ICES Marine Habitat Committee
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Report of the Benthos Ecology Working Group (BEWG)

19–22 April 2004
San Sebastian, Spain

International Council for the Exploration of the Sea

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1 Opening and local organisation

The Chair, Heye Rumohr, opened the meeting, welcoming the participants and offering apologies from colleagues unable to attend. He mentioned that a number of members have retired but welcomed new participants. A list of participants is included as Annex 1.

The Chair provided a brief update on the history of the group and drew attention to the BEWG's website (http://www.dvz.be/bewg/). Hans Hillewaert provided a brief outline of the 'marine portal' part of the website, and Heye Rumohr demonstrated the BEQUALM CD on the QA of benthic sampling that is linked from the BEWG web page. The BEWG website has a summary of 20 years of the group's activities with a page for each year's meeting. The Chair expressed thanks to Hans Hillewaert for his work on the website.

1.1 Appointment of Rapporteur

The Chair expressed his wish to have daily Rapporteurs, together with a Rapporteur 'editor' who would bring the daily contributions together into the final report. Jon Davies was appointed editorial Rapporteur; daily Rapporteurs were Ingeborg de Doois, Alexander Schroeder, Steven Degraer, and Hans Hillewaert.

1.2 Terms of Reference

The terms of reference (TOR) for BEWG 2004 are listed in Annex 2. The respective TOR item is included in the headings of subsequent sections for information.

2 Adoption of agenda

The agenda was adopted with minor changes (Annex 3). It was agreed that contributions to items 11 and 14 would be most efficiently given via small sub-groups of volunteers. Presentations were given by Hubert Rees and Hans Kautsky to explain the requirements for items 11 and 14, respectively.

3 Report on ICES meetings and other meetings of interest

3.1 ASC 2003 (Tallinn) / ICES Annual Report for 2003

Heye Rumohr provided a brief report on the ASC meeting in Tallinn. It was a very successful meeting at a modern, well equipped meeting centre.

3.2 Marine Habitat Committee, Tallinn 2003

Heye Rumohr provided also a brief summary on the meeting of the Marine Habitat Committee. He was the German representative and acted as Rapporteur to the group. Representation was poor, both from national representatives and Chairs of working groups. ICES needs extra support from national representatives to encourage experienced Delegates to attend. There was too little time for scientific discussion and the outgoing Chair, Paul Keizer, provided much encouragement for greater participation. Heye Rumohr was elected the new Chair of MHC. There must be an increase in the scientific discussions at the group – this will require additional resources and more support by the national Delegates to be successful.

3.3 Update on restructuring of ICES

The Chair gave a short presentation describing the recent restructuring of the ICES Secretariat, including the changes in staff. One of important aspects of the changes is the requirement for ICES to respond more rapidly to requests for advice, for example from OSPAR and HELCOM.

ICES will change in 2004 in an attempt to make the advisory function more integrated across the entire organisation. These changes include a new publication series (ICES Advice), reformatting fisheries advice towards using fisheries as the fundamental basis and not stocks as it has been the case hitherto, and start to merge the ACE and ACFM reports.

Members of the BEWG questioned the location of the group in the new structure (under 'Ecological Grouping and Integration`). Members expressed concern that BEWG is being treated in isolation and only required to report on benthos, and not on how benthos integrates with other studies. BEWG considers the whole ecosystem and its relation to benthos and therefore is appropriately qualified to give advice on 'ecosystem management'. BEWG was keen to become fully involved with these changes and make its own contribution to the debate on ecosystem approaches to management.

ICES provided a brief list of OSPAR requests for advice from BEWG.

Recommendation: BEWG will review progress of projects that address seamount ecology at its meeting in 2005.

3.4 Report of the ICES Advisory Committee on Ecosystems (ACE), 2003 (Coop. Res. Rep. 254)

No report was available.

3.5 SGQAE/SGQAB meeting, 24–27 February 2004, Copenhagen

A brief report of the SGQAE/SGQAB 2004 meeting was provided by Jon Davies, who is Chair of SGQAE. The main outcomes of the meeting relevant to BEWG were:

- SGQAE and SGQAB proposed that ICES seek permission from OSPAR and HELCOM to merge the two groups to create a single steering group for quality assurance. If accepted, the group would have Co-Chairs representing the two regions, together with regional sub-groups as appropriate.
- The groups compiled a list of planned QA activities including ring tests.
- SGQAE reviewed the proposed OSPAR Joint Assessment and Monitoring Programme (JAMP) and developed a plan of how the group could contribute to the QA aspects of the proposed assessments.
- The joint group reviewed recent developments with the ICES database and noted the change in policy to accept data in spreadsheet format. The group urged ICES to seek agreement with ITIS to ensure that countries submitting data could quickly obtain ITIS codes.
- SGQAE developed guidelines for the acceptability of biological data and requested input from other working groups.
- SGQAE proposes to seek collaboration with WGSAEM to develop standard data sets that would facilitate the testing and comparison of the performance of indicators of environmental quality. It was noted by BEWG that the Danish organisation (DMU) have large data sets that could potentially contribute to the development of these standard data sets.
- SGQAE noted that there was an increasing interest in developing internationally accepted standards for marine biological measurements through ISO and CEN, particularly in relation to the implementation of monitoring under the EC Water Framework Directive. SGQAE recommended that ICES seeks formal contact with ISO and CEN to offer its expertise in this area to avoid duplication of effort.
- SGQAE welcomed the publication of its guidance on QA of biological measurements in the ICES TIMES series (TIMES 32). A printed version is available for purchase from ICES or it can be freely downloaded from the ICES website (http://www.ices.dk/).

The full SGQAE report is now available for download from the ICES website (http://www.ices.dk/iceswork/wgdetail.asp?wg=SGQAE).

3.6 WGMHM meeting, 30 March–2 April 2004, Brest, France

Jon Davies gave a very brief update on the outcome of the meeting based on draft version report provided by the Chair of WGMHM. A new, large four-year international project on seabed mapping was starting in May 2004, funded through the Interreg IIIB fund. The project title is 'Development of a framework for Mapping European Seabed Habitats (MESH)'; it involves elevem partners and will be led by the Joint Nature Conservation Committee (JNCC), UK, coordinated by David Connor (Chair, WGMHM). Details of the project are available on the JNCC website (http://www.jncc.gov.uk) and a summary is included as Annex 4.

The Chair asked about the link between WGMHM and the SGNSBP 2000 and the request for information on the result of the NSBP 2000 to contribute to habitat mapping in the North Sea. Hubert Rees (Chair of SGNSBP 2000) commented on this request for data: the SGNSBP 2000 was concerned that the request for processed information came at an early stage in the publication cycle, before the contributing agencies to NSBP had had an opportunity to publish their data. The data providers to the NSBP 2000 had clearly stated that data and information would not be made available to other groups until they had been published to the satisfaction of the data providers.

3.7 Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT)

Hans Hillewaert reported on the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT), that met in Vilm, Germany, 30 March 2004–2 April 2004.

The WGEXT discussed electronic submission of extraction-related data to a central database. A summary table of these data was constructed to fulfil the requirements of the OSPAR request for extraction data to be provided by ICES. Questions were raised about the value of duplicating these data tables for the request of REGNS.
A response was given to the feedback from OSPAR on the WGEXT 2003 revision to the ICES Guidelines for the Management of Marine Extraction.

A lot of effort was invested into producing copy for the forthcoming *ICES Cooperative Research Report*. More specifically on the use of risk assessments in the management of marine sediment extraction and on considerations for opportunities for further developing the ecosystem approach to the management of these extractions.

3.8 Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species (SGSOBS)

Angel Borja gave a short presentation on the outcome of the recent meeting in Copenhagen (22–24 March). The terms of reference, according to Council Resolution 2ACE02, were, among others:

a) continuation of the development of EcoQ element density of sensitive and opportunistic species;
b) to identify possible species, taking into account developments in implementing the Water Framework Directive;
c) commence development, for the species identified, and on the basis of the criteria for sound EcoQOs established by ICES in 2001, of related metrics, objectives and reference levels for this EcoQO;
d) for these EcoQ elements, to consider further the spatial scale requirements of sampling;
e) reconstruct the historic trajectory of the metric.

Several presentations were shown by the participants. The group was divided into two sub-groups: sensitive species (led by Keith Hiscock) and opportunistic species (led by Angel Borja). The group agreed on the definitions:

Sensitive species: A species easily depleted by human activity and when affected is expected to recover over a long period or not at all. They will usually be k-strategists, with a long life-cycle (> 1 year), large size, slow growth and late sexual maturity. Sensitive species may act as key structural species for the community, with their loss creating cascading affects on the community.

Opportunistic species: they follow the reproductive (*r*) strategy, with short life-cycle (<1 year), small size, fast growth, early sexual maturity, planktonic larvae through the year and direct development. These species dominate in pronounced unbalanced situations, proliferating after intense disturbance or pollution episodes, occupying the space previously occupied by sensitive or tolerant species. They are often associated with disturbed (e.g., reduced) sediments. The trophic pattern is mainly dominated by surface or subsurface deposit-feeders.

The provisional list of 22 sensitive species included in the 2003 report of the Working Group on Ecosystem Effects of Fishing Aactivities was considered to inadequately reflect the range of species that could be identified as sensitive according to the Texel/Faial definition. Several of the initiatives drawn attention to during the current meeting provided a more promising list of sensitive species in relation to a range of factors (stressors). The initiatives are: AZTI Marine Biotic Index (AMBI); Swedish Tolerance values ($ESO_{0.05}$); *MarLIN* database; and Marine Biological Association of the UK. An exercise was undertaken during the meeting to combine information from the first three of the above listed sources to identify intolerance and sensitivity of species to a range of stressors. The exercise was a potentially large one and only species with names beginning with 'A' were included (242 species). The same was made with the opportunistic species, comparing more than 54 species.

