls on nutrient additions to coastal waters.

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3.1.1.4 Long-term development of the phytobenthic epifauna communities in the Baltic Sea area

Presented by H. Kautsky

Most of the presented results were based on data collected within the Swedish national monitoring programme financed by the Swedish EPA. A brief résumé was given of the long-term changes of the vegetation (i.e. *Fucus vesiculosus*) in the Baltic Sea. In the Gräsö-area, between the years 1944 and 1984, *Fucus* in the Åland Sea decreased in its maximum depth distribution and coverage by 3 m and a corresponding shift upward of the max coverage. Revisits of the stations in 1992, 1996 and 2006 showed a gradual increase again of the depth extension of *Fucus* in the area, and today it goes as deep as in the 1940s. Thus, the system seems to be back to the baseline of non-polluted areas. The trend of increased depth distribution of *Fucus* was also observed in the Askö area, northern Baltic proper. Here, the maximum depth of *Fucus* since the 1970s has increased from max 6 m to 8–9 m depth. In total, 30 stations are monitored annually since 1993. On a 10-station average, representing the inner, middle and outer archipelago area, Fucus increased its depth distribution with 1 m from 1993 to 2010. Also, WFD- EQ-values (in Sweden based on about 30 plant species max. depth distribution, where at least 5 should be present at the site) have increased significantly in the area. The EQ-values are also high for the Bothnian Sea and waters around the Island of Gotland.

The improved depth distribution of the plant communities was set in relation to a decrease in nutrients and pelagic spring primary production, which is reflected in an increase of the Secchi-depth the last decade. The decrease is expected to be reflected in the other organisms that are said to be dependent on e.g. nutrient contents and pelagic production.

The filter feeding blue mussel (*Mytilus edulis*) is the totally dominating animal in the Baltic proper phytobenthic system. It constitutes ca. 90 % of the total animal biomass. As a filter feeder it is dependent on the organic matter in the water column. As primary production decreases it is expected to decrease. At five out of the six stations in the Askö area it decreases (significant trend at three of them). The decrease is most pronounced in the inner archipelago area. The decrease is indicating a reduction in the eutrophication in the area.

The filamentous algae are expected to decrease with the decreased nutrient load. This is not the case. There is a significant increase since 1993, based on the trend line of biomass in the three sub-regions in the Askö area. An explanation for this could be the overfishing of top predators (cod) increasing intermediate predators which predate upon the herbivorous species, thus increasing algal growth. However, the herbivores have also increased significantly in the area. We have to find alternative explanations or analyse the data in more detail on the species level.

The detritivores have a consistent development as *Mytilus* in the area, where the decrease is significant on 4 of the six stations visited. This also confirms improved conditions in the area.

If we look to the filter feeders except *Mytilus edulis*, they partly show a significant increase in the area. This again contradicts the expected decrease of pelagic production dependent organisms. But this significant increase was mainly caused by a successful recruitment of the cockle (*Cerastoderma glaucum*). The increase occurred after an unusually warm summer around 2003, which favoured their reproduction as millions juvenile specimen could be seen in autumn and the following seasons. The cockle seems to be favoured by warm water, and probably increases in the Baltic Sea with climate change.

3.1.1.5 Acquisition and Application of Large Benthic Data Sets for the Pacific Coast

Presented by Walter Nelson

The Pacific Coastal Ecology Branch (PCEB) of the US EPA has conducted several research programs of relevance to BEWG. PCEB was the lead laboratory for the US EPA National Coastal Assessment (NCA) program on the US West Coast. The project developed methods and approaches, and implemented the assessment of new components of coastal resources (intertidal wetlands, near-coastal waters) not previously incorporated in the NCA which had been focused on estuarine open waters. The Western Regional program began with a two year assessment (1999/2000) of estuarine condition for the states of Washington, Oregon and California. The estuarine intertidal areas, including low emergent marsh habitats, of these states were sampled in 2002. In 2003, an assessment of condition of the continental shelf of these three states was conducted. This was followed in 2004 with a reassessment of estuarine condition largely equivalent to the 1999/2000 survey. The final NCA assessment of the estuaries of these three states was conducted in 2005/2006, with sampling effort divided approximately equally between the two years. The Western Regional NCA has generated the first comprehensive, probability based data set which may be used to describe the condition of soft sediment benthic resources across the bathymetric gradient from low salt marsh to 120 m on the continental shelf. The databases from these studies include 1217 benthic sample sites over an eight year period. Additional assessments were conducted in Hawaii, along multiple sections of the subarctic Alaskan coastline, and for the Pacific Islands of Guam and American Samoa.

Most of the NCA data from the Pacific states, as well as that for the Atlantic and Gulf Coast states, is available to download on line from the EPA Environmental Monitoring and Assessment Program (EMAP) web site http://www.epa.gov/emap/. The results of the NCA program are presented in a series of National Coastal Condition Reports which are available from: http://www.epa.gov/owow/oceans/nccr.

A thorough training website provides the background on the probability based sampling designs used by NCA and other components of EMAP: http://www.epa.gov/nheerl/arm/. Further information is available from Walt Nelson (nelson.walt@epa.gov).

PCEB has also compiled a benthic community and sediment condition database for the US West Coast which spans the period 1987–2007, with a similar geographic coverage for estuaries and near-coastal waters of the states of Washington, Oregon, and California. The database captures data for benthic species, sediment contaminants, sediment toxicity, salinity, sample depth, pH, sediment TOC and percent fines. Species names have been standardized across all data sets included in the database. The database includes 4413 benthic grab samples from 77 estuaries and the continental shelf of the west coast and includes data on some 2300 species. Further information is available from Dr. Melanie Frazier (frazier.melanie@epa.gov) or Dr. Henry Lee (lee.henry@epa.gov).

The third large database available at PCEB is the Pacific Coast Ecosystem Information System (PCEIS). PCEIS is an interagency collaboration with the US Geological Service (USGS), with cooperation from the North Pacific Marine Science Organization (PICES). Over the last several years, the EPA and USGS have developed an ecoinformatics framework and database to synthesize natural history information at regional scales. The PCEIS database allows analysis of native and non-indigenous species' distributions at different biogeographic scales. These spatial scales use modified coastal ocean classifications based on "Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas" by Spalding *et al*., 2007. The existing Access database was designed to evaluate non-indigenous species in the North Pacific, and it is in the process of being modified to better capture climate related attributes. The database will be migrated to the web. The database is currently in a beta version which is available for review. Contact Dr. Henry Lee (lee.henry@epa.gov).

3.1.1.6 Workshop announcement: The Ecological Implications of Climate Change on the Venice Lagoon

A UNESCO workshop was held in Venice 26–27 May 2011, the scientific part being organized by the CNR. This workshop intends to bring together a limited group of experts to discuss possible ecological scenarios for the lagoon of Venice in the light of the climate change projected for the end of this century. The workshop would like to shed some light on the possible future responses adaptations of the Venetian lagoonal ecosystem to future scenarios, taking examples from existing "warmer" lagoons. This workshop could be linked to climate change-related initiatives of ICES-BEWG, giving a special focus on climate change in coastal transitional waters (estuaries, lagoons) and its effects on lagoon benthos.

See programme at http://www.unesco.org for further details.

3.1.2 Explore the availability of long-term benthos datasets in US and Canada and consider links to the BEWG Benthos Long-Term Series Network (BELTS-net)

BELTS-Net (Benthic Ecology Long Term Series Network) is an initiative developed by the BEWG in 2009 and further developed by the SGCBNS and BEWG in 2010. The initiative is open to all scientists with an interest in joint long term series analysis. The aims of BELTS-Net are:

- to bring scientists together to jointly analyse data series, as such facilitating a joint analyses of marine benthic long term series.
- to further the understanding of temporal changes in marine ecosystems over larger scales and the effects of climate change, as such allowing for more general conclusions beyond regional results from single long term series.

To elucidate the difference of this initiative with many other long term series and/or geographically wide scale networks (e.g. MARBEF's LargeNet and Marine Environmental Change Network), it was clarified that this is a North-Atlantic initiative focusing on joint analyses in function of particular research questions (for an example: see 3.1.3), and not on the collection of long term data within a common database for analysis. In other words, BELTS-Net specifically does not target data collection. It is however important to also inform colleagues from these networks about the BELTS-Net initiative: A. Schröder is asked to take the appropriate action here.

As a first task within BELTS-Net an overview table with long-term data series on marine benthos has been compiled. A first list, as compiled during the BEWG 2009 and 2010 meetings, was very much skewed towards the North-East Atlantic. It was however stressed that the project does not necessarily focus on the North Sea or EU waters, but is open for a geographically much wider scope. Making use of the wide North-American expertise available during the meeting, it was agreed to update the list of European long-term data series on marine benthos with meta data on long-term series for the USA. From a preliminary screening it became clear that actions on long term series have also been recently launched in the USA and that further information and communication about BELTS-Net is needed.

BEWG decided that the further steps to be taken within BELTS-Net should first focus on communication and information about the network.

A first urgent action for BELTS-Net is the construction and launch of the website. A document with the context of the website from the BEWG 2010 meeting is available on the SharePoint site. It was decided to have both a public section of the website and a members only section. The former could be used to inform the public about BELTS-Net, its goals and its finalised and ongoing initiatives. The public section of the site should further provide background on who we are and what we are doing. Information on existing long term series (meta data) and an invitation for people to contribute and take contact should also be available in the public section. The members only section should be considered a working space for collaborative research and could take the form of a SharePoint site, where people, engaged in a particular initiative, can exchange information.

S. Degraer will invite VLIZ to construct and host the website. The facilitator of an initiative is however responsible for the information delivery and subsequent update, whenever needed.

An update of the BELTS-Net initiatives will be added to the ToR list of the SGCBNS meeting in October 2011.

3.1.3 Consider the status of the intersessional BEWG work on long-term data series analyses with special attention to climate change and to decide on future actions

S. Birchenough reported on a discussion document developed in collaboration with C. Van Colen to continue with the planning of the regime shift initiative.

The main objective of this BELTS-Net initiative, started in 2009, is to identify European-wide trends and regime shifts within the macrobenthos based on the common analysis of long term data series throughout European waters (see 3.1.2).

Contributors

- S. Birchenough (UK)
- A. Schröder (Germany)
- M. L. Zettler & A. Darr (Germany)
- S. Degraer, C. Van Colen & G. Van Hoey (Belgium)
- A. Borja (Spain)
- B. Tunberg (USA)

Decisions taken

- The subgroup already agreed on the information that was initially needed to assess patterns of change of annual values of the following parameters: abundance; biomass, species density (number of species per sample), species richness (ES50) Shannon diversity (log e) and Pielou's evenness;
- Community analysis: inter-annual similarity (Bray Curtis similarity measures, based on 4th root transformation of data sets);

- Identifying overall patterns (e.g. initially by MDS) and relating this information to existing published literature, which explains 'shifts' on specific areas.

Way forward

- Intersessional work will continue during 2011;
- A discussion document was developed by C. Van Colen and S. Birchenough and it was circulated for comments (Annex 6);
- A plan for future activities will be developed in consultation with all participants. S. Birchenough and C. Van Colen will take the initiative.

Plan/suggestions for the work

- Analyse the trends in macrobenthic community structure in relation to climate change throughout the North Atlantic;
- Use this knowledge to forecast changes in the benthos according to the various climate change scenarios;
- Prepare a publication with initial results.

3.2 Consider the 2010/2011 work of the Study Group on Climate-Related Processes within the Benthos of the North Sea (SGCBNS) and to formulate recommendations regarding its future actions

Presented by S. Birchenough and H. Reiss

The Study Group organised a meeting at Plymouth Marine Laboratory during 16-18th February, 2011 to start working on the case study 1 (CS1). This case study was developed as agreed at the last meeting held in Lowestoft in 2010.

Objective

To determine the extent to which a key ecosystem function (bioturbation) varies within and between years. To achieve this we will use a number of temporal reference datasets using macrofauna abundance and biomass, to answer the following four questions.

Does the potential for community level bioturbation vary over the course of a year?

If so, which species or traits are most responsible for this observed variation?

Does the strength and nature of any variation observed in an area depend on the geological location or the sediment characteristics or disturbance events?

Are observed patterns of intra-annual variation significant and are they conserved from year to year?

The contributors for this case study 1 (in alphabetical order) were: S. Birchenough, J. Bremner, J. Godbold, R. Parker, A. M. Queirós, A. Romero Ramirez, H. Reiss, A. Schröder, M. Solan, P. Somerfield, G. van Hoey, S. Widdicombe.

The following Terms of References were addressed during the meeting:

ToR a) Agreement about data policy for the CS1

ToR b) Compiling and analysing the processed data for CS1/ICES support share point

ToR c) Preparation of a publication based on the results and outline of a time table for finalising CS1

ToR a)

All participants agreed on the "Declaration of Mutual Understanding".

ToR b)

All data contributors provided on overview presentation of their study sites, these areas covered from the west coast of Ireland to the south-eastern North Sea.

Data preparation was carried out by compiling the species lists of the different data sets and by generating a master species list containing the bioturbation categories (as developed by Solan *et al*., 2004) for all species based on the following criteria for mobility (M_i) and reworking mode (R_i):

Mobility Mi

- 1 = in a fixed tube
- 2 = limited movement, sessile, but not in tube
- 3 = slow movement through sediment
- 4 = free movement via burrow system

Reworking mode R_i

- 1 = epifauna that bioturbate at the sediment-water interface
- 2 = surficial modifiers, whose activities are restricted to <1–2 cm of the sediment profile
- 3 = head-down/head-up feeders that actively transport sediment to/from the sediment surface
- 4 = biodiffusers whose activities result in a constant and random diffusive transport of particles over short distances
- 5 = regenerators that excavate holes, transferring sediment at depth to the surface

The master list was uploaded on the share-point (SGCBNS 2011) and was used by all data providers for calculating the bioturbation potential. The master list will be further distributed among the other CS1 contributors and will be made public at the end of the Study Group activities.

ToR c)

The details of the planned publication on temporal variation in bioturbation can be found in the Study Group report. The results section of this draft will be completed until the annual meeting of the SGCBNS in October 2011, where the work will be continued and responsibilities for further contributions will be appointed.