The potential stressors to which benthic species respond can be grouped into three categories:

- Chemical stressors, such as eutrophication, heavy metals, organic compounds, increasing organic matter, etc.;
- Physical stressors, such as changes in marine dynamics, changes in grain size, mechanical disturbance, changes in temperature, stressing in morphology, smothering, etc.; and
- Biological stressors, such as invasive species.

The approaches that have been developed in order to explain and reveal the impact of stressors on benthic communities can be grouped into three classes: (i) univariate individual-species data or community structure measures, such as species diversity, richness, abundance/biomass ratios, etc.; (ii) multimetric indices combining several measures of community response to stress into a single index; and (iii) multivariate methods describing the assemblages pattern, including modelling.

The multimetric indices can be grouped into four 'families':

i) Benthic Pollution Index (BPI)/Biotic Index/AMBI/ Bentix: These indices are based on the ecological adaptive strategies of species (*r*, *k* and *T*) and the progressive steps in stressed environments. The species should be classified into several ecological groups, based upon sensitivity/tolerance to pollution (or disturbance). The calculation of these metrics is based on proportions among the ecological groups.

ii) Coefficient of Pollution (CoP): is based on the empirical relationships between the number of individuals and species in unpolluted macrobenthic communities with specific sediment granulometry and water depths.

iii) Benthic Index of Estuarine Condition/Benthic condition Index (BCI)/Benthic Index of biotic integrity (B-IBI): These indices consider species diversity, total abundance, total biomass, percentage of abundance of pollution-indicative taxa, percentage of abundance of pollution-sensitive taxa, percentage of biomass of pollution-sensitive taxa, percentage of biomass >5 cm below sediment-water interface. These metrics combine structural parameters from the community and physico-chemical substrate conditions.

iv) Indicator Species Index/Benthic Quality Index: These indices are based on the assumption that increased disturbance leads to decreased diversity. Hurlbert's rarefaction index is used to calculate sensitivity/tolerance. Opportunistic taxa receive the lowest values of the index.

Adequacy of existing monitoring – taxonomic competence/specialization will affect this work since some groups are not well understood. Taxonomic issues will affect the calculation of indices. The draft report states 'the adoption of ISO/CEN standards is strongly recommended for surveys……'; BEWG disagreed with the restrictive nature of this statement. It should refer to other international (ICES/OSPAR) or National standards as appropriate.

Action: HR/JD to email KE to suggest an amendment to this statement – use the text from the COAST guidance.

The BEWG emphasised that studies should use a combination of metrics (or approaches), not just a single metric to assess status. A list of metrics was appended to the study group report.

3.9 Marine Biodiversity and Ecosystem Functioning (MARBEF)

MARBEF (www.MARBEF.org) is an EU-funded 'Network of Excellence' which commenced in February 2004. The programme is funded for five years but the collaborative initiative is expected to continue beyond then with, at its core, a European virtual marine biodiversity institute. The official start-up meeting was held in Bruges in March 2004, and was attended by about 120 people representing 56 marine institutes/organisations who are presently involved. The project coordinator is Carlo Heip, and it is managed by staff at the Centre for Estuarine and Marine Ecology, Yerseke, the Netherlands.

The three research themes are:

1) Global patterns of marine biodiversity across ecosystems;
2) Marine biodiversity and ecosystem functioning;
3) The socio-economic importance of marine biodiversity.

The first eighteen months of the project will involve 'infrastructure' developments in the following areas:

1) Integrating activities:
    - Data integration (VLIZ, Belgium)
    - Taxonomic clearing system
2) Integration of joint research activities:
    - Themes 1–3 (see above)
3) Spreading excellence:
    - Quality assurance
    - Training courses
    - 'Outreach'

A wide variety of workshops and meetings are planned to develop these initiatives, which will provide the basis for progress in subsequent years. Also, proposals for future research (i.e., commencing in year 2) will be formulated, in accordance with the objectives of the research themes and supporting activities. Further details of the project and its aims are given on the MARBEF website.

3.10 SPICE meeting, Galway, 5–7 April (H. Rumohr)

The Chair gave a brief summary of the SPICE meeting held in Galway, Ireland, in April 2004.

Sediment profile imagery (SPI) is a rapid reconnaissance technique for mapping habitat quality on the soft seafloor. Originally described by Rhoads and Cande (1971), the technique uses a camera functioning as an inverted periscope to image vertical distributions of physical, chemical, and biological properties in the sediment profile. Traditionally it has been used by commercial operators for mapping strong environmental gradients on the soft seafloor (fish farm impacts, sewage outfalls, etc.). However, SPI is a truly multidisciplinary tool, providing useful information for environmental managers, geologists, oceanographers and biologists. The increased requirement and ambition of environmental managers to map the seafloor has created an expanding demand for SPI, as the method offers rapid return of comprehensive data sets that can be used to direct more traditional benthic sampling programmes. In recent years, rapid development in digital imaging technologies, combined with novel applications and improved analysis techniques, have greatly improved the utility of SPI. This conference (SPICE) was focused on the use of SPI in all its guises, and aimed to devise and promote best practise guidelines in all stages of the SPI process. Specific aims were to:

1) Promote the use of SPI as a tool for routine monitoring of the seafloor by presentations of successful SPI applications in various applications (aquaculture, dredge spoil dumping, hypoxia, etc.).
2) Produce guidelines for best practise and standardisation of SPI analyses (including a ringtest). Dedicated software developed by the Vision Systems Group, Dublin City University for objective determination of the area of oxidised sediment will be made available to all participants on a shareware basis, provided that its use is cited by users.
3) Demonstrate novel applications of the SPI method such the towed SPI camera (Plowscan), the scanning SPI camera (Spiscan) and *in situ* time-lapse SPI.
4) Provide a forum for networking and technology transfer between leading international operators.
5) Produce a dedicated volume of *Deep Sea Research II* highlighting excellence in SPI research.
6) Form the basis for a definitive book on SPI, outlining methodologies in experimental design of sampling programmes, image aquisition, image analysis and data analysis. The sudden and unexpected death of Prof. Brendan Keegan overshadowed the SPICE meeting since he was the pioneer of SPI in Europe.
7) Web page: Robert Kennedy of Martin Ryan Institute, Galway has designed a web page on this conference: http://mri.nuigalway.ie/spice

4 Report of co-operative studies and other studies relevant to ICES

4.1 Mapping corals in Nova Scotia

Lene Buhl-Mortensen presented a summary of results from the ESRF-funded research program on deep-water corals conducted at the Bedford Institute of Oceanography, Canada (BIO) from 2001 to 2003. Deep-water corals have been known from around the world for many years, but still there are large gaps in the knowledge about their distribution and biology. There is increased concern that human activities in deep waters seriously affect the coral habitat. The presentation provided a summary of research on deep-water coral ecosystems off Atlantic Canada carried out during three years (2001–2003) under a research project at BIO. The project covered different aspects such as distribution, growth and associated fauna. Deep-water corals represent a varied habitat for other organisms. More than 80 invertebrate species have been found on gorgonian corals off Nova Scotia. This number is smaller than for reef-building deep-water corals, but it is comparable with tropical gorgonian corals. Several new species were recorded from the area and two crustacean species were new to science. One of these, a parasitic copepod, constitutes the new genus *Gorgonophilus*. In autumn 2003 the first documented *Lophelia* reef in Atlantic Canada was discovered at the Stone Fence in the mouth of the Laurentian Channel. The results from the project have been crucial for declaring two deep-water protection areas (Northeast Channel and The Gully). The process of designing a protected area around the Stone Fence reed is ongoing.

Lene Buhl-Mortensen also showed a video of corals in North East Channel, Nova Scotia that occur at >300 m depth and the colonies are >1 m high with many epibiota. There was some footage of damage by fishing – a long line snagged through a colony. If colonies are damaged, they are susceptible to over-growth by other organisms, for example, anemones. The area has been closed to fishing although 10% of the area remains open for long-lining. The video footage clearly shows that longlining can also damage the reefs although the coral morphology would appear more susceptible to longlines than *Lophelia*. There was some film of a *Lophelia* reef (Stone Fence) that appears to have had the top sections of the reef chopped off with surviving corals on the sides of rocks. The rubble creates a 3D structure with high diversity in amongst the 'holes' created by the rubble. The area is being closed to all fishing gear.

The study group has developed an approach for analysing video sequences taken out of video transects. It was noted that ROVs are limited in their capacity to 'map' because of their relatively restricted movement in comparison to towed video systems, an important point when planning monitoring programmes. ROVs do, however, provide a more stable, controllable platform than towed systems that facilitates the recording of high quality video.

The results showed damage to the corals from physical impact (fishing) but there is very limited information on recovery rates. Video analysis demonstrated that there was a higher probability of recording redfish amongst corals than boulder areas. Rarefaction curves and Shannon Weiner suggest a higher diversity associated with *Primnoa* than *Paragorgia*. Fauna associated with colder-water corals are at least as rich, if not richer, than tropical coral gorgonians.