Approach

A total of 16 data were identified for this work. Each data set contained estimates of macrofauna abundance and biomass. For each species in each replicate sample were calculated an index of bioturbation using the methods described in detail by Solan *et al*. (2004). In summary, the index was calculated using equation 1 and uses three biological traits known to influence sediment bioturbation: (i) mean body size (B_i, usually biomass in grams), (ii) extent to which the organism moves through the sediment (M_i), and (iii) method of reworking sediments (R_i).

$$BP_i = B_i\ 0.5 \times M_i \times R_i \qquad (Equation\ 1)$$

M_i and R_i were scored on categorical scales that reflect either increasing mobility (M_i) from 1 (living in a fixed tube) to 4 (free movement via burrow system) or increasing sediment turnover (R_i) from 1 (epifauna that bioturbate at the sediment-water interface) to 5 (regenerators that excavate holes, transferring sediment at depth to the surface).

For each species in each replicate sample BP_i was multiplied by its abundance (A_i) to determine the "population-level" bioturbation potential (BPp) of that species in that sample ($BPp = BP_i \times A_i$).

BPp values were then summed across all species in a sample to estimate the "community-level" bioturbation potential for that sample ($BPc = \sum BPp$).

A series of univariate and multivariate and analyses were planned to determine:

- The magnitude of intra-annual variation in BPc within each of the separate datasets;
- The identity of the species who, through changes in their BPp between sampling dates, contribute most to any variation observed in BPc;
- The degree to which intra-annual variation in BPc is consistent across habitat types and geographic locations;
- The relative importance of intra- versus inter-annual variability in BPc.

At this stage the first analyses and graphs needed were as follows

Seasonal changes

- BPc vs. Time (scatter plot of replicates)
- CV of BPc vs. Time (CV= SD/mean)
- Species richness vs. Time
- Evenness J (abundance) vs. Time
- Evenness J (biomass) vs. Time

Other exploratory graphs

- BPc vs. Species richness
- BPc vs. Total abundance
- BPc vs. Total biomass
- CV of BPc vs. Species richness
- BPc vs. Evenness J (abundance)
- BPc vs. Evenness J (biomass)

The initiative is still open to participants wanting to join this case study please contact S. Birchenough (silvana.birchenough@cefas.co.uk) or H. Reiss (henning.reiss@uin.no).

Recommendation and comments were made following the presentation

- The impact of fisheries in the study area should be taken into account considering differently impacted sites. The BPc (bioturbation potential of a community) based on the community composition and biomass, irrespective of possible impacts, is what is looked at. However general trends and possible links to climate change, if at all present, can as yet not be determined.

- Tackling bioturbation potential and vulnerability in the North Sea requires (i) assessment of spatial patterns in the North Sea in relation to habitat and environmental variability, and (ii) to investigate potential vulnerability of BPc to climate change across the North Sea.
- Benthic productivity (i.e. annual production) should be calculated using seasonal data obtained in case study one.
- Different extinction scenarios should be simulated by using models to see how benthic function is affected.
- Trait analysis is to be performed to determine adult/larval dispersal potential.

Due to workload and time restrictions of the group members, it is proposed that students could be involved in the various initiatives (e.g. thesis projects).

3.3 BEWG contribution to the ICES Position Paper on Climate Change: State of the Art and reedit for submission to WIRES climate change as a review for publication

The BEWG contribution to the ICES Position Paper on Climate Change is now accepted for publication and submitted to the ICES Editorial Office.

This review provides an assessment of the effects and mechanisms causing changes to the benthos (benthos by definition encompassing all the organisms living in/on the seabed; epifauna and infauna), which may be interlinked with climate change. The chapter reports on the current peer-reviewed literature and also considers areas where research gaps exist.

Direct evidence of climate change-related impacts on the marine benthos is still largely lacking, but information from other research areas, relevant in a context of climate change and variability, provides circumstantial evidence of climate change effects. Three main issues are addressed: (1) the relationship between physical aspects of climate change and the marine benthos; (2) the possible integrated impact of climate change on the benthos based on relationships with proxies for climate variability; and (3) the interaction between climate change- and human activity-induced impacts on the marine benthos.

1) The investigation of the relationship between the physical aspects of climate change and the marine benthos focuses on: (1) responses to changes in seawater temperature (biogeographic shifts, phenology, parasites), (2) altered hydrodynamics, (3) ocean acidification, and (4) sea level rise-coastal squeeze (Figure 8.2 of the paper).
2) Lessons learned from the relationship between the North-Atlantic Oscillation Index (NAOI), as a proxy for climate variability, and the marine benthos provide further insight into the possible integrated impact of climate change on the benthos.
3) As climate change might also modify human activities in the marine environment, indirect effects on the benthos are also to be expected. This section details interactions between climate change and impacts induced by human activities.

The chapter is concluded with the identification of knowledge gaps and research needs, as taken from the literature review.

No further changes can be made to this ICES Position Paper, which will be published as an ICES Cooperative Research Report. The BEWG however adopts the suggestion to try to publish a condensed version of the chapter in the WIRES journal "Climate Change". As such some new information (e.g. North-West Atlantic examples and deep sea coral gardens) and changes are still welcomed. S. Birchenough already took contact with the journal's editorial board, who thought the contribution could be of interest to their readership and invited the BEWG to submit a manuscript soon.

S. Birchenough will take the lead in the finalization of the manuscript. All participants were invited to have a look at the final version of the chapter, as well as to make suggestions for a final fine tuning and completion of the manuscript.

4 Benthos-related quality assessment

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

4.1.1 Saprobity in Coastal Transitional Ecosystems: An overlooked aspect of ecosystem functioning?

P. Magni reported

In the context of environmental quality assessment of coastal transitional ecosystems, we delineate the concept of habitat saprobity as a state of an ecosystem resulting from numerous processes of organic matter (OM) metabolism (Tagliapietra *et al.*, submitted). We review and expand upon classic conceptual models describing the succession of benthic communities along a gradient of organic enrichment (e.g. Pearson & Rosenberg, 1978; P-R) or confinement (e.g. Guélorget & Perthuisot, 1983; G-P). Similarities between different approaches and models are highlighted, whereby the P-R and the G-P models are unified under a single conceptual framework. Based on a critical analysis of existing models and indices, we propose a general framework where the processes of OM metabolism are a major structuring factor the benthic communities in coastal lagoons, and saprobity is used as a state descriptor of these processes. We assume that saprobity cannot be quantified by considering only the amount of OM *per se*. In fact, saprobity is the result of both input of OM and other processes, such as mineralization, burial, dilution and export of OM. The same organic input can, therefore, generate different degrees of saprobity in different systems and in different areas within a system. In addition, saprobity acts on benthic communities together with other components of the transitional gradient, such as salinity and sediment type. Due to difficulties to quantify saprobity itself, we foresee the use of benthic communities and the memberships of dominant species to different saprobic groups, as indicators of habitat saprobity.

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4.1.2 Development of Ecological Quality Objectives for threatened and/or declining habitats (TDHs): OSPAR Biodiversity Committee (BDC) & Experiences from MAREANO mapping sensitive habitats in Norwegian waters

L. Buhl-Mortensen reported

Spatial information is essential for management of natural resources, including biodiversity and vulnerable habitats (TDHs). Sensitive habitats are commonly characterised by the presence of habitat forming species that clearly can be affected by anthropogenic stressors such as fishing activities or pollution. Most habitat classification schemes are constructed to enable production of continuous maps and the OSPAR classification of TDHs provides maps of discrete patchy areas. However, the definition of the TDHs is still in development and does not enable direct comparisons of the distribution of such habitats between countries. The existing classes are too few, and some lack a clear definition which can complicate management of sensitive areas. Furthermore the definition needs to take into account what state(s) of the habitat can be viewed has healthy or impacted. It is of limited us to management to know the distribution of TFHs if there is no information on health status. At present OSPAR operates with 16 TDHs.

The MAREANO-program (www.mareano.no) has been mapping bottom communities in the varied marine environment off Norway since 2005. Results show that the OSPAR habitat classes are defined to widely to secure the protection of unique and threatened communities. It is in particular the TDHs: deep-sea sponges, corals gardens and, sea-pen and burrowing megafauna communities that needs more precisely defined classes. Results from MAREANO shows that these TDHs are present with very different key species depending on depth and environmental setting. Lumping these communities together in coarse classes risks that vulnerable and unique species and communities can disappear without being accounted for. Thus, off Norway there are several coral gardens dominated by very different species and there are at least two distinct sea-pen and sponge communities. The MAREANO results are at present communicated to OSPAR to improve the possibility for the TDHs classes to provide a relevant picture of the distribution and state of sensitive habitats.

OSPAR is at present developing EcoQOs for the TDHs. For this a clear definition of the TDHs and their health status is crucial.

The general EcoQOs for TDHs are:

1) Restore and/or maintain the areal extent of the habitat;
2) Restore and/or maintain the quality of the habitat (e.g. water and sediment quality, condition of defining species, species composition, ecological functions).

The quality of a habitat can involve three main components:

1) Habitat-forming or otherwise dominant species;
2) Other species contributing to the habitat specific community;
3) Physical aspects of the habitat (e.g. oxygen, sedimentation, silting, etc.).

To map the extent of a TDH we need to know how many organisms (abundance and/or coverage per m^2) and in what combination is needed for the habitat to be viewed as present. This definition is lacking for the TDHs. In addition to evaluate the quality of the TDHs we need to know the variation in abundance and composition that is represents a healthy undisturbed state. However, the difference between quantity and quality of a habitat is not always distinct and this is particularly the case for density aspects of habitats. A mussel bed may consist of a dense mat of mussels or patches of mussels with exposed sediment substrate in between. Based on field observations from video recording along 700 m long transects MAREANO are delivering abundance for key species in sensitive habitats. These registrations will together with similar information from other mapping activities provide important information needed for a clear definition of OSPAR habitats and condition indicators.

4.1.3 Assessing benthic health in stressed subtropical estuaries, eastern Florida, USA using AMBI and M-AMBI

B. Tunberg reported

The Indian River lagoon (IRL) and the St. Lucie Estuary (SLE) are affected by a variety of anthropogenic pressures. Benthic macro-invertebrates have been monitored quarterly since early 2005, at 15 sites, in order to assess benthic health. Since the SLE and IRL are situated in a subtropical area, it is affected by two major climatic seasons, dry (winter) and wet (summer). This contribution investigates the application of the AZTI's Marine Biotic Index (AMBI) and multivariate-AMBI (M-AMBI), to assess the ecological status of these estuaries. AMBI was firstly calculated after assigning most of the previously unassigned species to each of the five ecological groups. Three main benthic assemblages, associated to oligohaline, meso-polyhaline and euhaline stretches, have been identified (Figure 1). Reference conditions of richness, Shannon's diversity and AMBI have been derived for these assemblages; M-AMBI has then been calculated. Both methods show that the inner part of the SLE is affected by anthropogenic pressures (increased freshwater inflow, elevated nutrient input, and sedimentation), whilst the IRL is less affected. We have demonstrated that AMBI is insensitive to the dramatic seasonal changes occurring in the SLE/IRL. At some of the stations a significant positive trend has been identified, linked to the water discharges. The use of both tools seems to be promising in assessing benthic health in this area.

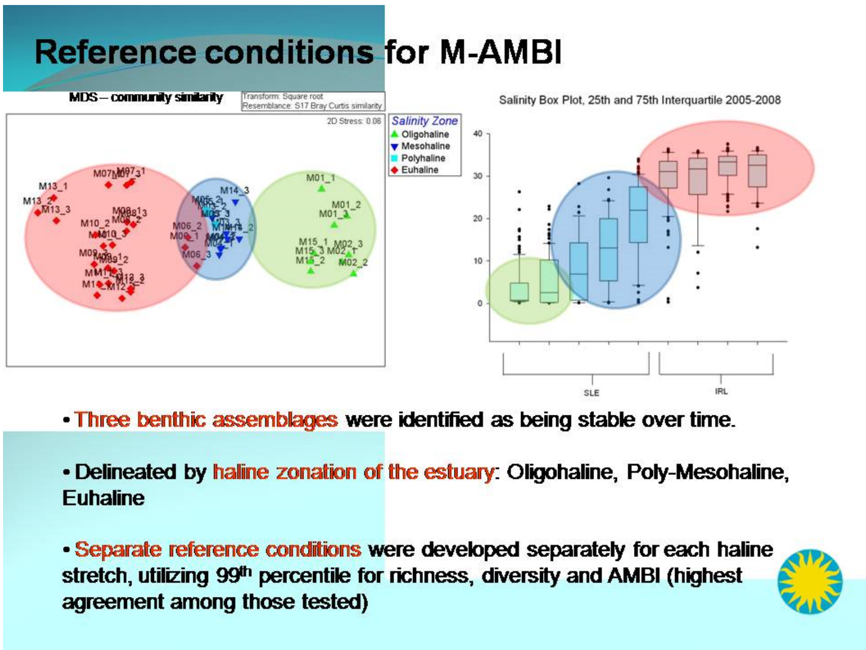

Figure 1. Reference conditions for M-AMBI.

It was pointed out that the change in sensitivity of a single species according to a salinity gradient has been demonstrated and that it is difficult to disentangle natural stress from anthropogenic stress.

4.1.4 Assessing the ecological status within European transitional waters (northeast Atlantic): intercalibrating different benthic indices

G. Van Hoey reported on work done by A. Borja, G. Van Hoey, G.Phillips, M. Blomqvist, N. Desroy, K. Heyer, J.-C. Marques, I. Muxika, J. Neto, A. Puente, J. Germán Rodríguez, J. Speybroeck, M. Dulce Subida, H. Teixeira, W. van Loon, J. Witt

The Water Framework Directive (WFD) has developed several methods to assess the benthic status of European marine waters. The WFD implementation requires the intercalibration of such methods, in order to ensure that the status classification is consistent and comparable across countries and waterbody types. A working group of 9 countries (Portugal, Spain, France, Belgium, Netherlands, Germany, Sweden, Ireland and the UK) has been established to intercalibrate methods in transitional (estuaries) waters, within the northeast Atlantic ecoregion. The following steps for intercalibration were agreed upon by this group:

- (i) to establish common waterbody types across Europe, based on salinity, tidal range, mixing conditions, intertidal area and estuary size (6 common types were identified);
- (ii) to compile a common dataset (9337 samples collated, from 59 estuaries and 8 countries, covering 5 out of the 6 types, and most of the ecotopes);
- (iii) to harmonise the taxonomy of the dataset (using ERMS, WoRMS and Fauna Europaea);
- (iv) to collate human pressures from each estuary;
- (v) to set reference conditions for each type;
- (vi) to calculate Ecological Quality Ratios for each of the 10 methods proposed for intercalibration (BAT, M-AMBI, BOPA, BO2A, QSB, MISS, BEQI, AETV, BQI, IQI);
- (vii) to interpret the response of these methods to different anthropogenic pressures;
- (viii) to determine boundaries for each of the 5 quality class (from bad to high status), using the 10 methods; and
- (ix) final agreement in the assessment and intercalibration.

This contribution presents the steps already taken and the way forward in this intercalibration exercise.

4.1.5 The use of benthic indicators to assess anthropogenic impacts: some cases from Belgium

G. Van Hoey reported

Environmental monitoring and the use of indicators for assessing anthropogenic impacts and the status of the marine environment are topics that get a lot of attention in current scientific research. The basis for this lays in the (recent) implementation of different European Directives, like the Habitat- and Bird Directive, the Water Framework Directive and the Marine Strategy Framework Directive. Policy makers and managers need objective tools to evaluate the impact on the marine ecosystem and to assess the recovery after enforcement of the measures. Three main groups of anthropogenic pressure types are here considered: (1) pollution (e.g. eutrophication, chemical); (2) physical disturbance (e.g. bottom trawl fishery, sand extraction, dredging) and (3) constructions works (harbours, land reclamation).

Currently, a wide variety of indicators are developed, including univariate, multimetric and multivariate approaches, the latter combining different parameters with different sensitivity levels. The aim of those indicators is to detect deterioration or improvement of the benthic habitat or community conditions as a result of a change in an anthropogenic pressure type. Because no benthic indicator is sensitive to all pressure types, it is worthwhile to test different benthic indicator types against the different pressure types.

The Bio-environmental research group of ILVO is currently performing environmental assessments using benthic indicators, on the effects of different anthropogenic activities on the benthos. The monitoring strategy is characterised by a control-impact design, an appropriate number of samples for a confident assessment, and lab analyses that adhere to international standards. The behaviour of two benthic indicators (BEQI [www.beqi.eu], m-AMBI) in relation to different anthropogenic activities (land reclamation in estuaries, dredge disposal, sand extraction, wind farm) is presented.

- Case 1: *Benthic habitat surface area changes in the Westerscheldt estuary due to land reclamation activities.* In the Westerscheldt estuary, the benthic habitat conditions were rather good, whereas their areal distribution is seriously declined in the last century. A lot of ecological important benthic habitats disappeared (e.g. mussel beds) or seriously declined (e.g. intertidal area) because of the deepening of the estuary and the construction of its embankments.
- Case 2: *Impact assessment of dredge disposal.* The relation between the indicator value and the dumping quantity per year at the different disposal sites over the period 2004–2008 was tested. The BEQI parameters decline with increasing dumped amounts, but this is not reflected in the m-AMBI.
- Case 3: *Impact assessment of sand and gravel extraction.* Despite the serious physical disturbance in one extraction area in the last years, neither indicator shows a negative impact. This is partly due to the increase in diversity (new colonizers) in this extraction area.
- Case 4: *Impact assessment of construction activities (e.g. wind farms).* Both indicators and specially their diversity component show a negative effect on the benthos in the period of the construction of the wind mills. This effect already all but disappeared a year later.

The results show that indicators react sometimes different, depending on the pressure type. Therefore, several indicators with complementary properties may be needed to provide a strong and effective support for management decision-making.

4.2 Broaden the geographic scope of the BEWG work on benthic indicators to North American waters

4.2.1 Regional Assessments of the Benthos and Overlying Waters throughout US Coastal Ocean Waters

J. Hyland reported on work done by J. Hyland and W. Nelson

Since 2003 NOAA, US EPA, and various coastal states have conducted studies to assess the status of ecological condition and potential stressor impacts throughout coastal-ocean waters of the US Protocols are similar to those used in EPA's Environmental Monitoring and Assessment Program (EMAP) and National Coastal Assessment (NCA), which have focused on estuarine and inland waters. The recent offshore series extends these prior efforts onto the continental shelf, from near-shore depths seaward to the shelf break (typically 100 m depth). Where applicable, sampling has been included in NOAA's National Marine Sanctuaries to provide a basis for comparing conditions in such protected areas to surrounding non-sanctuary waters.

To date surveys have been conducted throughout the western US continental shelf, from the Straits of Juan de Fuca, WA to the US/Mexican border; South Atlantic Bight; mid-Atlantic Bight; continental shelf off southern Florida, from West Palm Beach to Tampa; and north eastern Gulf of Mexico, from Tampa to the Mississippi delta. Multiple indicators of water quality, sediment quality, and biological condition (benthos and fish) are sampled throughout these waters using random probabilistic sampling designs. Synoptic sampling of the various indicators provides a "weight-of-evidence" approach to assessing condition and a basis for evaluating linkages between the status of condition and source drivers and pressures. In addition, the probabilistic sampling design provides a basis for making unbiased statistical estimates of the spatial extent of a region's health relative to the various measured indicators and corresponding management thresholds and using this information as a baseline for determining how conditions may be changing with time. Because the protocols and indicators are consistent with those used in previous EMAP/NCA estuarine surveys, comparisons also can be made between conditions in offshore waters and those observed in neighbouring estuaries, thus providing a more holistic account of ecological conditions and processes throughout the inshore to offshore resources of a region. Such information should provide valuable input for future National Coastal Condition Reports, as well as other evolving management priorities including marine spatial planning and ecosystem approaches to management.

4.2.2 FIBI: An Index of Benthic Integrity to determine Freshwater Inflow Needs to Maintain Estuarine Health

P. A. Montagna reported

Freshwater inflow is an important source of physical variability in estuaries. Yet, Amount of water in reservoirs quadrupled since 1960, withdrawals from rivers and lakes doubled since 1960, and there has been a huge loss of environmental flow (MEA 2005). Effects of water flow are dynamic, and it is impossible to sample all conditions as they vary over space and time. However, we do know that altered flow alters hydrology, nutrient loading, sediment loading, and salinity in receiving waters (Montagna *et al.* 1996, Palmer *et al.* 2011). The mechanisms that drive biological communities are indirect. Freshwater inflow drives estuarine condition, and biological resources

Benthos, however, are fixed in place, continuously sample the overlying water conditions, and demonstrate a variety of consistent responses to multiple sources of stress (Tenore *et al*. 2006). Benthic indices of biotic integrity (BIBIs) have been particularly useful for assessing aquatic systems. However most indices have focused on assessing effects related to changes in water quality rather than water quantity. This study develops a Freshwater Inflow Biotic Index (FIBI) to determine how changes in freshwater inflow affect benthic populations, which in turn reflect the ecological condition of an estuary (Carr *et al*. 2000, Morehead *et al*. 2008, Pollack *et al.* 2009). Based on benthic succession theory (Pearson and Rosenberg 1978, Rhoads *et al*. 1978) and long-term data (Montagna and Li 2010), 12 biotic metrics were chosen that characterized benthic community structure in response to inflow regimes. The metrics were ranked and then reduced to one variable using principal component analysis (PCA) to form the index.

The FIBI and hydrological PC variables were significantly correlated, indicating that benthic communities respond to changes in salinity and do so in a relatively predictable manner. If inflow is reduced (i.e., salinity increased), it will cause upstream communities to take on characteristics of downstream communities. The FIBI successfully characterized effects of a salinity gradient in the Lavaca-Colorado estuary, and application of the FIBI approach should be successful in other estuarine ecosystems.

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4.3 Discussion

After the introductory presentation, several research topics, which could be addressed by the BEWG, were discussed.

- The need to assess the response of indicators to natural variability of the ecosystems was emphasised. Along that line the group agreed to focus primarily on the scientific basis of the indicator selection and development, taking into account natural processes and adaptations. An evaluation of the species tolerance to anthropogenic disturbance along natural environmental gradients (e.g. salinity) was considered key. The underlying hypothesis is that the tolerance of species will differ in different environmental regimes along specific gradients.

- In addition, an update and evaluation of the indicator species list, based on the Pearson and Rosenberg publication in 1978 (Rosenberg and Pearson, 1978) was suggested as well as widening the scope of the list to a global scale. A methodological approach to generate this list could be to use the BQI method (Rosenberg *et al.* 2004) to identify indicator species in different habitats. Also the MarLIN list of species sensitivity could be used as a starting point (http://www.marlin.ac.uk).
- Furthermore the need to intensify research on historical (benthos) data and to make use of this information in the context of indicator species and changes in benthic habitats was mentioned. This information was frequently used for Swedish waters.

The group discussed the different approaches and research objectives and finally agreed to focus first on the investigation of species tolerance and its variability along environmental gradients.

4.3.1 New BEWG initiative: "On the myths of indicator species"

The use of static sensitivity/tolerance list of species in assessment tools around the world to define the ecological status of waters (using flora and fauna) is common. These lists are useful tools and were improved in the last decade (adding of species worldwide, revisions of autecology), but caution is required. This due to the fact that, for some/many species a change of life history strategy or its autecology requirements and consequently its sensitivity along distinct environmental gradients are expected. Our subgroup will formulate an approach/proposal to investigate this change. For that both data from the Atlantic (including Gulf of Mexico and East coasts, North and Baltic Seas) and the Mediterranean Sea will be considered.

Both macrozoobenthos (soft and hard bottom) and if possible macrophytobenthos data have to be taken into account. Although different gradients have to be considered, in a first step the focus is on the salinity gradient as an example.

1) Considered gradients have to be defined: e.g. salinity, temperature, organic content. Each gradient will be divided into 6 to 7 levels: e.g. for salinity: <5, 5–10, 10–15, 15–20, 20–25, 25–30, >30 psu.

2) Only species which occur at least at 3 levels (better more) will be selected from the data for eventual statistical analysis.

3) Only species which will change their autecology along one (or more) gradients will be considered. This could for instance be a change of habitats (substrate, sediment, nutrition) where the species occur. The goal will be to determine whether the species changes sensitivity to environmental parameters.

4) The minimum data that need to be contributed for soft bottom fauna include: specific aspects of the species (taxon, abundance and biomass), station information (water bodies, coordinates, date of sampling), depth, organic content (loss of ignition), grain size, oxygen and salinity (any other?). Note, that this procedure will filter the existing data sets rapidly. Thus we have to be careful with defining a minimum on the one hand and on the other hand a minimum of accompanying environmental data which is essential for the subsequent analysis. Separate tables will be prepared for other major systems like hard substrates and macrophytes which may in-

clude different environmental attributes (e.g. sedimentation rates, turbidity, light reduction, Secchi depth).

5) Selection of data: a) where gradients exist species will be defined as outlined above; b) species defined by the first step also occur elsewhere and these data are needed as well in order to reflect the whole habitat characteristics (certain dimensions of the organisms' niche) of one species depending on selected environmental data.

6) This subgroup will provide the metadata table to everyone who is interested in contributing.

7) Following steps are not yet defined in detail, but will be a task of future cooperation. A hypothesis stating that response to some stressors will differ [or NOT in the null form] along gradient(s) has been suggested. A possible way to test this hypothesis with the data gathered is needed. This however is left to future discussions, and as always, exciting ideas are welcomed.

This initiative will be lead by M. L. Zettler & C. E. Proffitt. Contributors so far are: G. Van Hoey, H. Kautsky, P. Magni, B. Tunberg, P. Montagna, W. Nelson, M. Frazier, A. Darr, H. Reiss, S. Degraer and J. Hyland.

This project is still susceptible for new ideas, suggestions, input and contributors from BEWG.

5 Marine habitat modelling and mapping: where BEWG and WGMHM meet

5.1 Report on recent initiatives on species distribution modelling and mapping

5.1.1 Species Distribution Modelling of North Sea Benthos

H. Reiss presented

In this study several species distribution models (SDMs) have been applied to predict the distribution of benthos species in the North Sea. The understanding of species distribution patterns is essential to gain insight into ecological processes in marine ecosystems and to guide ecosystem management strategies. Therefore nine different SDM methods: GLM, GBM, FDA, SVM, RF, MAXENT, BIOCLIM, GARP and MARS were compared, by using 10 environmental variables and 20 marine benthos species.

Most of the models showed good or very good performance in terms of predictive power and accuracy, with the highest mean AUC values of 0.845 and 0.840 for the models MAXENT and GBM, respectively. The poorest performance was found for the BIOCLIM model with a mean AUC of 0.708. Nevertheless, the mapped distribution patterns varied remarkably depending on the model used, with up to 32.5 % disagreement in predictions between models. Furthermore, the distribution type (niche width) of the species seems to affect the model performance. For species with a narrow distribution range in the North Sea, the models showed a better performance based on the AUC than for species with a broad distribution range, which can be most likely attributed to the restricted spatial scale and the model evaluation procedure.

Bottom water temperature and depth was found to be important environmental variables affecting the distribution of many benthos species based on MAXENT results.

The relevance of these findings for predicting future distribution of benthos species in response to climate change is discussed.

5.1.2 Remote sensing and mapping shallow phytobenthic communities in the Baltic Sea, present and future aspects

H. Kautsky presented

The project for remote sensing EMMA (www.emma.slu.se) financed by the Swedish EPA, was briefly described. The problem of biotope mapping using elaborate statistical methods and presented as GIS-maps was briefly mentioned. A major problem is that the statistically sane models present colourful maps over large areas. These maps are based on a fraction of areas with real observations (video, diving transects, etc.). Thus, the maps are an educated guess of what could be in a given area, but too often have no or little relevance to reality. However, in many cases, e.g. as background for decision making by authorities, these maps are used as if they reflect the real world. Incorrectly, the maps obtain the same status as the more relevant land maps, where every scale of a subarea can easily be checked for relevance (dm scale resolution of aerial photography etc.). To solve this problem, a method for producing total area covering distribution maps of biotopes is essential. One method applicable for shallow areas could be laser-techniques as LIDAR. Some examples of LIDAR measurements performed in the county of Skåne (*Zostera*-community and in the Askö area were presented. Future steps would be to develop a laser technique with a set of wavelengths able to distinguish between different plant species and groups. Results from a lab study were presented, which showed that the variance within species as well as within the species from different stations was low. The reflectance differed between species. Also *Mytilus edulis* and sediment were included and formed separate groups. The results indicated that it should be possible to map plant communities using e.g. a set of different wave lengths. The problem with the filtration of light by the water column is still to be solved.