4.2 A biological valuation map for the Belgian continental shelf

Steven Degraer outlined the background and objectives to a project that will develop a map showing the value of the Belgian continental shelf. The continuously increasing socio-economic interest in marine resources (e.g., fisheries, aggregate extraction, windmill farms and marine protected areas) urges the need for a decision-making framework to objectively allocate the different user functions at the Belgian Continental Shelf. This calls for a spatial structure plan, preferentially firmly based on the concept of integrated marine management, in which biological value should be carefully taken into account. Unfortunately, so far an integrated view on the biological value of the Belgian Continental Shelf is largely lacking. A first attempt to assess the biological value of (parts of) the Belgian Continental Shelf exists, but this study only took into account one ecosystem component (i.e. macrobenthos) and non-extrapolated to the whole shelf, generally failing to provide an integrated, full-coverage Biological Valuation Map of the Belgian Continental Shelf. The general objective of the project is therefore to set up a Biological Valuation Map for the Belgian Continental Shelf.

Since no marine Biological Valuation Maps have been set up in other parts of the world yet, a novel approach should be searched for. The generation of the Biological Valuation Maps for Belgian marine waters should therefore preferably be based on the experience acquired during the actualisation of the terrestrial valuation maps: the creation of the marine Biological Valuation Map demands close cooperation with terrestrial experts, already in an early stage of the project. Because of fundamental differences between the terrestrial and marine ecosystem structure and functioning, a team of experts in terrestrial biological valuation and marine biology experts will search for an adapted approach for the biological value of the Belgian Continental Shelf (e.g., valuation criteria). A separate request for funding of an international expert workshop on the use of biological criteria in the marine environment will be submitted to the OSTC for which support from interested members of BEWG was requested.

The marine Biological Valuation Map should include and integrate information on all marine ecosystem components for which detailed spatial distribution data are available. At the Belgian Continental Shelf such data are primarily available for the macrobenthos and seabirds (macrobenthos: UGent-MACRODAT database; seabirds: IN database). To a lesser extent, but still useful from a valuation perspective, data on the spatial distribution of the epi- and hyperbenthos exist (UGent and DVZ databases). It was decided to base the biological valuation of the Belgian Continental Shelf on the spatial distribution of seabirds and macrobenthos (full coverage baseline Biological Valuation Map), while epi- and hyperbenthos data will be used as an upgrade (upgraded Biological Valuation Map for selected areas).

The seabird database consists of a set of points where densities are known. In order to cover the entire Belgian marine area, a GIS-aided interpolation and extrapolation will be performed. Contrary to avifauna data, in which direct observations provide almost full-coverage information for numerous areas at the Belgian Continental Shelf, benthos data should be regarded as point data. To spatially extrapolate these point data, which is needed to obtain a full coverage spatial distribution map, a predictive model, based on the close link between the macrobenthos and its physical habitat, will be set up. Once developed and validated, the model will enable extrapolation of the spatial distribution of the macrobenthos to the full Belgian Continental Shelf, using existing data on the physical habitat (GIS-aided).

Even though large databases on seabirds are available, there are still areas at the Belgian Continental Shelf (mainly the outer parts) with a poor coverage of data. Supplementary seabird counts will fill the gap in these areas. New samples on macrobenthos will be collected to ground-truth the predicted full-coverage distribution maps.

Once a full-coverage map of the spatial distribution of macrobenthos and seabirds is generated, these maps will be evaluated according to the set of valuaton criteria. Through a GIS-aided combination of the different valuation maps (macrobenthos-seabirds and criteria), a full-coverage base Biological Valuation Map will be obtained. This baseline Biological Valuation Map will further be upgraded using data on the epi- and hyperbenthic value, within areas where information on these components is available (upgraded Biological Valuation Map for selected areas).

To ensure that the project finally leads to a Biological Valuation Map, which is supported by a wide board of policy-makers and managers, a diverse team of governmental and non-governmental endusers will regularly meet throughout the project and help to obtain a useful tool in integrated marine management.

A separate request for funding of an international expert workshop on the use of biological criteria in the marine environment will be submitted to the OSTC for which support from interested members of BEWG was requested. Heye Rumohr reported on a workshop he attended in 1997 on ecological economics with Prof. R.K. Turner, Univ. of Norwich as lecturer. The main topic was, i.a., the comparative valuation of ecological goods and services. Jan van Dalfsen noted that a similar question has arisen in the Netherlands. They plan to integrate all kinds of information in relation to a large offshore windpark project to develop a decision-support system.

Eike Rachor noted that the World Conservation Union (IUCN) provides a list of criteria for the selection of sites to protect, and that the functional 'value' of biotopes should be considered. However, a system is only valid for a certain period of time, or you have to have a long time series in which temporal changes are included. Steven Degraer responded that it is not going to be a static map and will be updated as new information becomes available.
Action: Steven Degraer to report on the progress of BWZEE at BEWG05.

4.3 EUMARSAND

Wendy Bonne described this project that addresses the urgent need for integrated and coherent approaches (at a European level) to resource prospecting and the assessment of the environmental impacts of marine aggregates (sand and gravel) extraction (Annex 5). Its objectives include (i) the compilation of information on resource availability, usage and relevant regulatory (licensing) regimes at a European level; (ii) the evaluation of existing geophysical/geological survey strategies, instrumentation and interpretative techniques used to prospect resources; and (iii) the assessment of existing methods to assess the physical and ecological impacts of the extraction. The project comprises both 'desk'- and 'fieldwork'-based investigations. With regard to the field studies, the Kwintebank (North Sea) and the areas Tromper Wiek, Graal-Münitz and Wustrow (Baltic Sea) are designated as case study sites and will be prospected using state-of-the-art geophysical/geological techniques and instrumentation. The physical impacts of the extraction on the seabed/adjacent coastlines will be assessed using innovative hydro-, sediment and morphodynamic modelling, calibrated/validated by high quality *in situ* measurements. The ecological impacts will be assessed using improved research protocols. The integration of the results will be then used to formulate improved research protocols and guidelines.

The strategic objective of the project EUMARSAND is to investigate and train, to a high level, young researchers in the complex issues associated with marine aggregate exploitation. These issues are addressed through the application of a wide range of scientific approaches (geological, sedimentological, physical, ecological and engineering based). The integration of these approaches will improve significantly both resource management and our knowledge on the impacts of aggregate extraction on the state and dynamics of the inner shelf and coastal environments.

Nine institutes in eight countries led by AZTI are involved in the project that will run November 2002–31 October 2005 (see http://www.azti.es/eumarsand/).

4.4 Study of post-extraction ecological effects in the Kwintebank (SPEEK)

Wendy Bonne and Hans Hillewaert described the background and the early results of this investigation. Full details of the project are included in Annex 6. In summary:

Duration: 2 years: December 2003–December 2005
Funded by the Belgian Federal Science Policy
Scientific Support Plan for a Sustainable Development Policy
Partners:

- Marine Biology Section, Biology Department, Ghent University, Belgium (Jan Vanaverbeke, Maaike Steyaert)
- Renard Centre of Marine Geology, Ghent University, Belgium (Vera Van Lancker)
- Sea Fisheries Department, Agricultural Research Centre, Ministry of the Flemish Community, Belgium (Hans Hillewaert)
- Marine Research Division AZTI, Technological Institute for Fisheries and Food, Spain (Wendy Bonne)

The project aims to:

1) integrate long-term data (20 years) of the Kwintebank for different benthic components (nematode, copepod and macrobenthos communities). The ecological impact of extraction activities will be assessed analysing these long-term data;
2) refine and discriminate appropriate disturbance indicators for the impact assessment of sand extraction; and
3) investigate the ecological changes after cessation of the exploitation of the central zone of the Kwintebank. The nature and the rate of potential recovery of the benthic community (meiobenthos and macrobenthos) will be examined and linked with temporal variation of the grain-size variables.

The meiobenthic communities will be investigated by:

- Densities, diversity and community composition of meiobenthos (nematodes and harpacticoid copepods);
- Size class distributions (Nematode Biomass Spectra) ;
- Classification functions for nematode communities;
- Ecotype distribution for harpacticoid copepod communities.

Recovery of the larger size classes of the benthos (macrobenthos) will be assessed according to changes in species diversity, density and biomass after the cessation of extraction activities. Species sensitive to sand mining will be designated as indicator species for aggregate extraction.

Data on geomorphological changes of the Kwintebank, based on geo-acoustic measurements and recorded in the framework of the Marebasse (OSTC)/Eumarsand (EU-FP5) projects will be used to support the biological data.

The evaluation of the ecological effects on different members of the benthos in areas subject to intensive extraction and in areas where extraction activities are ceased will ultimately provide management information (rotation of extraction areas/ frequency of extraction activities).

4.5 Assessment of recovery processes on Kwintebank

Hans Hillewaert described a comprehensive study to consider the recovery of communities after sand extraction. A summary of the study is presented in Annex 6. Since 1996, all sand dredgers have to carry a 'black box' to track the location of their dredging activities. These data have helped target investigations into the effects of dredging. He noted that there might not be a recovery to the pre-dredging community, rather a change to a different (related) community. The project will sample three times a year (starting in 2003) and initial results suggest some recovery although it may be a seasonal development in the community through the year.

4.6 The impact of the *Prestige* oil spill on the benthic and demersal communities of the Continental Shelf off Galicia and in the Cantabrian Sea (Annex 7)

Santiago Parra gave a presentation on the impact of the *Prestige* oil spill. In November 2002, the single-hulled tanker *Prestige* sank 130 miles off the coast of Muxía (La Coruña, Galicia). Roughly 20,000 tonnes of fuel oil spilled into the sea, causing a vast oil spill which has affected the entire Galician coast. This report contributes new data on the evolution of the benthic and demersal communities living on the shelf affected by the oil spill. The information presented in this report was taken from different surveys conducted by the IEO in 2003. Samplings were carried out using a number of complementary systems to be able to quantify the different compartments of the bottom ecosystem (infauna, epifauna and megafauna) and to shed light on the state of its communities and resources. A sampling strategy was designed to include bottom stations organized in a radial arrangement, located in five geographical sectors and three depth strata.