5.1.3 Application of geophysical technologies and hydrodynamical modelling for benthic habitat mapping and classification in the western Mediterranean Sea

P. Magni reported

Acoustic methods for seafloor mapping have been widely developed over the last decades. In particular, the development of swath bathymetry has allowed obtaining detailed maps of seabed morphology and the analysis of related acoustic backscatter has made it possible to classify sediment types and habitat typology. Those techniques, coupled with ground truth data, provide useful information for the evaluation of environmental quality of coastal areas, they are useful for the evaluation of marine geo-hazards (e.g. landslide) and can provide useful data to evaluate marine biological (fishery) and non-biological resources (sand deposits for beach nourishment). Here, I present such an application from a study conducted in the inner shelf of central western Sardinia (western Mediterranean sea), a site characterized by a complex sea bed including sandy and gravelly sediments, *Posidonia oceanica* seagrass beds growing on hard grounds (i.e. biogenic carbonates) and sedimentary substrates (De Falco *et al*., 2010). A map of seabed classification, including sediment types and seagrass distribution, was produced through a combination of information derived from backscatter data and morphological features derived from multibeam bathymetry, which were validated by ground-truth data.

Furthermore, an evaluation of the hydrodynamics is fundamental to understand the factors which control the distribution of benthic habitats. In this framework, high resolution hydrodynamic numerical models coupled with numerical tools are presented here as a tool for reproducing the ecosystem dynamics. A three-dimensional hydrodynamic modelling was performed in order to simulate the influence of waves and currents at the seabed level on the sedimentary features in the inner-middle shelf of the strait of Bonifacio (western Mediterranean). In particular, two main carbonate factories were identified: *Posidonia oceanica* seagrass meadows in the shallower zone (<40 m) and *Maërl* beds (free living calcareous red algae) in deeper water (40–80 m) (De Falco *et al*., 2011). These were conditioned by hydrodynamics: (i) the sediment carbonate production associated to Posidonia oceanica meadow was higher in sectors sheltered from waves; (ii) currents at the seabed level, forced by the main winds of the region, limited the extension *Maërl* beds.

The application of geophysical technologies allowed high resolution mapping of benthic habitats, whereas the hydrodynamic modelling was instrumental to evaluate the spatial distribution of benthic communities producing carbonate sediments in modern temperate shelves.

References

De Falco G., Tonielli R., Di Martino G., Innangi S., Simeone S. and I.M. Parnum (2010). Relationships between multibeam backscatter, sediment grain size, and Posidonia oceanica seagrass distribution. Continental Shelf Research Shelf, 30:1941-1950.

De Falco G., De Muro S., Batzella T. and A. Cucco (2011). Carbonate sedimentation and hydrodynamic pattern on a modern temperate shelf: The strait of Bonifacio (western Mediterranean). Estuarine, Coastal and Shelf Science, doi:10.1016/ j.ecss.2011.03.013

5.1.4 Spatial modelling of North Sea benthos: combining scientific and economic data from windmill farm investigations

J. Dannheim reported

The StUKplus-data project deals with the evaluation of the BSH (Federal Maritime and Hydrographic Office) standard investigation concept (StUK) of monitoring windmill-farm effects in the German exclusive economic zone (EEZ) of the North Sea. The project aims at (a) investigating the cumulative impacts of windmill farms on the benthic system (changes by large-scale renewable energy plans) and (b) identifying benthic spatial patterns and main drivers for species distribution or assemblages, in order to provide evaluation criteria for identifying spatially sensible areas. Hitherto, one windmill farm is in use (alpha ventus), one under construction, 26 approved and another 57 are planned (Figure 2, state of the art: November 2010). The base of all environmental assessment studies in each farm is a BACI design: samples are taken in a reference and impact area before, while and after the 1st, 3rd and 5th year of construction.

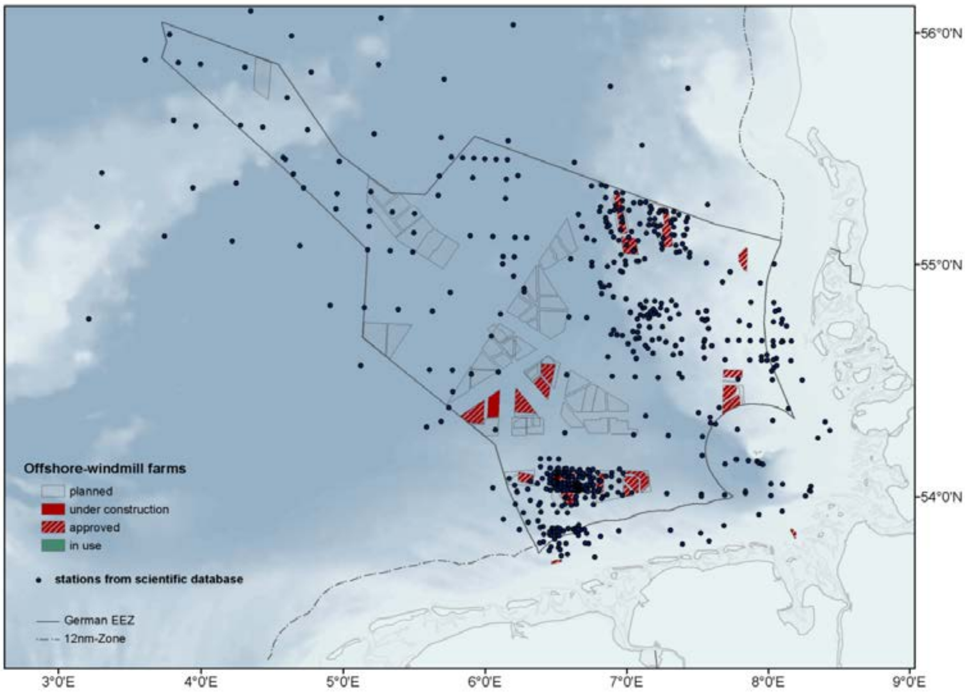

Figure 2. Benthic stations in the German EEZ of the North Sea. Data are available from environmental assessment studies of approved offshore-windmill farms (red-coloured areas, state of the art: November 2010), as well as monitoring programs and scientific projects (blue dots).

Data are harmonised and quality controlled by benthic experts at the AWI and stored in an "economic benthic invertebrate database" (data from environmental assessment studies) at the BSH. Hitherto, more than 3000 van Veen-grab stations and > 1500 beam-trawl station entries are stored from the last decade. Each station contains data on depth, salinity, temperature, water-oxygen content, grain size and organic matter of the sediment. Overall more than 150 000 taxonomical entries were registered with abundance and biomass data (wet weight). In addition, a "scientific benthic invertebrate database" is under construction with data from long-term series, monitoring data and data from scientific projects (Figure 2). This database contains > 700 van Veen-grab and beam-trawl stations with environmental data and species information on abundance and biomass (wet weight). Both databases were used to model species distribution in the German EEZ in the North Sea. Information on species occurrence along sediment and depth gradient was generated from the economic and scientific benthic invertebrate database. Information on habitat, i.e. full-coverage data on sediment and depth distribution, were provided by the BSH. A binominal logistic regression model (Gogina & Zettler 2010) was used to predict species occurrences in the German EEZ of the North Sea. Spatial distribution was calculated on the base of sediment and depth raster layers (1 km² grid) in ArcGIS. This method has the advantage to provide information on the probability of species occurrence within each grid cell.

The unique large dataset provides the opportunity to model spatial distributions of species, to revise benthic associations in the German part of the North Sea, to evaluate spatial coverage of functional traits (functional mapping) in order to identify functionally important areas for ecosystem services and goods. This might, finally, serve to manage spatial planning in the marine system. In the future, the enormous data flow from environmental assessment studies of windmill farms might help to improve the spatial resolution for species distribution modelling and might enable to compare different marine ecosystems on a high-resolution scale.

Reference

Gogina M., Zettler M.L., 2010. Diversity and distribution of benthic macrofauna in the Baltic Sea. Data inventory and its use for species distribution modelling and prediction. Journal of Sea Research. **64**(3):313-321.

5.1.5 Habitat/biotope modelling in the National Mapping Program MAREANO

L. Buhl-Mortensen reported

The MAREANO project, starting in 2005, is a multidisciplinary seabed mapping programme conducting physical, biological and environmental mapping in the Lofoten - Southern Barents Sea area, northern Norway. The major project partners - Geological Survey of Norway (NGU), Institute of Marine Research (IMR), and Norwegian Hydrographic Service (SKSK) - cooperate closely to conduct the mapping. Maps, data and analysis arising from this project will contribute to a systematic database for Norway's coastal and offshore regions and will be made available via the internet (www.mareano.no). This information provides the basis for ecosystem based management of the region.

Multibeam bathymetry and backscatter data is acquired by SKSK. The multibeam data have been processed to produce co-registered bathymetry and backscatter grids and these form the basis for further analysis and integration with other datasets including seismic data, seabed samples, and video surveys. Video surveys are conducted by IMR using the CAMPOD towed video system. Seabed samples are acquired using a range of sampling gears (multicorer, grab, boxcorer, beam-trawl, and epibenthic-sled) and analysed for geological and biological information is conducted by NGU and IMR respectively. Using multibeam data, seismic data, seabed samples, and video surveys, NGU has compiled a suite of seabed maps. These interpreted map products provide information on the seabed geology (sediment grain size distribution, sedimentary environment and genesis). Methods used to develop thematic maps include data processing, statistical analysis, terrain modelling and techniques for habitat prediction and modelling. IMR and NGU also work in collaboration to integrate biological and geological information in order to develop benthic habitat maps, which are an important component of the MAREANO programme.

Mapping procedure:

1) Multibeam mapping covering total areas ½-1 year before mapping biology and geology;
2) Selecting transects for video documentation (~10 / 1000 km^2) 700–1000 m long covering 1000–1500 m^2 each;
3) Sampling stations for ground-truthing of biology and geology (~3 stations / 1000 km^2).

Species data from video and environmental correlations are analysed using detrended correspondence analysis (DCA). The analysis has been carried out at two different scales using two data sets: 50 meter video transect subsamples and 200 meters subsamples. The 200 m subsamples have so far proven to provide the best fauna/environment match. Data for 17 environmental variables from video and multi-beam has been used for the analysis. From video recordings: Depth, soft sediment, pebble, cobble, boulder, stones, shell, old trawl tracks, new trawl tracks, lost fishing gears. From multi-beam: Depth, BPI (Bottom position index), curvature, rugosity, slope angle, aspect, and backscatter. The analysis revealed six distinct biotopes related to a set of environmental variables. Supervised classification using ground-truthed classified data to 'train' GIS layers (see Figure 3) was used to get from observed point information to area covering maps. This modelled relation between environmental variables and biotopes is used to predict occurrence in neighbouring area. The prediction is 86% correct with respect to training data. Further analysis using MAXENT showed that five biotopes might provide a better representation of the fauna and environment distribution in the area.

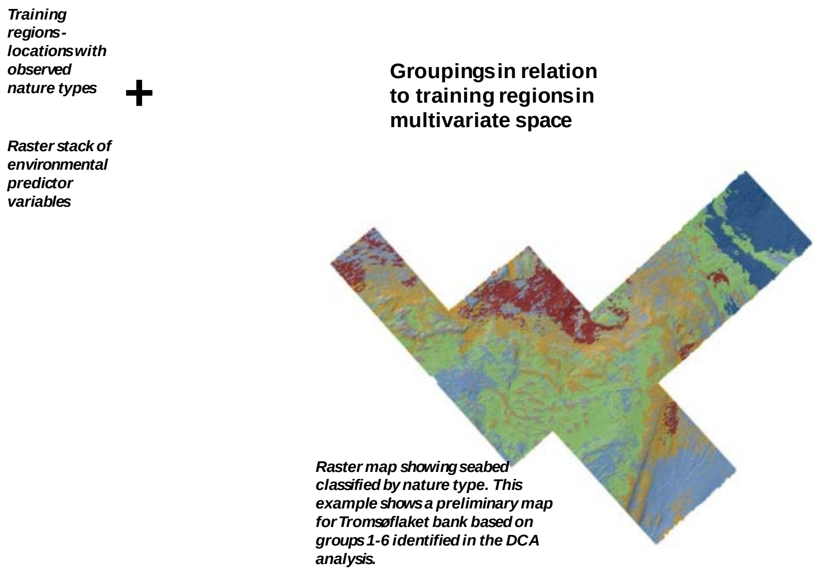

Figure 3. Schematic representation of the supervised classification.

Habitats was also modelled on landscape level using DCA and MAXENT. Six biotopes were identified with dominating species (see Table 1). Six models were used, one for each biotope, and matched to form the map shown in Figure 4.

From the MAREANO experiences with modelling of biotopes/habits the conclusions are so far:

- Biotopes with a few characteristic species should be carefully described to avoid lumping together.
- Analyzing samples from very different environments may hide details in classification. More effort should be put into analyzing the effect of scale (spatial resolution) on the classification of biotopes.
- Better maps of the seabed environment (currents, temperature, etc) will probably enable better predictions.
- Make the maps useful for management (fill the biotopes with useful information, e.g. presence of threatened or red-listed species, normal biodiversity).

Table 1. Showing six classes of biotopes identified from DCA with some related and common species

CANYON	LOWER SLOPE	UPPER SLOPE	SHELF PLAIN	BANK	TROUGH
violet Cerianthidae	Nephtheidae	*Crossaster*	*Henricia*	*Sebastes*	*Stichopus*
Lycodes	*Hymenaster*	*Polymastia*	encrusting Porifera	*Lithothamnion*	*Kophobelemnon*
Ophiopleura	*Rhizocrinus*	*Drifa*	*Hippasteria*	*Gadus morhua*	*Ditrupa*
Stylocordyla	*Lycodes frigidus*	Antedonacea	*Phakelia*	*Tethya citrina*	*Flabellum*
Bythocaris	*Caulophacus*	*Gorgonocephalus*	Echiuridae	Galatheidae	*Raja*

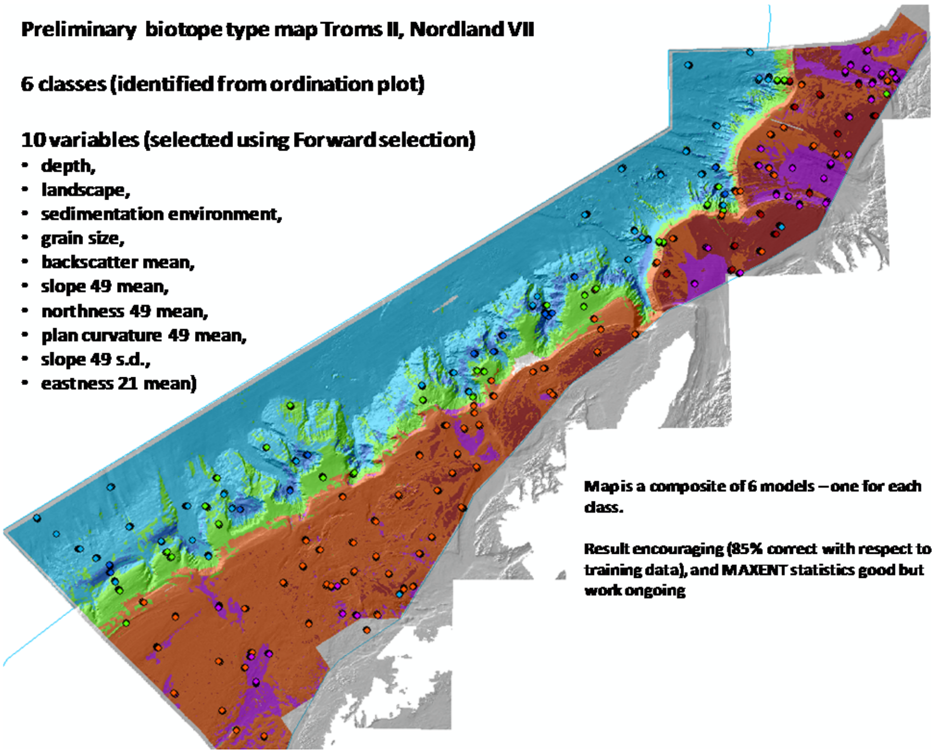

Figure 4. Preliminary biotope type map for the areas Troms II and Nordland VII.

5.1.6 Modelling the distribution of macrozoobenthos in the Baltic Sea in response to selected environmental factors

M. Gogina reported on work done by M. Gogina, M. L. Zettler, M. Glockzin, R. Bochert and A. Darr.

The patterns in the spatial distribution of benthic macrofaunal communities and exemplary species of the Baltic Sea are linked to near-bottom environmental parameters, based on the data for regional and sea-wide spatial extents. For brackish ecosystem of the Baltic Sea salinity is regarded as a major driving factor that determines benthic biodiversity, but prevailing factors differ on the more regional scale. For two regional case studies (Mecklenburg Bight and Pomeranian Bight) preliminary investigation revealed characteristic species to indicate the most well-defined responses to depth and sediment parameters as total organic content, median grain size and sorting. The applied technique for predictive modelling of species distribution in response to abiotic variables is based on single-factor binomial logistic regression models (response curves that describe the occurrence of species along single environmental variable) combined with the use of AIC and Akaike weights for the multimodel inference. For selected species probabilities of occurrence were modelled and mapped. The obtained response surfaces indicated fairly high degree of success. Water depth was key factor determining the species distribution among the parameters considered within the study scale in the Mecklenburg Bight. In the Pomeranian Bight e.g. for *Bathyporeia pilosa* total organic content explained most of variability in regional distribution. Based on an inventory dataset that compiled The discriminating ability of salinity, bathymetry and substrate types as predictors for probability of species occurrence on a more global scale was tested on the inventory dataset compiling the information on macrozoobenthos distribution in the whole Baltic Sea, including historical data. Empirical logistic regression based species distribution models allowed to satisfactorily predict the potential distribution of exemplary species (background), yet implementation of other variables (e.g. characterizing oxygen and temperature fluctuations, total organic content, nutrient supply) would obviously increase the model accuracy and applicability. Thus the suitable and sufficient data covering the distribution patterns for these environmental variables is highly demanded. Development and application of methods for quantitative modelling of species distribution (e.g. of abundance or biomass) are required to further promote the understanding of ecosystem functioning.

Further reading

Gogina M., Zettler M.L., 2010. Diversity and distribution of benthic macrofauna in the Baltic Sea. Data inventory and its use for species distribution modelling and prediction. Journal of Sea Research. 64(3):313-321.

Glockzin M., Gogina M., Zettler M.L., 2010. Beyond salty reins – modelling benthic species' spatial response to their physical environment in the Pomeranian Bay (Southern Baltic Sea). Baltic Coastal Zone, 13(2):79-95.

Gogina M., Glockzin M., Zettler M.L., 2010a. Distribution of benthic macrofaunal communities in the western Baltic Sea with regard to near-bottom environmental parameters. 1. Causal analysis. Journal of Marine Systems 79:112-123

Gogina M., Glockzin M., Zettler M.L., 2010b. Distribution of benthic macrofaunal communities in the western Baltic Sea with regard to near-bottom environmental parameters. 2. Modelling and prediction. Journal of Marine Systems 80:57-70.

5.2 Discussion

The group discussed which future initiatives on species distribution modelling within the BEWG can be started. Possible methodological approaches and applications of species distribution models (SDM) for addressing specific research questions and how SDM can be used to give advises or recommendations were argued.

- The BEWG pointed out that is important to understand the ecology behind maps, i.e. moving beyond pure mapping towards species modelling and functional predictions. On both sides of the North Atlantic, a considerable amount of mapping studies has been done in the USA as well as in Europe, particularly in relation to spatial planning of marine areas. However, only minor studies have been carried out in the context of understanding ecosystem functioning, although knowledge on the ecology of benthic ecosystems is fundamental for ecosystem management purposes. In the long-term, the BEWG decided to focus on the possibilities and limitations of species distribution modelling to understand ecosystem functioning, i.e. to enlarge the knowledge on the environmental drivers which explain species distribution and to use species biological traits for large-scale predictions (across benthic systems). One of the main problems is that there are no quantitative models known that are capable of predicting species abundance and biomass, i.e. all hitherto used models uses presence/absence data of species. The BEWG will carry out an extended literature research to solve this problem hopefully. M. Gogina will take the initiative here.

- As a short-term aim, the BEWG decided to write a review paper on species distribution modelling (SDM) in the marine environment and its relevance for ecosystem management. The review should focus on SDM for marine ecosystem management and marine spatial planning. In contrast to the terrestrial realm, SDM as a tool is relatively new in the marine environment. It is thus of particular importance to point out the application possibilities of SDM but also the limitation of this approach for ecosystem management and marine spatial planning. The publication should focus on the lessons we have learned from the terrestrial ecology, expose the speciality of marine ecosystems, pinpoint special features of the marine environment, and emphasise a critical use of marine prediction maps by e.g. governmental agencies, ministries and administrative bodies.

The BEWG decided to draft a work plan to tackle its short-term objective to write a review paper on SDM in the marine environment and its relevance for ecosystem management.

5.2.1 New BEWG initiative: Review paper on species distribution modelling in the marine realm

A review of species distribution modelling and its relevance for marine ecosystem management was instantiated. The main aim is to give an overview of these modelling techniques and discuss their prospects and limitations as a tool for ecosystem management approaches. The outline of the review (Annex 7) summarizes the main topics identified during the meeting and the authors in charge for each topic.

The deadline for the first draft is 16 December 2011. A second round will follow, so that a first reasonable draft can be compiled at the BEWG 2012 meeting.

This initiative is open to all BEWG members, who are working on this topic and would like to contribute. If you want to contribute, please send an e-mail to the author of the corresponding topic and to H. Reiss (addresses can be found in Annex 1).

5.3 Consider the outcome of the intersessional meeting between BEWG and WGMHM and the format of future collaboration

The chairman informed the group about plans for collaboration with WGMHM, as initiated during last year's BEWG meeting. Both Chairs of BEWG and WGMHM met during the ICES Annual Science Conference (ASC) 2010, discussed about opportunities for collaboration between both groups, as well as the risk of duplicating work. It was decided that a shared Theme Session on Species distribution Modelling at the ASC 2011 would be a good starting point for further exploration of common activities. As such, the WGMHM request for the organization of a Theme Session was slightly adapted, as to accommodate the BEWG interests in this matter and S. Degraer was added to the list of conveners. The Theme Session proposal has been accepted (see 5.4).

In the mean time a request for closer collaboration with BEWG and WGMHM has been received from WGEXT. Based on a first email communication it has been decided that a web-conference between the three Chairs will be organized, as a way of exploring what further engagement could be achieved. It has been agreed that a smaller but active engagement would be more beneficial, than a wider though less active collaboration. The broader scope for collaboration between ICES expert groups could be dealt with at the Science Steering Group (SSG) level. It should however be noticed that BEWG, WGMHM and WGEXT are allocated to two different SSGs.

The BEWG further discussed how and to what extent collaborations with other ICES groups could be initiated. The group agreed upon that before collaboration steps can be taken, the expertise on benthic species distribution modelling (and mapping) should be strengthened within the BEWG. Thereby, the BEWG should focus on its biological expertise in benthic ecology for future studies on species distribution modelling. This will tweak future work and collaborations for both groups: the WGMHM, with focus on mapping by environmental factors, and the BEWG with focus on benthic species distribution modelling.

First initiatives on species distribution modelling and mapping are already in progress: the WGMHM will be invited by H. Reiss to contribute to the BEWG review paper on species distribution modelling in the marine realm.

5.4 Joint WGMHM - BEWG Theme Session at ICES Annual Science Conference 2011 (Gdánsk, Poland, 19–23.09.2011) "Habitat modelling and mapping for better assessment and monitoring of our seas"

Coordinated plans have been developed for the ICES Annual Science Conference 2012. A Theme Session G: "Habitat Modelling and Mapping for better assessment and monitoring of our seas" (conveners: R. Coggan (WGMHM), J. Populus (WGMHM, Chair) & S. Degraer (BEWG, Chair).

The Theme Session received quite some attention and will consist of a 16 oral presentations time slot, completed with twelve poster presentations. The lessons learnt from this Theme Session will be used to further outline the potential for collaboration between both expert groups.

6 Ongoing benthos-related initiatives

6.1 Report on exciting developments in ongoing phyto- and zoobenthic research in the ICES area, with special attention to North-American activities

6.1.1 Assessing consequences of natural disturbance events for benthic ecosystem functioning using BTA approach on long-term monitoring data

M. Gogina reported on work done by M. Gogina and M.L. Zettler

In the Baltic Sea ecosystem services provided by benthic fauna are compromised by hypoxia stress thereby affecting the ecological functioning. Goals of the case study based on the data for three long-term monitoring stations are to assess structure and changes of functional diversity in the SW Baltic over the last 2 decades (1991–2009), investigate patterns of response to hypoxia and examine variability in the functional traits pools of different habitats. The working hypotheses to be studied are (1) local effects of hypoxia lead to local loss of traits and (2) global temporal effects are induced by large-scale salinity fluctuations. Fuzzy coding approach is used to combine available information for 47 modalities of 13 traits reflecting morphological, life history and ecological strategies of 110 recoded taxa. Analysis of abundance- and biomass-weighted traits-by-stations tables indicates clear differences in structure of prevailing functional traits between 3 stations. Direct response to hypoxia and subsequent recovery are not always evidently observed in biological traits data.

6.1.2 Oyster restoration and conservation in Atlantic Florida Coast and Gulf of Mexico

C. E. Proffitt presented

The Eastern Oyster, *Crassostrea virginica*, is an important fishery and habitat-forming species in the Gulf of Mexico and Atlantic coasts of the United States. Oysters form both intertidal and subtidal reef flats in different regions and in subtropical Florida there are substantial "reefs" beneath and on red mangrove (*Rhizophora mangle*) prop roots. Oysters, *C. virginica* and related taxa, have declined in many parts of the world from a variety of pressures. We are studying: a) oyster reef restoration in the St. Lucie River estuary (southeastern Florida), which has been impacted by fresh water diverted from Lake Okeechobee and b) the effects of and recovery from the Deepwater Horizon Oil Spill in the Gulf of Mexico. In the St. Lucie project, oysters have colonized over the last 1.5 years as have numerous species of estuarine invertebrates. We are using structural equation modelling to link oysters and the abundance and diversity of associated species with various environmental variables (e.g., freshwater discharge, salinity, distance to ocean, dissolved oxygen, chlorophyll a, nutrients, etc.) in hypothesized causative models. These models will be tested for overall fit with the covariance structure of the dataset, and then compared with one another to determine the most parsimonious model that fits the data. In the Gulf of Mexico oil spill project, we lead a team of colleagues exploring oil impacts on adult and newly settling oysters and associated species on Florida reef flats, the genetic diversity and connectivity of oyster populations throughout the Gulf of Mexico, and the presence of polyaromatic cyclic hydrocarbons in oyster tissue. This work is in the sample collection and preliminary analysis stage.

6.2 Future BEWG collaboration: Suggestions and planning

6.2.1 Development of regional macrobenthos Red Lists (rationale, strategy, application)

J. Dannheim presented a possible future collaborative research initiative on "Red List Species" proposed by E. Rachor

Every few years the stock developments of plant and animal species are reviewed in Germany and other countries; and the threat of species is evaluated in the so called "Red Lists". In the German part of the North Sea and Baltic Sea (including the EEZ), 32% of all considered benthic invertebrate species are endangered. About half of these species, however, are extremely rare and thus "potentially threatened", which leads to the comparatively high number of endangered species. Compared to terrestrial and freshwater environments, the percentage of threatened marine invertebrates is only slightly lower.

However, Red Lists covering the whole North Sea do not exist, but are particularly essential for the assessment of its ecological state. Thus, there is the suggestion to initiate a first meeting to bring scientists from the bordering states of the North Sea together and discuss the possibilities of North Sea wide Red Lists, including an evaluation of different approaches (like by IUCN and in several countries).

The BEWG agreed that such an initiative is needed, since single state lists covering only a sector of the whole ecosystem will be misleading in open systems like the North and Baltic Seas. The BEWG supports E. Rachor to initiate a first meeting e.g. in Bremerhaven in autumn 2011 and to invite competent and interested scientists especially from the BEWG.