The infaunal communities of sector MF generally exhibited minor variations between winter and spring. The most significant changes in spring were a slight decrease in total abundance as well as in the abundance of some less important groups and a modest increase in crustaceans, especially in the deepest stratum. Species richness was down, while diversity and equitableness rose slightly in spring. All the parameters of the community declined in sector FE with the exception of diversity and equitableness, which grew slightly. The most prominent decrease was in total abundance and in crustaceans. The principal species observed to diminish was the amphipod crustacean *Ampelisca* spp.

In the suprabenthic communities inhabiting the shallowest stratum, there was a notable increase in the abundance of the euphausiaceans together with a marked decrease in amphipods and mysidaceans. In the middle stratum, we observed a substantial rise in amphipods in spring and a less important decrease in cumaceans and euphausiaceans. In contrast, in the deepest stratum, where the community was dominated by decapods in winter, these animals declined considerably, while euphausiaceans rose sharply.

No differences were found in the structure of the epibenthic communities as compared to previous studies. Richness biomass and diversity indices are similar to those obtained using the same sampling methodology on the Cantabrian shelf in the years prior to the oil spill. Specific composition follows the same pattern as defined for equivalent environmental conditions on the Galician and Cantabrian shelf. There was no evidence of a predominance of opportunistic species, as has been reported in sediments contaminated by fuel oil.

As regards the megabenthic communities, a comparison of the ecological indices among surveys and by depth strata shows an increase in all these indices in the spring 2003 survey versus the autumn 2002 survey. The comparison by depth strata pointed to an overall increase in all the indices in the spring 2003 survey compared to the one conducted in autumn 2002. An analysis of the indices by stratum shows that the average richness in stratum 70–120 m in the spring survey was significantly higher than the values found in autumn 2002. The same occurred in stratum 121–200 m. However, no significant differences were found in species richness between the two surveys in the deepest stratum. In terms of the other indices, there were no significant differences in biomass (P), abundance (N), diversity (H'W and H'N) between the two surveys.

4.7 AMBI

Angel Borja (AB) gave a presentation on the use of the AMBI biotic index, including the results of a recent investigation showing how the index was used to assess the status of the benthic environment under different types of anthropogenic pressure. A summary is included at Annex 8.

He also described an approach to classifying estuarine macrophyte assemblages using intertidal algae for the Water Framework Directive (WFD). There are no parallel developments to consider coastal macrophyte assemblages or sub-tidal macrophyte assemblages in transitional or coastal waters of Spain or elsewhere in Europe. Not considering subtidal macrophyte assemblages is a potentially important shortcoming in any assessment of stutus under the WFD.

4.8 Hypoxia in Norwegian fjords

Lene Buhl-Mortensen outlined a study (see Annex 11) that will consider three bottom fauna components (hyperbenthos, macro-infauna and foraminifera) of fjords in relation to hypoxia. Sill depth controls the carbon flux in fjords and carbon flux is linked to benthic diversity. Sill depth is therefore linked to faunal diversity. Sill depth is linked to the degree of hypoxia in fjord basins – some deep basins behind shallow sills are naturally hypoxic. Anthropogenic inputs (nutrients) may significantly affect the oxic status of these deep basins. Natural and anthropogenic hypoxia may be revealed through an analysis of foraminifera from bottom sediments to look at historical hypoxic events.

4.9 Benthic communities and morphology

Jan van Dalfsen presented work being done on the relation between macrobenthos and seabed characteristics (morphology, sediments, and dynamics).The results of two projects, BEAST (Benthic evaluation and assessment System) and Ecomorphodynamics of the sea floor, showed zonation and a relation between benthic communities and morphology. Differences were found in the macrobenthos (abundance and diversity) between areas and within areas between morphological features as troughs and crests of sand waves. These could possibly be explained by hydrodynamics differences. This has consequences for field surveys (e.g., monitoring programmes) in defining sample locations and in reproducibility of results. Reports are available (Baptist *et al*., 2002, 2003).

Furthermore, Jan van Dalfsen pointed out that increased concern over the potential impact of human activities offshore (especially of the oil and gas industry) has identified the need to critically evaluate the methodological links between environmental risk assessment (ERA), environmental effect monitoring (EEM) and ecologically relevant impacts. Although ERA and EEM aim for the same goal: protection of the environment, the results of EEM studies and ERA models have not been, or cannot be, compared in a general scientifically sound way, due to differences in measurement endpoints and assessment endpoints and a lack of methods to couple these. Nonetheless, validation is required to ensure that the assessments are reliable.

BEWG was asked whether it should put in its expertise in addressing this problem.

Baptist, M. J., Bergen Henegouw, C. N. van, Boers, M., Dalfsen, J. van, Heteren, S. van, Hoogewoning, S., Hulscher, S. J. M. H., Jacobse, J. J., Kaag, N. H. B. M., Knaapen, M. A. F., Mulder, J. P. M., Passchier, S., Spek, A. J. F. van der, Storbeck, F. 2001. Eco-morphodynamics of the seafloor – Progress report 2000. Delft Cluster, Delft. 74 pp.

Baptist, M.J., Bergen Henegouw, C.N. van , Bijker, R., Dalfsen, J. van, Damme, R.M.J. van, Holzhauer, H., Hulscher, S.J.M.H., Kaag, N.H.B.M., Knaapen, M.A.F., Lewis, W., Morelissen, R., Németh, A.A., Passchier, S., Spek, A.J.F. van der, Weber, A. 2002. Eco-morphodynamics of the seafloor - Progress report 2001; Delft Cluster, Delft. 86 p.

Heteren, S. van, Baptist, M.J., Bergen Henegouw, C.N. van, Dalfsen, J.A. van, Damme, Dijk,T.A.G.P. van, Hulscher, S.J.M.H., Kaag, N.H.B.M., Knaapen, M.A.F., Lewis, W., Morelissen, R., Passchier, S., Penning, W.E., Storbeck, F., Spek, A.J.F. van der, Groenewoud, H. van het, Weber, A. 2003. Eco-morphodynamics of the seafloor - Final Report. Delft Cluster, Delft. 52 pp.

4.9.1 Seasonal variability of benthic communities in different areas of the southern North Sea

Henning Reiss presented the initial results from an ongoing study that is investigating seasonal variability in benthic communities. As a shelf sea in temperate regions, the North Sea, particularly the relatively shallow southern North Sea, is characterized by strong seasonal fluctuations of temperature, salinity and primary production, which in turn influence the benthic fauna. In contrast to inter-annual and long-term changes of diversity and community structure of benthic communities, studies about intra-annual changes are rare up to now, although a detailed knowledge of the short-term temporal as well as spatial variability of the benthos is essential to assess long-term changes in benthic communities.

To fill this gap, the purpose of this study was (I) to describe the seasonal variability in species number, abundance and biomass of the benthos at three diffierent stations in the southern North Sea, and (II) to detect correlations between faunal patterns and environmental parameters.

Between September 2000 and May 2002, epi- and endobenthos was sampled monthly with a 2 m beam trawl and a 0.1 m² van Veen grab at three stations along a transect from the southern German Bight towards the northeastern part of the Dogger Bank (North Sea) in order to investigate the seasonal variability of the epibenthic communities. The stations were chosen to reflect a gradient in the hydrographical regime, organic matter supply, and fishing effort. These stations are also part of a long-term series where endobenthos is sampled in spring since 1995.

Differences in the seasonal patterns of epi- and endobenthic communities were found between the three study sites with the highest seasonal variability at the southern site in the German Bight, which is characterized by the highest seasonal amplitude of environmental parameters like temperature and food supply. The communities of the Dogger Bank and the Oyster Ground remained rather stable throughout the study period. Temperature seems to trigger the seasonal variability of the epibenthic communities, whereas the endobenthic communities especially at the northern stations are supposed to be also affected by input of fresh organic matter.

4.9.2 Digital imaging and identification

The internet and a good camera/microscope combination can prove to be very helpful in finding information about organisms that defy identification.

A wormlike animal, found on the Kwintebank (Belgian Continental Shelf) was digitally imaged and put on a website (http://www.dvz.be/benthos/unknown/spec1.htm). The URL was posted to two well-known list-servers (Annelida and MarBIO, references on http://www.biosis.org.uk/zrdocs/zoolinfo/news_gps.htm). Response was substantial and

more than 600 visitors from 38 countries checked the website (http://www.nedstatbasic.net/s?tab=1&link=1&id=2927223).
The worm turned out to be a Nemertean (probably *Paranemertes neesii* (Ørsted, 1843)).

Hardware used was an AxioCam Digital Microscope Camera on a Zeiss Zoom microscope with AxioVision software.

4.9.3 RESPONSE project (A. Schroeder)

A project titled '*Response of benthic communities and sediment to different regimens of fishing disturbance in European coastal waters*' (RESPONSE) is a shared-cost RTD action funded within the EU 5th framework (Q5RS-2002-00787). It involves six partners from four different countries (ICM-CSIC, IEO and MSM, Spain; CIBM, Italy; UWB, Wales; AWI, Germany) and runs from 10/2002 to 09/2005. Details can be found on the project's website at www.icm.csic.es/rec/projectes/response. RESPONSE is part of the informal EU-cluster INTERACT ("Interaction between environment and fisheries", www.interact-cluster-web.org).
The main objective of the project is to study possible impacts of bottom fishery on:

1) morphology, texture and composition of sediments;
2) the structure and recovery of benthic invertebrate and demersal fish communities;
3) the secondary production of the benthic system.

Four study areas are situated in the Adriatic Sea, the Catalan Sea, the Irish Sea, and the German Bight (North Sea) on silty to sandy sediments at water depth between 20 m and 60 m

A similar sampling approach is followed in all areas. The local fishing intensity, its spatial distribution and temporal development is estimated by a combination of all available information for the respective study area (catch statistics, overflight data, VMS satellite data, direct observations and recording of trawl marks by sidescan sonar mapping). Regarding the influence on benthic communities, two approaches are followed depending on the local fishing regime: 1) a comparison of fished and unfished areas, and 2) a comparison of the situation in areas of high and low fishing effort or even periods of varying fishing intensity.

The German study is centered around a recently installed research platform within an area of very high fishing effort (FINO1, www.fino-offshore.de) just north of the "plaice box". A perimeter of 500 m around the platform is closed to all shipping/fishing activities, which is controlled by radar from the platform. This area is used to study the recovery of the benthic communities after cessation of bottom trawling. Sampling took place before the installation and will continue with five consecutive samplings up to 15 months, when the project ends, but should be continued further on, needing additional funding. Direct influences from the platform are avoided by keeping a minimum distance of 150 m. Fishing intensity is estimated by sidescan sonar surveys and VMS data; benthos is studied by van Veen grabs, beamtrawls, photography and video; sediment samples are taken for grain size and organic content analysis. Continuous measurements of hydrographical factors are taken on the platform.

No results are available at the moment; the progress will be reported at the next BEWG meeting.

Action: Alex Schroeder to keep BEWG informed of the progress with this study.

4.9.4 MAFCONS

Henning Reiss described the project MAFCONS ('Managing Fisheries to Conserve Groundfish and Benthic Invertebrate Species Diversity') is funded under the European Union Quality of Life and Management of Living Resources programme (Contract no: Q5RS-2002-00856; http://www.mafcons.org). The project started in January 2003 and will last 42 months.

The primary aim of MAFCONS is to provide the scientific advisors to fisheries managers with the tools that would allow them to quantify the consequences to groundfish and benthic invertebrate species diversity of achieving particular fisheries objectives (e.g., increasing or decreasing the Total Allowable Catch (TAC) of Cod). If successful, MAFCONS will develop the mathematical tools to the point where they could be used in the current ICES fisheries stock assessment procedure. This would present ICES (the scientific advisory body) with the opportunity of providing the EC and fisheries ministers with advice regarding the impact of fisheries policy on the wider marine ecosystem, as well as on the fish stocks themselves. MAFCONS is firmly established in the belief that any model (mathematical tool) designed to predict the potential impact of varying fisheries activity on the diversity of marine communities should be based on a sound understanding of ecological theory.

With this in mind the specific objectives of MAFCONS are to:

1) Bring together and formalise the relevant ecological theory in order to develop suitable hypotheses related to the mechanisms through which the ecological disturbance of fishing affects the diversity of fish and benthos communities;
2) Collect the relevant data to test these hypotheses, including data on:
   - variation in fishing effort to estimate variation in ecological disturbance,
   - variation in benthic invertebrate productivity and species diversity,
   - variation in groundfish species diversity;

3) Establish the relationships between fishing effort (which will be used to predict ecological disturbance) and the tools used to manage fisheries (at present TACs, but moving towards restriction of effort and closed areas or seasons in some situations).

4.9.5 Catch efficiency of a standardized 2-m beam trawl (Epicatch) (Henning Reiss)

In cooperation with the Institute for Sea Fisheries (S. Ehrich), the catch efficiency of a 2-m beam trawl was estimated by an experiment carried out in two different areas in the southern North Sea. The objectives of this study were (I) to quantify the proportion of the epibenthos sampled with a 2-m beam trawl and to determine whether there are differences in this catch efficiency between (II) different sediment types and (III) different epibenthic species. For that purpose, three standard 2-m-beam trawls were tied one after the other by steel ropes of 6 m length. We hypothesized that the catch would decrease from the first to the third trawl depending on the catch efficiency of the gear. In January 2004 during the standard GSBTS into the German Bight, six hauls were carried out with this triple 2-m beam trawl in addition to the standard single trawl to monitor the epibenthos. On the head line of the first one, a net sonde was fixed to determine the exact point in time when the gear touched and left the bottom.

The preliminary results indicate that the proportion of the epibenthos caught by one trawl in terms of total abundance and biomass is less than 50 %. The disturbance caused by the first trawl is supposed to flush the mobile epibenthic species resulting in higher abundance and biomass of these species in the second or the third trawl compared to the first trawl, e.g., shrimp species such as *Crangon crangon* and *Crangon allmanni* or the swimming crab *Liocarinus holsatus*. In the case of the swimming crab, this leads to a catch efficiency of less then 15 %. Also the number of endobenthic species was higher in the second and third trawl, probably dug up by the first trawl.

In the discussion following the presentation, Heye Rumohr commented that video data haveshown shrimps and prawns ‘jumping’ to avoid on-coming gear – they may then sink (tired) and are captured. Hubert Rees suggested that a low catch efficiency is a benefit for many studies since it reduces the volume of the catch to manageable proportions. Furthermore, he noted that expert judgement is often required when interpreting the results since a single boulder on a sandy seabed can markedly skew the composition of a trawl.

4.9.6 The feeding ecology of sea duck in the Pomeranian Bay

Heye Rumohr reported about recent investigations by one of his students (Ulf Evert) about the feeding ecology of sea ducks in the Pomeranian Bay. In general, a large number of nordish waterbirds are wintering in central Europe. There are only a few areas with a high concentration of wintering waterbirds. One of these areas is the Pomerian Bay in the southern Baltic Sea. The following questions were answered in the investigation: Analysis of the diet composition of two wintering sea duck species: Long-tailed duck (*Clangula hyemalis*) and Common Scoter (*Melanitta nigra*) because studies for sea ducks as a factor of controlling the benthic macrofauna are sparse. Sea ducks were collected from fishermen as by-catch of the nearshore gillnet fishery on the coast of the Island of Usedom. Long-tailed ducks (*Clangula hyemalis*) were collected from January to April in 2001 and 2003. The have a common size of about 36 cm (without long tail feathers) and weigh about 800–900 g. Common Scoters (*Melanitta nigra*) were collected from January to April in 2001, 2002 and 2003. The estimated population is at least ten million and the average number of wintering long-tailed ducks in the Pomeranian Bay: 800.000 (17 % of the NW European winter population. Common Scoters (*Melanitta nigra*) were collected from January to April in 2001, 2002 and 2003. Their size is about 41 cm, and their mean weight 1.5–1.8 kg. The estimated population is at least one million. The average number of wintering common scoters in the Pomeranian Bay: 100.000 (7.7 % of the NW European winter population. The ducks were collected from fishermen were and brought frozen to the Institute for Marine Research in Kiel. Stomachs were taken out, cleaned and weighed before the diet was extracted. Empty stomachs were weighed again and the diet analysed and measured. Diet was also extracted from the oesophagus and analysed as well.

130 Long-tailed ducks (*Clangula hyemalis*) have been investigated: 86 males, 37 females and 7 immatures. Long-tailed ducks mainly feed on bivalves: soft-shell clam (*Mya arenaria*), Baltic tellin (*Macoma balthica*), *Cerastoderma lamarkii* and blue mussel (*Mytilus edulis*); but there were also found other invertebrates such as *Palaemon adspersus* or *Crangon crangon* and even fish up to a size of 17 cm (*Ammodytes tobianus*). 15 long-tailed ducks from March 2001 only had herring spawn included. Empty stomachs of spawn eaters weighed 18.7 g compared to 23g of bivalve eaters on average.

274 Common Scoters (*Melanitta nigra*) have been investigated: 243 males, 17 females and 16 immatures. They only fed on bivalves: soft-shell clam (*Mya arenaria*), Baltic tellin (*Macoma balthica*) and *Cerastoderma lamarkii*.
The avian-benthic link is important when considering benthic community structure, particularly on bivalve populations: for example, eider ducks consume up to 2 kg per day and the ducks consume ~20% of local annual mussel production over winter. Common scoter can dive to ~30 m, eider can diver to 60 m but generally feed around 15–20 m on shallow stony grounds with residual sediments covered with algae.