The main aim of such a meeting should be the evaluation of existing procedures, the definition of common methods to be applied, and the areas to be covered. Furthermore, an agreement should be made about the taxa to be considered first (e.g. sponges, bivalves, gastropods, decapods and echinoderms), when to start the work, and by whom.

6.2.2 Organization of a workshop on the offshore-windmill farm impact on benthos

Over the last decade, many countries gained knowledge on the effects of offshore-windmill farms on the benthic system. The direct effects of single structures on the soft-bottom benthos, as well as the impact of a whole windmill farms on the benthic system have been studied. Benthic ecologists from different countries have improved their knowledge on understanding how windmill farms affect the ecological functioning of benthos. Nowadays, approaches start to focus on large-scale effects caused by the spatially very-large covering renewable energy plans in shallow marine areas. Overall, 49 windmill-farms are in use, 32 farms are approved and another 250 windmill farms are planned in European waters (see Figure 5). Hence, windmill farms will, most likely, become an important and large-scale anthropogenic impact on benthic systems of coastal areas.

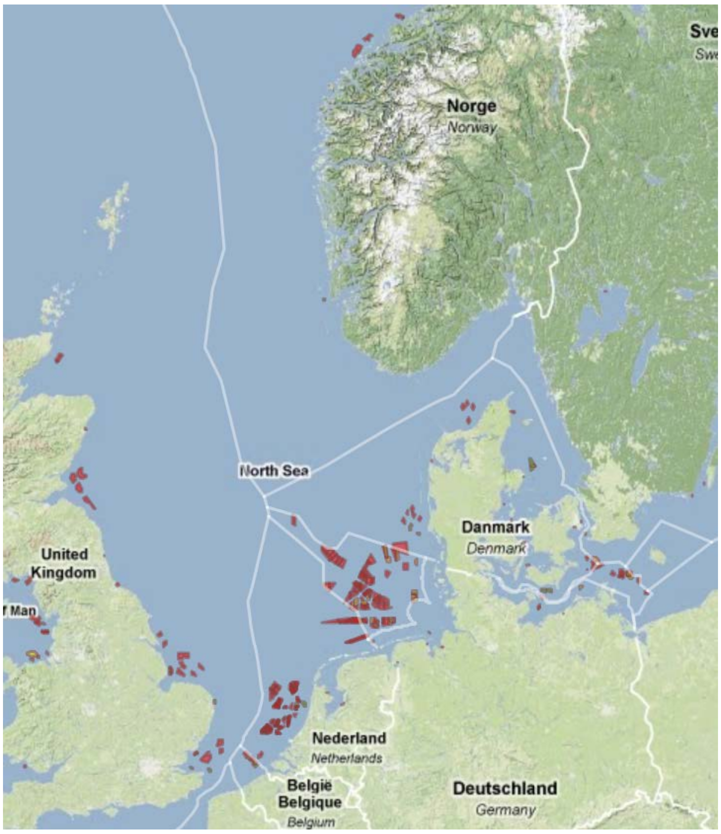

Figure 5. Map extract of offshore windmill farms in the North Sea and parts of the Baltic Sea (from http://rave.iset.uni-kassel.de/rave/pages/map).

Therefore the BEWG will support the organization of a workshop on the impact of offshore windmill farms on benthos. Scientists that are working on or interested in this topic will be invited to exchange knowledge of the state of the art between experts, to condense knowledge on windmill farm effects and to identify possible redundancies in the monitoring research and potential knowledge gaps. The workshop will be organised by J. Dannheim and S. Degraer.

6.2.3 Notification of EU expected call FP7-KBBE-2012-6

The group was informed about the expected EU call FP7-KBBE-2012-6: Integrating the role of benthic systems in fisheries management, a potential topic for the coordinated cross-thematic activities under "The Ocean of Tomorrow" (http://www.euresearch.ch/?id=760#c5034).

7 ICES matters

7.1 Comments from the BEWG on the "Report of the Workshop on Marine Biodiversity (WKMARBIO): furthering ICES engagement in biodiversity issues"

The Benthos Ecology Working Group responded to a request to review the report of the workshop on Marine Biodiversity (WKMARBIO). Comments were collected but there was limited time to go into details and no guidance was provided on how to comment and what specific questions they needed addressing.

Specific comments were:

- The BEWG believes that this is a good strategic initiative and feels it can play an important role in many aspects of this work. In particular the BEWG can contribute to the review of the scientific merit or reliability in the use of indicator species and guidance on best practice for selecting such species. Also the work the BEWG carries out on ecosystem functioning is relevant to actions t-x in section 4.2 of the report.
- The BEWG acknowledges that this was a first exploratory workshop and would like to see the list of collaborators reconsidered for the future. They also feel there is a need for a clear list of objectives and action plan.
- The BEWG feels like a definition of the term 'biodiversity' as how it is used within the report, and group, is required. If marine biodiversity advice is to be given then a clear definition of this term is needed and has to include ecosystem function, processes and structure. It is stated in the introduction but it is not subsequently shown in the body of the report how this will be considered.
- Section 3 of the report lists the different policy drivers related to marine biodiversity issues. The BEWG advises reviewing these initiatives for common goals, identifying the similarities and differences. In all these initiatives biodiversity conservation is always the main goal. However, the basic role of biodiversity and ecosystem functioning is not well understood, so this highlights a need for more research.
- Table 4.1.2.1. Classes of indicators that would be of short term or medium use to policy and management agencies. This table needs more detail on the background of the information within it in order to for it to be reviewed.

7.2 BEWG contribution to the MSFD Steering Group

The BEWG group listed available information and knowledge useful for the implementation of the benthic part of the MSFD descriptors and their respective indicators (Table 2). In the column "BEWG initiatives", current and previous BEWG activities are listed. This information might aid to the implementation of a certain indicator of a descriptor. In the "Members" column, a non-exhaustive list of activities of individual BEWG members is provided.

From a benthic point of view it is rather hard to construct a universal approach on how Good Environmental Status (GES) can be defined for the given indicators because they often differ on a geographical and habitat scale. Additionally, the indicators per descriptor can be interpreted in different ways, rendering a common interpretation and definition of those indicators and GES on a European scale to be essential.

The approach proposed by the Water Framework Directive (WFD) (incl. reference sites, historical data, modelling) can form the basis to define GES, together with a combination of scientific evidence and best professional judgment (Van Hoey *et al.*, 2010).

The items below indicate some limitations when filling in GES for benthic ecosystems.

7.2.1 Biodiversity

The MSFD requires marine biological diversity to be maintained, meaning that the condition, extent/size and distribution of habitats and species are in line with prevailing physiographic, geographic and climatic conditions.

Whereas the information, needed to apply these indicators, is available for various well-studied ecosystem components, such information is largely lacking for the benthic flora and fauna. For instance, although the distribution and extent of several benthic habitats might be known from project such as MESH, it proved to be extremely difficult evaluate habitat condition. Furthermore, reliable information on population size and condition of benthic species is largely lacking.

Even if such information would be available, the next problem would then be to evaluate whether the benthos' characteristics are in line with what could be expected: such evaluation (again) necessitates the availability of reference data, but also raises questions related to shifting baselines.

Even though the above mentioned limitations are to be acknowledged, information on the benthos might still be useful in a benthos – MSFD context. For example, as it comes to the integration of ecological information regarding the benthos, the Biological Valuation methodology, as developed by Derous *et al.* (2007a, b), proves useful, as demonstrated by Borja *et al.* (2011) in the first European assessment within the MSFD undertaken in the Bay of Biscay, whereas Species Distribution Modelling might help unravelling species-environment relationships and hence habitat and population potential as a measure of extent/size and distribution.

7.2.2 Non-indigenous species

The MSFD requires that non-indigenous species do not adversely alter the ecosystem. At present, many non-indigenous species have become part of the ecosystem, mainly resulting in negative impacts. In some cases, the invaders play a beneficial role in the ecosystem functioning or for the productivity of commercial resources. Therefore, research should focus on the ecological effect of those species or in other words to define its function or occupied niche in the ecosystem. This would act as a basis to determine whether a non-indigenous species has to be defined as 'suitable' or not.

Another aspect taken into account is the economic consequences a non-indigenous species can cause. Thereby considering that the economic value of a species can change over time by changes in the productivity of commercial resources. Invasive species can change the availability of some commercial species and the market adjusts eventually, for example as in the shifts in the last century in Europe of the production of the European Flat Oyster, blue mussel and the Pacific Oyster.

7.2.3 Food web

In this descriptor indicators focusing on the lower levels of the food web and inter-level interactions are lacking. Knowledge about the basis of the food web is important to define 'sustainability' or 'carrying capacity' of the ecosystem for the top levels of the food web.

7.2.4 Sea Floor integrity

The WFD methods and approaches to define the good ecological status of the benthic ecosystem are also valuable in the MSFD context. It is not necessary to develop new ones, but to invest in the existing ones (e.g. stressor-response) and improve them to better assess structural and functional benthic aspects (Van Hoey *et al.*, 2010). To define the structure and function of benthic systems as highlighted in 'Seafloor integrity' are not trivial tasks, especially when, for such systems, the definition and understanding of function is still in its beginnings. We need sound tools to provide an accurate assessment of these benthic ecosystems, so we can begin to underpin processes that can be directly related to function (Birchenough *et al.*, 2011).

The use of a static sensitivity/tolerance list of species in assessment tools around the world to define the ecological status of waters (using flora and fauna) is common. These lists are useful tools and were improved in the last decade (adding of species worldwide, revisions of autecology), but caution is required. This due to the fact that, for some/many species a change of life history strategy or its autecology requirements and consequently its sensitivity along distinct environmental gradients is expected

Table 2. Overview of available information and knowledge useful for filling in the benthic part of the MSFD descriptors and its indicators.

DESCRIPTOR	INDICATORS	BEWG INITIATIVES	MEMBERS
BIODIVERSITY	Species distribution Distributional range	Species suitability modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Rees *et al.*, 2007; Kröncke *et al.*, 2011)	Most BEWG members were involved in national monitoring programs throughout the ICES area (Europe/America)
	Distributional pattern within the latter	Species suitability modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Kröncke *et al.*, 2011)	
	Area covered by the species (for sessile/benthic species)	Species suitability modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Kröncke *et al.*, 2011)	
	Population size Pop abundance/biomass	Currently no information available, Quantitative modelling techniques were under review within the group (BEWG work Mayya Gogina)	Bivalve survey Dutch Coast (e.g. J. Craeymeersch, IMARES)
	Population condition Pop demographic characteristics	/	MAFCONS project
	Population genetic structure	/	
	Habitat distribution Distributional range	Species distribution modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Kröncke *et al.*, 2011)	US Seabed map, MESH project, MAREANO project
	Distributional pattern	Species distribution modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Kröncke *et al.*, 2011)	
	Habitat extent Habitat area	Species distribution modelling, North Sea Benthos survey (1986 and 2000) (Künitzer *et al.*, 1992; Kröncke *et al.*, 2011)	
	Habitat volume, where relevant	/	
	Habitat condition Condition of the typical spp and communities	Benthic red species list, North Sea Benthos survey (1986 and 2000), Climate position paper (Birchenough *et al.*, in prep), Benthic indicator work (e.g. Van Hoey *et al.*, 2010)	BTA work Baltic??
	Relative abundance/biomass, as appropriate	/	
	Physical, hydrological and chemical conditions	/	
	Ecosystem structure	North Sea Benthos survey (Reiss *et al.*, 2010)	

	Composition and relative prop of ecosystem components		
Non-indigenous species	Trends in abundance, temporal occurrence and spatial distribution	See ICES WGITMO, North Sea Benthos survey (1986 and 2000) (Künitzer *et al*., 1992; Kröncke *et al*., 2011)	Non-indigenous benthic species expertise available in the group
	Ratio between invasive and native	See ICES WGITMO	
	Impact of non-indigenous invasive spp at the level of species, habitat and ecosystem	See ICES WGITMO	
Food web	Performance of key predator species using their production per unit/biomass	/	
	Large fish (by weight)	/	
	Abundance trends of functionally important selected groups/species	North Sea Benthos survey (2000) (Rees *et al*., 2007)	
Sea Floor integrity	Type, abundance, biomass and areal extent of relevant biogenic substrate	Species distribution modelling/mapping	MAREANO project
	Extent of the seabed sign affected by human activities for different substrate types	See ICES SGVMS	
	Presence of particularly sensitive and/or tolerant species	Benthic red species list, Sensitivity/tolerance characteristics of species (BEWG work M. Zettler)	
	Multi-metric indices assessing benthic community condition and functionality, such as species diversity and richness, prop of opportunistic to sensitive species	Benthic indicators (e.g. Van Hoey *et al*., 2010), WKBEMET (ICES, 2008)	A lot of publications on this topic made by BEWG members (e.g. Angel Borja, various publications, and Birchenough *et al*., 2011)
	Proportion of biomass or number of individuals in the macrobenthos above length/size	/	
	Parameters describing the characteristics of the size spectrum of the benthic community	/	

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Birchenough, S., Degraer, S., Reiss, H., Borja, A., Braeckman, U., Craeymeersch, J., De Mesel, I., Kerckhof, F., Kröncke, I., Mieszkowska, N., Parra, S., Rabaut, M., Schroeder, A., Van Colen, C., Van Hoey, G., Vincx, M., Wätjen, K., in preparation. Responses of marine benthos to climate change, ICES report.

Borja, Á., I. Galparsoro, X. Irigoien, A. Iriondo, I. Menchaca, I. Muxika, M. Pascual, I. Quincoces, M. Revilla, J. Germán Rodríguez, M. Santurtún, O. Solaun, A. Uriarte, V. Valencia, I. Zorita, 2011. Implementation of the European Marine Strategy Framework Directive: A methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay). Marine Pollution Bulletin, 62: 889-904.

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Kröncke I., H.g Reiss, J.D. Eggleton, J. Aldridge, M.J.N. Bergman, S. Cochrane, J.A. Craeymeersch, S. Degraer, N. Desroy, J.-M. Dewarumez, G.C.A. Duineveld, K. Essink, H. Hillewaert, M.S.S. Lavaleye, A. Moll, S. Nehring, R. Newell, E. Oug, T. Pohlmann, E. Rachor, M. Robertson, H. Rumohr, M. Schratzberger, R. Smith, E. Vanden Berghe, J. van Dalfsen, G. van Hoey, M. Vincx, W. Willems, H.L. Rees (2011, accepted). Changes in North Sea macrofauna communities and species distribution between 1986 and 2000. Estuarine, Coastal and Shelf Science.

Künitzer, A., Duineveld, G.C.A., Basford, D., Dewarumez, J.M., Dörjes, J., Eleftheriou, A., Heip, C., Herman, P.M.J., Kingston, P., Niermann, U., Rumohr, H., de Wilde, P.A.W.J., 1992. The benthic infauna of the North Sea: species distribution and assemblages. ICES Journal of Marine Science 49:127-143.

Rees, H. L., Eggleton, J. D., Rachor, E., and Vanden Berghe, E. (Eds). 2007. Structure and dynamics of the North Sea benthos. ICES Cooperative Research Report No. 288. 258 pp.

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Van Hoey, Gert; Borja, Angel; Birchenough, Silvana; Degraer, Steven; Fleischer, Dirk; Kerckhof, Francis; Magni, Paolo; Buhl-Mortensen, Lene; Muxika, Iñigo; Reiss, Henning; Schröder, Alexander; Zettler, Michael, 2010. The use of benthic indicators in Europe: from the Water Framework Directive to the Marine Strategy Framework Directive. Marine Pollution Bulletin 60:2187-2196

7.3 BEWG contribution to the Strategic Initiative on Area Based Science and Management

Following ToRs were added for consideration by the BEWG and duly discussed:

ToR. Take note of and comment on the Report of the Workshop on the Science for area-based management: Coastal and Marine Spatial Planning in Practice (WKCMSP)

The BEWG acknowledges the report from SIAMS and has answered to the listed requests to ICES Working Groups presented in the report from the Workshop.

ToR. Has or can the WG, identified or developed priorities or scenarios (or behaviour or ecosystem models that could be used) in terms of natural or anthropogenic pressures and/or ecosystem status, function, structure, and/or process that could be helpful in setting good environmental status (MSFD-GES) or for marine spatial planning.

The BEWG is not presently directly involved in developing priorities and scenarios that are related to setting good environmental status (MSFD-GES), however, the group is and has been involved in relevant projects and activities:

Many of the BEWG members and their institutes are participating in the European project MESMA (e.g. AZTI, ILVO, IMR, and others).

Members of the BEWG have been involved in a paper submitted to Marine Pollution Bulletin:

Stelzenmüller, V., P. Breen, F. Thomsen, F. Badalamenti, A. Borja, L. Buhl-Mortensen, J. Carlstöm, G. D'Anna, N. Dankers, S. Degraer, M. Dujin, F. Fiorentino, I. Galparsoro, M. Gristina, K. Johnson, P.J.S. Jones, S. Katsanevakis, L. Knittweis, R. Kyriazi, C. Pipitone, J. Piwowarczyk, M. Rabaut, T. Sorensen, J. van Dalfsen, V. Vassilopoulou, T. Vega, M. Vincx, S. Vöge, A. Weber, N. Wijkmark, R. Jak, W. Qiu, R. ter Hofstede (submitted). Monitoring and evaluation of spatially managed areas: A generic framework for implementation of ecosystem based marine management and its application. Marine Pollution Bulletin (in press).

Additional relevant papers are:

Galparsoro, I., P. Liria, I. Legorburu, J. Bald, G. Chust, P. Ruiz-Minguela, G. Pérez, J. Marqués, Y. Torre-Enciso, M. González, A. Borja (accepted). A Marine Spatial Planning approach to select suitable areas for installing wave energy converters (WECs), on the Basque continental shelf (Bay of Biscay). Coastal Management.

Galparsoro, I., Á. Borja, I. Legorburu, C. Hernández, G. Chust, P. Liria, A. Uriarte, 2010. Morphological characteristics of the Basque continental shelf (Bay of Biscay, northern Spain); their implications for Integrated Coastal Zone Management. Geomorphology, 118:314-329.

Pascual, M., A. Borja, S. Vanden Eede, K. Deneudt, M. Vincx, I. Galparsoro, I. Legorburu (submitted). Marine biodiversity valuation mapping of the Basque continental shelf (Bay of Biscay), within the context of the Marine Spatial Planning. Estuarine, Coastal and Shelf Science.

In other papers published since 2009, some marginal references have been included to this topic. Some important insights are given also in papers related to the MSFD, by some members of the group:

Borja, A., 2011. Good Environmental Status Indicators for benthos within the Marine Strategy Framework Directive: taking advantage from the Water Framework Directive. Progress in Marine Conservation in Europe 2009 2nd International Conference, Federal Agency for Nature Conservation (Germany). H. von Nordheim, J.C. Krause, K. Maschner (Eds.): 219-224.

Borja, Á., M. Elliott, J. Carstensen, A.-S. Heiskanen, W. van de Bund, 2010. Marine management - Towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin, 60:2175-2186.

Borja, Á., I. Galparsoro, X. Irigoien, A. Iriondo, I. Menchaca, I. Muxika, M. Pascual, I. Quincoces, M. Revilla, J. Germán Rodríguez, M. Santurtún, O. Solaun, A. Uriarte, V. Valencia, I. Zorita, 2011. Implementation of the European Marine Strategy Framework Directive: A methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay). Marine Pollution Bulletin, 62 889-904.

Ferreira, J. G., J. H. Andersen, A. Borja, S. B. Bricker, J. Camp, M. Cardoso da Silva, E. Garcés, A.-S. Heiskanen, C. Humborg, L. Ignatiades, C. Lancelot, A. Menesguen, P. Tett, N. Hoepffner, U. Claussen, 2011. Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. Estuarine, Coastal and Shelf Science, 93 117-131.

Rice, J., C. Arvanitidis, A. Borja, C. Frid, J. G. Hiddink, J. Krause, P. Lorance, S. Á. Ragnarsson, M. Sköld, B. Trabucco, L. Enserink, A. Norkko, 2011. Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. Ecological Indicators, In Press, Corrected Proof.

Van Hoey, G., A. Borja, S. Birchenough, L. Buhl-Mortensen, S. Degraer, D. Fleischer, F. Kerckhof, P. Magni, I. Muxika, H. Reiss, A. Schröder, M. L. Zettler, 2010. The use of benthic indicators in Europe: From the Water Framework Directive to the Marine Strategy Framework Directive. Marine Pollution Bulletin, 60:2187-2196.

ToR. Has or can the WG identify indicators for assessing which species or habitats need protection or which might be key indicator species for assessing the effects of human activities. Particular consideration should be give to assessing the impacts of very large renewable energy plans with a view to identifying/predicting the potentially catastrophic outcomes. For such plans tipping point/carrying capacity analyses, models and indicators are needed.

- For assessing which species or habitats need protection the BEWG suggest that the Red List that has been developed by many countries for their marine areas should be used. An initiative is planned to prepare a Red List for the whole North Sea (see 6.2.1). In the Baltic Sea the Helcom started a similar project already where some BEWG members contribute (to be finalized in 2012).
- The BEWG has not investigated species or habitats that need protection, key indicators or carrying capacity analysis for assessing the effects of large renewable energy plans on benthic systems yet. The BEWG will initiate a workshop on the topic of impact on benthos by the upcoming large renewable energy plans (see 6.2.2).
- From the MESMA project, a paper is being prepared, related to habitats and MSP:

Salomidi, M., S. Katsanevakis, Á. Borja, U. Braeckman, D. Damalas, I. Galparsoro, R. Mifsud, S. Mirto, M. Pascual, C. Pipitone, M. Rabaut, V. Todorova, V. Vassilopoulou, T. Vega Fernández (in preparation). Goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone for ecosystem-based marine spatial management. Mediterranean Marine Science.

ToR. Can the WG provide or identify where habitat maps covering system function and process, methods to assess resistance and resilience of ecosystems (vulnerability mapping), assessment of connectivity (e.g. life history traits), carrying capacity, impacts (including cumulative) and potential synergies may exist? Or provide suggestions on how such maps could be generated or where data for their production could be found should also be provided.

At present, to the knowledge of the BEWG, there are no such habitat maps available. However, the BEWG has formulated a group with the general goal of species distribution modelling and many ongoing projects are involved in the production of relevant maps.

The generation of such habitat maps will involve several steps including the:

- Identification of the relation between habitat and bottom community distribution including abundance, biomass and functional groups.
- Identification of the connection between fisheries pressure and impact on bottom community with focus on resilience and vulnerability of species and communities.

ToR. ICES should prepare a spatial/temporal map of fisheries management/regulation under the CFP or national regulation – scale/extent/duration/ closures/restrictions etc. In addition the maps showing the areas of each of the RAC would be helpful. This will facilitate the incorporation of fisheries management into the planning process at an early stage. Has the WG prepared or is it aware of the existence of such maps or could it provide data / information that assist in their preparation?

This request was not deemed relevant to the competence of the BEWG.

7.4 Prepare contributions for the 2011 SSGEF session during the ASC

Due to the eruption of the Icelandic Eyjafjallajökull volcano and its consequent impact on the flow and organisation of the BEWG 2010 meeting (see BEWG 2010 report), last year's meeting focused on the finalisation of ongoing activities, leaving ample time for discussing the possibilities for future BEWG initiatives. This year's meeting hence focused on plans for future collaboration within (and beyond) BEWG and as such assured the development of a renewed research plan for the BEWG.

Consequently, new exciting findings cannot be presented at the SSGEF session, but the group decided to present an overview of the major findings of the BEWG viewpoint paper on benthic indicators, as published in December 2010, and to present the state of the art of the development of the BEWG review paper on species distribution modelling and mapping in the marine realm.

7.5 Election BEWG Chair 2012–2014

The Chair explained his conviction that a 3-years cycle of chairmanship is not only promoting a shared responsibility within the Expert Group, but is also the guarantee for the necessary dynamism within the Expert Group. The Chair hence expressed his wish to step down. However, in absence of further candidates, the group decided unanimously to elect S. Degraer for one further year as Chair of the BEWG. During this year the Chair will (again) actively look for replacement from 2013 onwards.

8 Closure of the meeting

The Chair thanked the local host and his team for their hospitality and generosity. He also thanked the participants for their input and closed the meeting on Friday, 6 May 2011, 17:30 hours.

Annex 1: List of participants

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Contributions were received from A. Borja, E. Rachor, A. Schröder and C. Van Colen.

Planned WebEx meeting throughout the whole week with R. Langton, T. Noji and NOAA colleagues were cancelled due to continued technical problems.

Apologies were received from D. Connor, J. Craeymeersch, B. Diaz, C. Greathead, M. Guerra, J.G. Hiddink, V. Kostylev, I. Kröncke, A. Norkko, F. O'Beirn, R. Osman, S. Parra, M. Rabaut, M. Robertson, L. Robinson, R. Rosenberg, H. Rumohr, D. Schiedek, P. Snelgrove, J. van Dalfsen, E. Verling, R. Whitlatch, and J. Warzocha.

Annex 2: Agenda

ICES-BEWG MEETING 2011

TIME SCHEDULE

Fort Pierce, Florida (USA), 02/05/2011 – 06/05/2011

Yet to be plugged into the agenda, whenever time is available:

- Identify elements of the EGs work that may help determine status for the 11 Descriptors set out in the Commission Decision
- Provide views on what good environmental status (GES) might be for those descriptors, including methods that could be used to determine status.

Weekend 30/04 – 01/05/2011

- Travel of participants
- Airport pick-ups coordinated by Björn Tunberg

Monday 02/05/2011

AM: 9h00 – 12h30

- Practicalities (internet connection, coffee breaks, lunch, …)
  - Björn Tunberg
  - Steven Degraer: WebEx facilities (optional)
- Adoption of the agenda: Introduction to the workplan and time schedule of the meeting

– Steven Degraer

- Introduction to ICES and BEWG

– Steven Degraer

- Round table presentation of the participants

– All participants

PM: 13h30 – 17h00

- 1.A.1 Report on recent findings on long-term data series analyses and other climate change-related benthos activities
  - Coordination: Steven Degraer
  - Introductory presentations: Silvana Birchenough, Dennis Allen, Paul Montagna, Hasse Kautsky
- 1.A.2 Explore the availability of long-term benthos datasets in US and Canada (ToR b) and consider links to the BEWG Benthos Long-Term Series Network (BELTS-net)

– Coordination: Björn Tunberg, Paul Snelgrove, Alex Schröder

17h30 – 20h30

- Welcome American buffet with drinks at the Smithsonian Aquarium (sponsored)

Tuesday 03/05/2011

AM: 9h00 – 12h30

- 1.A.3 Consider the status of the intersessional BEWG work on long-term data series analyses with special attention to climate change and to decide on future actions (ToR a)

  – Coordination: Silvana Birchenough, Carl Van Colen

PM: 13h30 – 18h00

- 1.B: Consider the 2010–2011 work of the Study Group on Climate-Related Processes within the Benthos of the North Sea and to formulate recommendations regarding its future actions (ToR d)

– Coordination: Henning Reiss, Silvana Birchenough

- 1.C: BEWG contribution to the ICES Position Paper on Climate Change: State of the Art and re-edit for submission to WIRES climate change as a review for publication

– Coordination: Steven Degraer / Silvana Birchenough / Henning Reiss

Wednesday 04/05/2011

AM: 7h30 – 14h00

- Social event: Pontoon cruise Jonathan Dickinson State Park (incl. lunch)
  - Coordination: Björn Tunberg

PM: 14h00 – 18h00

- 2.A: Report on recent developments in environmental quality assessment covering phytobenthic and zoobenthic topics

– Coordination: Angel Borja, Gert Van Hoey

– Introductory presentations: Paolo Magni, Lene Buhl-Mortensen

- 2.B: Broaden the geographic scope of the BEWG work on benthic indicators to North American waters (ToR f)

– Coordination: Björn Tunberg, Angel Borja

– Introductory presentations: Paul Montagna, Jeff Hyland

Thursday 05/05/2011

AM: 9h00 – 12h30

- 3.A: Report on recent initiatives on habitat suitability modelling and mapping

– Coordination: Henning Reiss

– Introductory presentations: Hasse Kautsky, Paolo Magni, Jennifer Dannheim, Lene Buhl-Mortensen

- 3.B.1 Fine tune the outline of a BEWG review paper on habitat suitability modelling