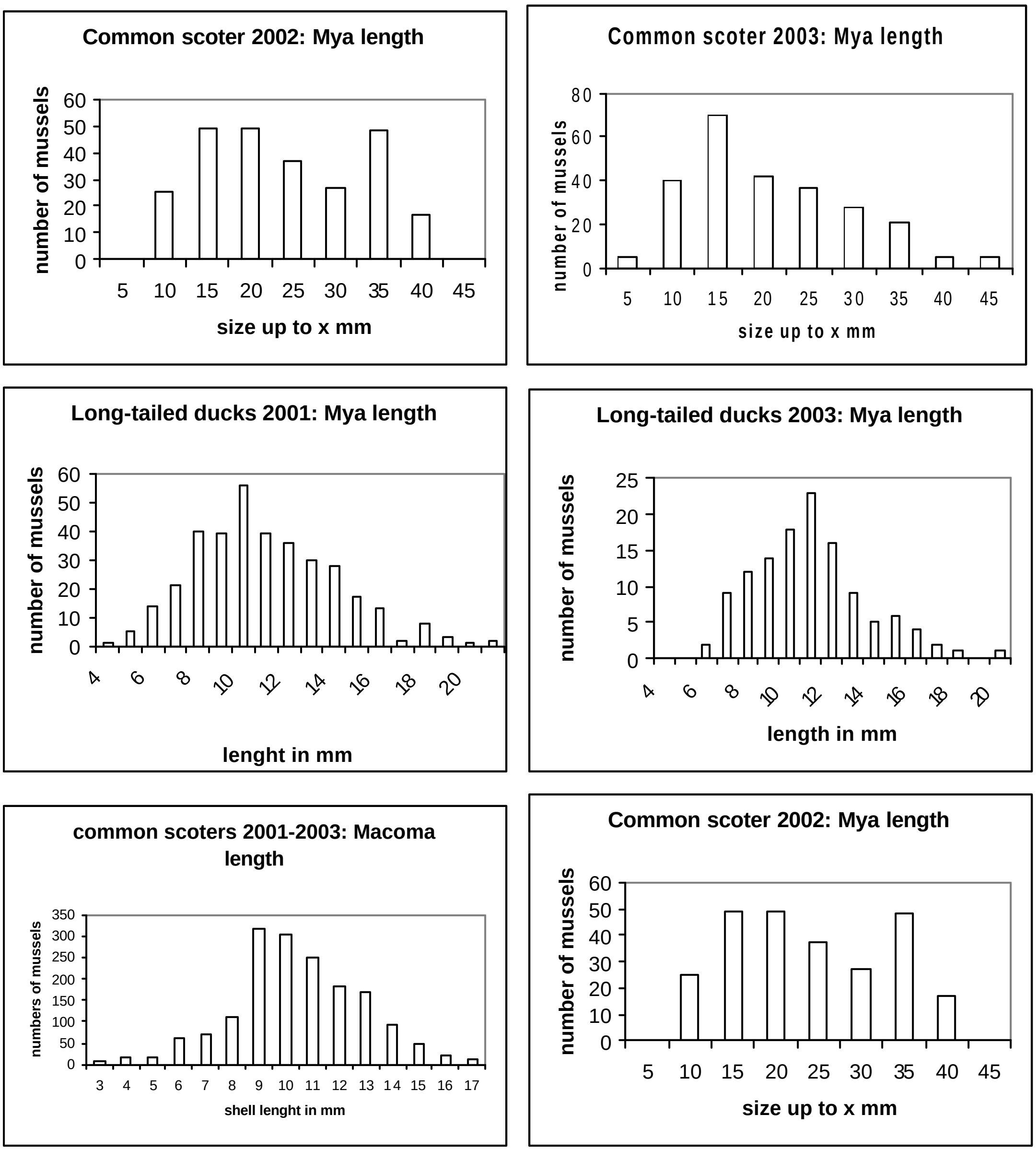

Figure 4.9.6.1. Size spectra of stomach contents.

4.9.7 BEOFINO (A. Schroeder)

Alexander Schroeder reported on a national research project titled 'Ecological Research on the impact of Offshore Windfarms based on research platforms in the North and Baltic Sea' (BEOFINO; see http://www.fino-offshore.de), funded by the German Federal Environmental Agency (Umweltbundesamt). A final goal of this study is to contribute to the development of methods and criteria for an evaluation of the effects of offshore windfarms on the marine environment.

The project contains three major parts, which are studied by three institutes:

1) Effects on migratory birds (IfV, Institut für Vogelforschung, Helgoland);
2) Processes in the vicinity of the piles (AWI, Alfred-Wegener-Institute, Bremerhaven & IOW, Baltic Research Institute, Warnemünde);
3) Effects of electromagnetic fields (IOW).

Up to now, one platform has been installed (FINO1 in July 2003) approximately 30 nm north of the island of Borkum in the German Bight (North Sea) at a water depth of 30 m. It is situated in a proposed area for windfarms. A second platform is planned for 2005 in the Baltic Sea near Rügen.

In the study of the processes in the vicinity of the piles, the focus is on the influence of artificial hard subtrate on surrounding soft-bottom fauna and sediments. In this context, the fouling on platform piles, its succession and seasonality as well as meroplankton diversity and abundance as a potential pool for settling larvae is included in the project.

Infauna and epifauna in the close vicinity of the pile are studied by grab samples (also used for sediment analyses) and videos taken regularly from the platform. Additional sampling from ships in the surrounding waters occurs three times per year, and includes also beam trawl hauls. The growth on the underwater construction of the platform is monitored weekly by a remotely operated digital camera/video system controlled online via internet. The results of the photo analyses are backed up by annual sampling by divers. Plankton samples are taken fortnightly from the platform and on the cruises. Meterological conditions and several hydrographical measurements at various water depths are continuously recorded by a fixed set of sensors: waves/tides, currents, temperature, conductivity and oxygen concentration.

Preliminary observations showed a very quick, complete colonisation by hydroids within few weeks, followed by a succession with a quickly increasing number of taxa. No results for the surrounding soft-bottom fauna and meroplankton dynamics are available at present; the progress will be reported at the next BEWG meeting.

Action: Alexander Schroeder to keep BEWG informed of the progress with this study.

4.9.8 Artificial reefs in Gothenburg harbour (S. Smith)

Susan Smith described an on-going project in the archipelago outside Gothenburg, Sweden where artificial reefs have been erected out of some 800,000 m^3 of blasted rock that was generated from the redevelopment of the fare ways to the harbour. This five-year research project started in 2003 to study the colonisation of flora and fauna by means of ROV documentation, fishing and diving. The objective is to determine whether the reefs will improve the populations of fish and shellfish in the area.

The seven reefs were built at a minimum of 30 m on soft bottom in two areas measuring generally more than 300 m in length and being 15 m high and 50 m wide. A few reefs were placed on sediment that was too soft and the rock sank. Both areas have become a no-fishing area.

A. The ROV documentation has been done twice so far. In May 2003 there was a baseline study in the area of the planned reef constructions. In January 2004 the ROV made seven transects at 10–37 m on the reefs showing one case of extensive colonisation of the tunicate *Ciona intestinalis.* There was a dense cover at the first reef built 8 months earlier of this typically opportunistic species, especially at central and shallower parts of the boulders. As their larvae exhibit negative phototaxis, horizontal parts of the stones were devoid of tunicates. Shoals of fish fry (Gobiids) were also observed in this environment.

B. Investigations of lobsters showed a fast colonisation and the first specimens were captured already a few weeks after a reef was completed, suggesting a lack of suitable homes even though the surroundings consist of a rocky archipelago. In this natural invasion, the size structure of individuals was similar to natural populations in a reference area. After tagging with Floy anchor tags (lobsters only), they were released again in order to be able to study their movement patterns, 309 individuals in all. In the autumn, the populations of crabs were smaller on the reefs than in the reference area.

C. At gillnet fishing in August and October, 21 species of fish were recorded with a similar composition to communities from adjacent areas, and two-year old cod were frequent close to the reefs.

D. Colonisation of invertebrates and algae was much slower. Diving and photo documentation were undertaken at four occasions during the first year showing:

- Fish fauna colonisation appeared within 2 months;
- Fish abundance was equally great at artificial reefs and natural hard bottoms in the reference area after 5.5 months;
- Colonisation of invertebrates species was low at artificial reefs – 28 taxa as compared to 68 at natural hard substrates;
- *Ciona intestinalis* was dominant from August and onwards on artificial reefs only; and
- Colonisation of macroalgae was also low – 3 taxa (only in August) as compared to 24 at natural hard substrates.

Heye Rumohr queried why the rock was used for the reef rather than in terrestrial building. In response, Susan Smith commented that the idea originated from her as a mitigation measure for fisheries and was laid down among the conditions in the judgement of the environmental court.

5 Review the report and activities of the Study Group on the North Sea Benthos Project 2000

Hubert Rees reviewed progress with the above project, including the outcome of the SGNSBP 2000 meeting held at Wilhelmshaven in March 2004. Significant effort was devoted to preliminary uni- and multi-variate analyses of the 2000 data set, including comparisons of the distributions of selected species in 2000 and 1986 (the ICES North Sea Benthos Survey). New data from the eastern English Channel provided insights into the biodiversity of offshore gravel deposits, relative to those in the North Sea. These results are given in the 2004 ICES Study Group report.

Recommendations were made for a variety of tasks relating to the further work-up of the data at an intersessional sub-group and Study Group meeting in 2004/2005.

Eike Rachor is leading on the production of an overview paper on the benthic communities of the North Sea, and a final draft is expected to be completed after the November 2003 Workshop. Other lead authors were identified for the following topics:

- Fishing activities/impacts;
- Natural and human impacts (other than fishing);
- Functional properties – in particular feeding types;
- Comparison of epifaunal and infaunal community patterns;
- Benthos/habitat linkages;
- NSBP 2000 data management.

It was noted that some misunderstanding existed regarding the present and future availability of data from the NSBP 2000 initiative. The full data set will become available via the VLIZ website as soon as the outcomes of the analyses had been published. This followed the precedent of the ICES NSBS (1986) and acknowledged the primary needs of the data contributors. A protocol explaining access to, and use of, data sets contributing to the ICES NSBP 2000 is given in the forthcoming 2004 SG report.

Karel Essink (Chair of SGSOBS) proposed that the SG NSBP 2000 employ the North Sea benthos data set to explore the distributions of opportunistic and sensitive taxa, and associated community metrics, identified by SGSOBS, and this was endorsed by the SG NSBP 2000.