– Coordination: Henning Reiss

- 3.B.2 Consider the outcome of the intersessional meeting between BEWG and WGMHM and the format of future collaboration (ToR e)

– Coordination: Steven Degraer

- 3.C: Joint WGMHM - BEWG Theme Session at ICES Annual Science Conference 2011 (Gdánsk, Poland, 19-23/09/2011) "Habitat modelling and mapping for better assessment and monitoring of our seas": State of the Art

    – Coordination: Steven Degraer

PM: 13h30 – 18h00

- 4.A: Report on exciting developments in ongoing phyto- and zoobenthic research in the ICES area, with special attention to North-American activities (ToR c)

– Coordination: Bjorn Tunberg, Steven Degraer

– Presentations: Mayya Gogina

- 4.B: Future collaborative BEWG research projects: Suggestions and planning

– Coordination: Steven Degraer

    – Suggestions: Eike Rachor, Lene Buhl-Mortensen

- 4.C: BEWG strategic planning

– Coordination: Steven Degraer

19h00 – evening

- Workshop dinner

– Coordination: Björn Tunberg

Friday 06/05/2011

AM: 9h00 – 12h30

- 5.A: Review, report on and develop the outputs of the ICES SIBAS Workshop on 'Biodiversity indicators for assessment and management'

– Coordination: Steven Degraer

- 5.B: Prepare contributions for the 2010 SSGEF session during the ASC

– Coordination: Steven Degraer

- 5.C: Election BEWG Chair 2012-2014

– Coordination: Steven Degraer

Submission of candidatures

PM: 13h30 – 18h00

- Spare time for issue finalization (break out group session)
- Any other business
- Reporting: State-of-the-art overview and delegation of tasks
- Closure of the meeting

Annex 3: BEWG terms of reference for the next meeting

The **Benthos Ecology Working Group** (BEWG), chaired by Steven Degraer, Belgium, will meet in Sandgerdi, Iceland, 7–11 May 2012 to:

a) Consider the status of the intersessional BEWG work on long-term data series analyses (BeLTS-net activities) with special attention to climate change and to decide on future actions;

b) Consider the 2010/2011 work of the Study Group on Climate-Related Processes within the Benthos of the North Sea and to formulate recommendations regarding its future actions;

c) Consider the status of the BEWG paper on "The myths of benthic indicators" and plan for future (intersessional) work on benthic indicators;

d) Consider the status of the BEWG review paper on "Species distribution modelling and mapping (SDM) in the marine environment and its relevance for ecosystem management" and plan for future (intersessional) work on SDM;

e) Consider the outcome of the intersessional meeting between BEWG, WGMHM and WGEXT and the format of future collaboration;

f) Report on exciting developments in ongoing phyto- and zoobenthic research in the ICES area.

BEWG will report by 15 June 2012 (via SSGEF) for the attention of SCICOM.

Supporting Information

Priority	The current activities of this Group will lead ICES into issues related to the ecosystem affects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Scientific justification	ICES Science Plan, Priority 1 "Understanding ecosystem functioning" Research topic "Climate change processes and prediction of impacts" Terms of Reference a) and b) Evaluating the intersessional analyses of long-term data series (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. Knowledge of the processes behind these changes (ToR b) will assist in elucidating cause-effect relationships as a prerequisite for future forecasts. ICES Science Plan, Priority 2: "Understanding interactions of human activities with ecosystems" Various Research topics Term of Reference c) While a wide suite of benthic quality indicators were developed and applied, many authors already pinpointed towards shortcomings and pitfalls in the application of various indicators. The BEWG will investigate the variable tolerance of (indicator) species to pressures along natural environmental gradients as one of the key pitfalls in indicator application. Term of Reference f) This is a prerequisite for the scientific information status of the group.

	ICES Science Plan, Priority 3: “Development of options for sustainable use of ecosystems” Various Research topics Terms of Reference d) and e) 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. Lessons learned from SDM in the terrestrial environment and earlier applications of SDM in the marine realm will allow outlining the state-of-the-art in the marine environment as well as the way forward (ToR d). Three EGs are currently embracing SDM, namely the BEWG, the WGMHM and WGEXT. To maximize the use of human resources in SDM, clear agreements between all EGs are needed (ToR e).
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The BEWG is normally attended by some 15–25 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are no obvious direct linkages with the ICES advisory services.
Linkages to other committees or groups	There is a very close working relationship with the Study Group on Climate-related Benthic Processes in the North Sea (SGCBNS), Working Group on Marine Habitat Mapping (WGMHM), the Working Group on Aggregate extraction (WGEXT) and WGECO.
Linkages to other organizations	

Annex 4: Recommendations

Recommendation	Adressed to
1. To update the list of BeLTS-Net initiatives during its Autumn 2011 meeting.	Study Group on Climate-Change related Benthic Processes in the North Sea (SGCBNS)

Annex 5: Action points

- B. Tunberg and North-American colleagues to update the long term series table with special attention to North-American data series (see 3.1.2).
- A. Schröder to inform colleagues from other relevant networks, focusing on large-scale and/or long-term trends within the benthos, about the BELTS-Net initiative and its programme (see 3.1.2).
- S. Degraer to invite VLIZ to construct, launch and host the BELTS-Net website (see 3.1.2).
- SGCBNS to update on the BELTS-Net initiatives during its annual meeting (October 2011) (see 3.1.2).
- S. Birchenough and C. Van Colen will plan for future activities on the BELTS-Net initiative on "Long term trends and regime shifts" in consultation with all participants (see 3.1.3).
- A plan for future activities on long-term data series analyses with special attention to climate change will be developed in consultation with all participants (see 3.1.3). S. Birchenough and C. Van Colen to take the initiative.
- The Case study 1 initiative of the SGCBNS (see 3.2) is still open for participation. Contact S. Birchenough (silvana.birchenough@cefas.co.uk) or H. Reiss (henning.reiss@uin.no).
- S. Birchenough to take the lead in drafting a manuscript on benthos and climate change to be submitted for publication to the WIRES journal Climate Change (see 3.3).
- All participants to have a look at the final version of the BEWG chapter on benthos and climate change as to make suggestions for a final fine tuning and completion of the manuscript to be submitted to WIRES "Climate Change"(3.3).
- B. Tunberg and P. Magni to report on the outcome of the UNESCO workshop on The Ecological Implications of Climate Change on the Venice Lagoon and its relevance to the BEWG.
- The new BEWG initiative "On the myths of indicators" (see 4.3.1) is still open for participation. Contact M. Zettler (michael.zettler@io-warnemuende.de) or C. E. Proffitt (cproffit@fau.edu).
- The new BEWG initiative on a review paper on species distribution modelling and mapping in the marine environment and its relevance for ecosystem management (see 5.2.1) is still open for participation. Contact the author of the corresponding topic and H. Reiss (henning.reiss@uin.no). Further addresses can be found in annex 1.
- H. Reiss to invite WGMHM to contribute to the BEWG review paper on species distribution modelling in the marine realm (see 5.2.1)
- M. Gogina will take the initiative for an extended literature search on quantitative models that are capable of predicting species abundance and biomass (see 5.2).
- S. Degraer to liaise with the Chairs of WGMHM and WGEXT (web conference) to explore what further engagement could be achieved by a collaboration between the three ICES of exploring what further engagement could be achieved by a collaboration between the three expert groups (see 5.3).

- S. Degraer to report on the outcome of the joint WGMHM-BEWG Theme Session at the ICES Annual Science Conference 2011 (see 5.4).
- The BEWG supports E. Rachor to initiate a first meeting on the development of regional macrobenthos red lists (see 6.2.1).
- The BEWG supports J. Dannheim and S. Degraer to initiate a workshop on the impact of offshore windmill farms on benthos (see 6.2.2).

Annex 6: Regime Shifts Discussion document

Task 1.A.2 " Consider the status of the intersessional BEWG work on long-term data series analyses with special attention to climate change and to decide on future actions (ToR a)"

- The proposed analyses decided at the BEWG meeting in Askö are still fit for the purpose of this work (we were/are looking for contributions across a wide geographical range; contributions should have (nearly) the same timeframe and the same level of detail (at least 3 replicates, max. time interval 1–2years)). However, CV suggested the addition of some extra analysis regarding the detection/predictability of regime shifts (i.e. the next step, see further).

Available data sets were identified and there are results available for the following data sets, based on the agreed SOP (at the BEWG meeting in Askö during 2009). These are:

- Alex Schroeder (Germany),
- Silvana Birchenough (UK),
- Carl Van Colen and Gert Van Hoey (Belgium),
- Angel Borja (Spain),
- M. L. Zettler and Alexander Darr (Germany)
- Bjorn Tunberg (USA)

The information available was collated in a single document by SB. The next step from this work is to explore the data sets. Can we observe at some of the long-term data sets: i) are there similar/same patterns across the stations? ; ii) What may cause the observed patterns and how to statistically proof this? and iii) which stations will be selected for a more detailed analyses?

- We would restrict to data originating from areas with little anthropogenic disturbance. Almost all changes to the benthic ecosystem are induced by a combination of natural processes, climate change en anthropogenic activities (besides human-induced CC). Anthropogenic pressures generally occur along a spatial gradient, the potential for cumulative effects and multiple stressor interactions is high, with such interactions likely to result in sudden (i.e. definition of regime shift), rather than gradual change (e.g. gradual increase in SST).

- Detection of regime shifts.

  - SB co-authored paper by Spencer *et al.* that you used RSD method to detect regime shifts. This technique could be further explored with the existing data sets available for the BEWG initiative.
  - CV suggested that also in connection to the detection of regime shifts, the big step forward would be to predict them(this is a challenging task, surely because we do not completely understand the system yet) ,though not impossible. This approach could also be further explored as phase 2.

CV produced some suggestions on the way to explore the data sets available. For example if, (1) large changes in abundance/biomass of key species and (2) increased temporal variability are two promising indicators of impending regime/state shifts. Further work on the predictability of regime shifts should thus focus on these two aspects. The latter has mainly be demonstrated by modelling work and it would be quite new to proof this with benthos field data alone (we need long-term replicated data for this). So, it should be feasible to analyze both aspects based on the gathered datasets within this BEWG-initiative. Are the detected regime shifts preceded by so-called 'flickering' and changes in abundances of key species? Regarding the detection of "flickering": for univariate data we can simply look at the variance among replicates; for multivariate data the index of multivariate dispersion in addition to the within year dissimilarity may be informative. So for this, we do not necessary need data from 'largely undisturbed' areas *per se*, we only need long-term datasets with a proper level of detail.

- In addition, we can try to perform multiple regressions to identify the most important contributing parameters/variables to the variability (e.g. NOA vs. nutrient load). In order to understand what is driving the shifts, such approach may be more efficient than try to look for similar patterns across a wide geographical range (which would then point towards broad-scale CC-impacts or natural cyclical patterns). Note that (1) this analysis requires a lot of environmental parameters (related to anthropogenic activities) which may not be available for all stations and (2) that I am certainly not suggesting that we need to skip the stations without anthropogenic disturbance (but a gradient on this would be interesting to identify the drivers of regime shifts, I think). SB also suggested the usage of VMS data available for the North Sea areas, these data sets could be requested via ICES and be also used as part of the analysis.

Annex 7: Outline new BEWG initiative: Review of Species Distribution Modelling in the Marine Environment and its Relevance for Ecosystem Management and Spatial Planning

Authorship: BEWG (contributors to this topic)

(first draft intended for December 2011)

__Contents__

1. Introduction

(Henning Reiss)

- Application of Species Distribution Modelling (SDM) focused on the linkages between SDMs and marine ecosystem management and spatial management (what is needed in ecosystem management?).
- Specific characteristics of marine environments compared to terrestrial systems, where SDMs are much more commonly used
- Objective: What are the possibilities and the limitations of SDMs regarding its usefulness for marine ecosystem management or marine spatial planning?
- …

2. Methods

2.1 Environmental data

(Contribution from the Habitat Mapping Group; contacts via ; Pål Buhl-Mortensen and Lene Buhl-Mortensen)

- Habitat mapping and data availability in the marine environment (which data are needed or lacking?)
- Difficulties and methods (briefly) of mapping and generating full scale environmental variables in marine systems (e.g. hydroacoustics, hydrodynamic modelling)

- Differences in data availability between marine and terrestrial systems (e.g. climate change scenarios)
- …

2.2 Biological data

(Jenny Dannheim)

- Difficulties with biological data (for using SDMs) in the marine environment (real absence data; highly mobile species (fish); etc.)
- Advantages and disadvantages of using presence only data/presence absence data
- Maybe (?): what part of the ecological niche will be primarily modelled when using different types of biological data (realized vs fundamental niche)
- …

2.3 Overview of SDM methods

(Mayya Goggina)

- Brief overview of methods for modelling species distribution and communities
- Including already existing application of these method in marine environments and link to ecosystem management needs
- Advantages and disadvantages of the different model types for ecosystem management purposes (over- and under prediction; realised or fundamental niche – depending on the conservation or management aim)
- …

2.4 Limitations

(Steven Degraer, Hasse Kautsky)

- Limitations of SDMs in general, focused on management issues (more specific modelling problems should be addressed in the chapters of application)
- For what purpose can distribution maps not be used?
- What information is needed in addition to the modelling output to make the information useful in a management context?
- …

3. Application of SDMs

3.1 Marine spatial planning (e.g. MPAs)

(Jenny Dannheim, Henning Reiss)

- Using distribution predictions for marine spatial planning
- What does a distribution map tells managers?

- Using SDMs to design MPA networks
- …

3.2 Monitoring design

(Gert van Hoey, Silvana Birchenough)

- Possibility to design monitoring surveys based on SDM outputs
- Maybe also vice versa: optimal sampling strategies for SDMs (e.g. Hirzel and Guisan 2002, Ecol Model 157, 331-341)
- …

3.3 Invasive species

(Henning Reiss, Hermann Neumann)

- Can SDMs help to manage effects of invasive species?
- Difficulties in modelling distribution of non-natives
- …

3.4 Future scenarios

(Henning Reiss, Steven Degraer)

- Modelling distribution based on climate change scenarios (is it realistic?)
- What are the weaknesses and possibilities?
- Can it provide guidance for management?
- …

4. Outlook and recommendations

(Michael Zettler, Henning Reiss)

- What kind of SDM are needed in the future (e.g. quantitative methods?)
- Modelling distribution on sub-species level (populations)
- …