BEWG expressed its strong support for the continued activities of the SG NSBP 2000 and the maintenance of close interactions between the two groups.

In the discussion, Lene Buhl-Mortensen suggested that the most interesting results would come from a detailed analysis of the temporal changes within communities, together with the change in the distribution of the communities. Alexander Schroeder made the important comment that irregular spatial surveys show the broad changes in pattern but must be supplemented by local, regular, time-series investigations to properly understand temporal changes. Such temporal changes may help explain changes observed in the spatial survey.

Recommendation: The BEWG endorses the activities of the SGNSBP 2000 and requests that ICES continues to fully support the group for the duration of its work, expected to be five years in total (as stated and agreed in the originally agreed TOR).

6 Start preparations to summarise the status of benthic communities in the North Sea for the period 2000–2004, and any trends over recent decades in these communities. Where possible, the causes of these trends should be outlined; for input to the Regional Ecosystem Study Group for the North Sea in 2006

The group discussed a request from REGNS for information to contribute to an ecosystem assessment of the North Sea. Heye Rumohr considered this a large task and beyond the scope for a working group meeting once a year. He suggested that this is a task for a contractor with BEWG offering to review the products. The NSBP 2000 will generate material that could contribute to this task but they have their own timescale and not many products may be available.

BEWG should support the work of RESG by encouraging their direct participation in BEWG. Hubert Rees expressed concern over the way ICES is embracing the 'ecosystem approach' through the establishment of new groups.

These groups then request information from existing working groups who have considered the 'ecosystem' since their inception – the BEWG is a good example.
Eike Rachor noted that there is an international group looking at long-term trends in all habitats (http://www.ILTER.edu).

Action: all members should report on studies on long-term trends, preferably via short presentations, at BEWG05. Eike Rachor will try to contact Russian colleagues to seek a presentation on long-term series studies from the Barents Sea region

Recommendation: BEWG will encourage the presentation of the results of studies considering long-term trends. At BEWG05, there will be a review of studies of long-term trends in benthic communities (soft and hard bottom, zoo- and phytobenthos) to help establish working relations to identify any common patterns.

6.1 Long-term development of macrobenthic communities in the German Bight (Eike Rachor and Alexander Schröder)

The development and interannual variability of sublitoral soft-bottom communities of the German Bight have been studied continuously at four representative permanent stations as well as by occasional large-scale mappings during the last 35 years (infauna sampled by 0.1 m² van Veen grabs). The benthic communities at the permanent stations show a large interannual variability as well as some changes on roughly decadal time scale. In accordance with large-scale system changes documented for the North Sea, also the composition of benthic communities changed since the late 1960s. To estimate possible climatic, oceanographic and anthropogenenic influences, the development of the benthic communities was correlated with various environmental data (climate (NAOI), water temperature, wind, salinity and nutrient concentrations at Helgoland, Elbe river runoff):
The development of the communities showed at all stations a clear correlation to the NAOI. The most dramatic changes followed the cold winters of 1970, 1979, 1986 and 1996, with decreasing species numbers and organism densities. The shallower stations are characterised by strong interannual variations, and the situation after cold winters is not as much different from other years as it is at the deeper stations.
The main factors influencing the development of the benthic communities besides biological interactions are the climate, food availability (eutrophication) and the disturbance regime. The most common disturbances are sediment movements during strong storms or by bottom trawling gears; extremely cold winters and occasionally also hypoxia add important large-scale disturbing influences.
Local conditions shape the development of the communities and details about local population densities may differ largely between stations. An integrated overview on a larger scale would require the inclusion of more stations, or better, a combined analysis of several existing time series from various regions of the North Sea.
BEWG04 highlighted the value of long-term time series data, and noted that any study less than ten years is probably too short and will record 'noise' rather than community patterns.
The complete text on the development and dynamics of soft-bottom macrozoobenthic communities in the German Bight (1969–2000) should be available as a pdf file on the web within a few weeks.

6.2 Ecosystem approach

Eike Rachor suggested that BEWG strongly supports the principle of the ICES move towards the ecosystem approach. Benthic ecologists have a strong understanding of the benthic ecosystem and therefore it may be insufficient if ICES establishes small, select groups to consider the 'ecosystem'. Instead, such groups should ensure that there is appropriate representation from all sectors, plus scientists who are experienced in integrated assessment to ensure that any ecosystem assessment and advice are undertaken in a holistic manner.

7 Review the outcome of the 2003 Theme Session on "The Role of Benthic Communities as Indicators of Marine Environmental Quality and Ecosystem Change", and make recommendations on future developmental work

Heye Rumohr commented that there was a disappointing response to the call for papers: seven presentations were made at the meeting but only three really addressed the theme topic. Angel Borja and Hubert Rees both addressed the issue of communicating the results of monitoring to a wider audience, particularly 'marine managers'. Such efficient communication is the big challenge to benthic ecologists to facilitate the wise management of marine ecosystems.

The lack of response to the call for papers may be linked to the remainder of the conference having a strong fisheries bias. For non-fisheries staff, it is hard to justify attending a week-long conference for a single theme session. This is a general problem with ICES meetings and conferences that the breadth of scientific topics of the whole meeting is not sufficiently broad to attract people from non-fisheries institutes, especially from North America.

Hubert Rees commented that ICES has agreed to a support a symposium in 2007 on 'Environmental indicators: utility in meeting regulatory needs' (see ICES website).

Recommendation: The BEWG recognises the importance of ongoing developments on indicators and their application and therefore recommends to ICES that it reviews the status of indicator metrics for 2005, including phytobenthic and epibenthic assemblages on hard substrata.

8 Collate information and recommend biological criteria for selection of dredged material disposal sites, including material from the Working Group on Marine Sediments in Relation to Pollution and the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem

A sub-group of BEWG04 addressed the topic of 'biological criteria for selecting dredging disposal sites'. It was recognised that, while it will be important for the future decision-making process to employ sound biological criteria for selection, such criteria could not be viewed in isolation: they would be inseparable from other considerations, including non-scientific issues such as operational factors, costs and convenience. Indeed, the latter criteria were probably the only ones used for the identification of long-established sites near to some major ports. Of course, the materials that are currently permitted for disposal at such sites are generally subject to more stringent quality criteria than in the past. Nevertheless, the scope for moving many of these may be very limited, in the absence of strong evidence for significant adverse effects.

Basic requirements for the implementation of sound environmental protection measures included:

- The need for adequate characterisation of the local environment and the associated benthic communities before disposal, as a means to determine the 'value' and sensitivities of components of the benthic ecosystem;
- The desirability for disposing of material of similar character to that of the receiving area;
- The management of disposal practices so as to minimise effects (e.g., tidal restrictions);
- Prior knowledge of the speed of recolonisation/recovery of benthic communities in receipt of intermittent inputs.

The sub-group emphasised the importance of providing a concise but thorough introductory account of the relevant issues presently associated with the activity of dredged material disposal (i.e., including national/international regulatory frameworks, stakeholder interests, economic and strategic considerations) as a background to the present task of identifying biological criteria. Also, these criteria should be derived in collaboration with other groups (e.g., Working Group on Marine Sediments in Relation to Pollution (WGMS) and Working Group on the Effects of the Extraction of Marine Sediments on the Marine Ecosystem (WGEXT)) to prevent an unrealistic outcome, relative to other intrinsically-linked considerations.

The sub-group noted that guidance on site selection does not presently appear to be available within HELCOM or OSPAR, who consider that the responsibility lies with national agencies.

The sub-group identified the following actions for intersessional work (see Section 17), leading to the drafting of guidance on biological criteria for site selection at the 2005 meeting:

- Compile existing information on biological criteria for the selection of dredged material disposal sites (as available in guideline documents, reports and published papers).
- Gather relevant information on a selection of existing disposal sites (dispersive characteristics, nature, frequency and amounts disposed of, contaminant status, presence of other human influences, ecological status and so on). A small number of case studies are needed, which are representative of good and not-so-good locations from an environmental management perspective. From these, lessons may be derived regarding future approaches to effective site selection from a biological standpoint.
- Compile relevant information on the sensitivity of the fauna to coverage by sediment which might aid site selection.

Recommendation: The group recommends intersessional work on this topic.

9 Consider output from the Working Group on the Statistical Aspects of Environmental Monitoring (Term of Reference a) for future studies

BEWG was asked to consider extracts from the WGSAEM reports from 2003 and 2004. WGSAEM was tasked with developing tools for biological community analysis for benthic monitoring programmes. Ideally, WGSAEM aims to develop a standard approach to community analyses to enable intercomparison between studies within the ICES area.

BEWG expressed some reservation over developing a standard approach since this might result in the unwitting endorsement of a single software product. One valuable output from WGSAEM would be advice on the benefits and pitfalls of the different analytical methods for biological community analyses. BEWG welcomed a closer collaboration with WGSAEM and offered that members of BEWG could attend relevant sessions of WGSAEM meetings. Similarly, members of WGSAEM would be welcome to attend BEWG meetings to foster improved collaboration between the groups.

Heye Rumohr pointed out that this initiative by WGSAEM relates to analyses for international comparison within the ICES framework, and that every researcher has the freedom to use any statistics he or she feels reasonable to answer the scientific questions of individual investigations.

10 Determine priorities for assistance from the Working Group on the Statistical Aspects of Environmental Monitoring with statistical analyses and develop with this Working Group a plan for the necessary collaboration

SGQAE suggested using standard data sets that could be processed by the difference packages to highlight the respective differences. Alex Schroeder suggested that WGSAEM review the different methods of analysis and highlight the common pitfalls with their interpretation. The group could use the 1986 NSBS data that are available on the web. WGSAEM should review the advantages, pitfalls and possibilities of interpretation (strengths and weaknesses?) of different statistical methodologies to assist biologists in meeting their targets for robust statistical analyses of their data. Recommendation: BEWG welcomes the offer to collaborate with WGSAEM and offers to supply datasets for statistical methods (for example the 1986 NSBS data).

Lene Buhl-Mortensen asked whether WGSAEM could consider a power analysis on data from different monitoring programmes with different sampling strategies, preferably on shallow sandy sediments with deeper muddy sediments to assess their potential for detecting change. It should also consider circumstances whether there are changes in the sampling technique.

BEWG would recommend that WGSAEM invite specific members of BEWG to its meetings when discussing benthic issues.

11 Develop guidelines for phytobenthos community sampling with a view to publication in the ICES TIMES series

Hans Kautsky reported on the status of preparing a proposal for guidelines of phytobenthic community sampling with the view of publication in the ICES TIMES series. The main objective of the paper was briefly presented. The guidelines will deal with diving techniques and visual methods investigating the (macroscopic) plant and animal communities of the tidal and subtidal zone on hard to soft substrates down to 30 m depth. The lower limit is not fixed but should be within the limits of safe diving and to some extent coincide with the lower limit of macroscopic, non-crustose plants.

A first draft suggested a set of SCUBA diver methods that were described in detail. The methods are presently used in the Baltic Sea, and are relevant for surveys and monitoring of the plant and animal communities found there, but have been practiced in more fully marine temperate and tropical regions. The main purpose of the methods is to give species depth distribution and coverage and describe their environmental conditions (e.g., substrate, wave exposure, salinity) and to collect quantitative samples. The maximum depth of plants will reflect the water quality. For quantitative description and biodiversity studies, destructive, quantitative samples are collected by randomly tossing frames of relevant size – in the Baltic Sea, quadrangular frames with a side length of 0.2 m and 0.5 m are used.

The immediate future work on the guideline will be to compile and review the literature on methods used to describe the plant and animal communities; relevant terminology should be adopted. A small sub-group of BEWG (Jon Davies, Les Watling, Angel Borja, Mario de Kluiver, I. Bartsch, and Hans Kautsky) was established to help develop this guideline. The literature list will be distributed among the members of the subgroup to add relevant references. Thereafter, methods will be discussed with emphasis on what they can do and what they cannot do. The prime target audience will be those who want to start a monitoring programme and working in connection with, for example, the EC Water Framework Directive. Depending on the objective of a study, suggestions will be given of appropriate techniques and what should be included.

It was noted that many methods are variations of one theme: the use of frames for estimating coverage, either with or without grid lines. The variations will only be described briefly, but relevant references to these methods will be given.

12 Review the outcome of the Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species for further use in formulating EcoQOs for the North Sea region

This agenda item is linked to item 3.8 described earlier. It was difficult for BEWG to address this agenda item since the full report from SGSOBS was not available to the group. From the excerpt presented, some concern was expressed over the statement under 9.1 that 'for the use in soft substrates the potential of using sensitive species only is relatively low'. BEWG requires clarification of this statement since there are studies under way to identify such species in soft sediments, and some species are known to be clearly sensitive to pressures.

Under section 9.2, Angel Borja suggested that the text advocating the use of 'one or more of biotic indices' should be amended to refer to 'one or more metrics/approaches'. BEWG agreed with this proposal.

BEWG acknowledges the work of SGSOBS; it recommends that SGSOBS continues its work and meets again in the future, and report to BEWG05.

13 Consider requests from the co-Chairs of the Study Group to Review Ecological Quality Objectives for Eutrophication for information in preparation for the Study Group

A background paper was submitted and included at Annex 13. The Chair introduced the paper and made a very strong case for adding a precautionary measure to the currently proposed EcoQO for the benthos component. BEWG recommends that a precautionary element is added to the proposed EcoQO and would strongly support the proposal to this effect in the draft paper submitted to SGEUT.

14 Update and finalise guidelines for sampling of the epibiota for publication in the ICES TIMES series

Hubert Rees introduced this item and suggested that a small sub-group of BEWG members be established to review the existing text and aim to finalise the text by the end of the meeting. A small group was established. Participants committed to providing draft text by lunchtime on 21 April for review by the whole BEWG.

A few general comments were provided at the outset. Due to the gestation period of the draft report, some of the text was a little out of date and should be edited to ensure that it is contemporary. Overall, it was considered too long and the text should be shortened: detailed technical information should be removed and replaced by appropriate references to sources of the technical information. The appendix on definitions should be removed and replaced with a short paragraph explaining the confusion within 'definitions' and providing the acceptable definitions. BEWG agreed to use the term epibenthos rather than epifaunal/epiflora.

Hubert Rees successfully coordinated the review and brought a revised text to BEWG for their consideration. The group reviewed the text and proposed a series of editorial changes. Hubert Rees agreed to make the final editorial changes after the meeting and then send the completed text to ICES for publication. Heye Rumohr recommended that Hubert Rees is listed as the author of the report. This proposal accepted by BEWG. Members noted, however, that it is important to recognise the contribution of others. Where individuals contributed a clearly attributable section, their names should be listed on a page of 'contributors' (or perhaps on the contents page); individuals who have provided advice and editorial comments should be listed in an acknowledgements section.

15 Review progress in environmental assessments of offshore windfarms in relation to the underpinning regulatory rationale, and make recommendations concerning the role of benthic community studies

Eike Rachor and Alexander Schroeder reported on plans, legislation, designated potential windfarm areas, approved pilot farms, extension plans in Germany, focused on North Sea area. There are several ongoing research projects: OFFSHOREWEA (final report from 11/2003 in English soon at www.UBA.de), BeoFINO (www.fino-offshore.de) and several accompanying studies for each windfarm EIA and later monitoring by private consultants; data are collected nationally by the BSH (Federal Maritime and Hydrographic Agency). The research is focused on birds, marine mammals, benthos and fish. Detailed EIA-regulations are in place (www.bsh.de, English version soon), covering baseline survey (2 years before construction), construction phase (1–2 years) and 3–5 years of the operational phase.

There is a need to harmonize approaches to designate possible areas and assessment procedures. A small group (J. v. Dalfsen, E. Rachor A. Schroeder and S. Smith) agreed to draft a short text. This sub-group gathered information from BEWG members via a short questionnaire. The results are presented in Annex 10, including a series of recommendations to ICES, and a table on windmill EIA procedures in the several present ICES countries. The table was thoroughly discussed and amended.

15.1 Report on the status quo of windpark research (macrozoobenthos) in the North Sea

Windfarm development has priority in Germany. There are proposals for large windfarms (200–500 mills) in the North Sea area, but at present, permission has only been granted for pilot farms (~50 mills). Most proposals for windfarms are in the offshore zone. Germany has developed guidelines for research and monitoring to deal with such developments within the German EEZ. Whilst there is currently a stakeholder consultation process, several areas have already been claimed and so the options for a coordinated spatial planning approach appear limited. Some guidelines on development are available, for example there should not be a big increase in hard substrata in otherwise sedimentary areas, although such guidance is applied at a local level. The only formal environment factor that is considered during the licensing is the potential effect on birds.

There are a number of on-going research projects that are considering the impact of windfarms on the marine environment. Standards for EIA have been developed and an additional English version will be published soon (Alex Schroeder can provide a MS Word version). These standards require consideration of benthos (sediment structure, epifaunal, infauna, fouling and phytobenthos), fish, birds and marine mammals. Detailed protocols including the methods to be used and the presentation of results are provided.

Reference areas: there is an ongoing discussion whether fishing will be blocked in these areas since trawl fishing will not occur within the windfarm area.

15.2 Swedish windpark update

Hans Kautsky provided an update on Swedish windpark developments. The Swedish government (through the EPA) has financed a project with the goal of describing and evaluating the quality of areas proposed for the placement of offshore wind farms. The hydrology, geology and biology of a given number of areas along the Swedish west coast, in the Baltic proper and in the Gulf of Bothnia are being investigated in the years 2004 and 2005. The goal is to create maps of the areas using GIS applications. The plant and animal communities are surveyed using a new technique for Sweden of hanging, remote video equipment. The principle resembles the technique of the area photography on land for landscape mapping. It will create a map based on a series of photographs from the substrate. Due to the limited areas seen by the video, a GIS application will be used to integrate data over the whole area of the shallow reefs down to 30 m depth by using depth charts and geological information. Based on the video-film, a protocol is written containing the position of each observation (GPS), the depth of the substrate, the type of substrate and its composition (percent) as well as the observed species and their coverage. Taxonomic identification of algae will be a problem but there will be some ground validation by diving. There is a good understanding of the range of species present within depth bands and this information will help with the video analysis. In addition, divers transects are performed for ground-truthing and the collection of samples for species determination and quantitative samples for biodiversity and the comparison with other areas and the coastal region. Parallel to the methods used in the diving transects, the observations are noted into the protocol as soon as the composition of the substrate changes and/or a new species occurs or disappears or if there is a change in coverage. The GIS application has a resolution of 10x10 m squares.

Susan Smith reported that a table of existing windfarms in different Countries (Denmark leading) can be found at http://www.offshorewindenergy.org provides a map to show the existing and planned windfarms in NW Europe. Sweden is planning a project to consider the effect of the turbine noise on fish communities – do BEWG members know of contacts who specialise in fish acoustics?

15.3 Wind energy in the Netherlands

Jan van Dalfsen gave a short presentation on windfarm developments in Netherlands. There are already two proposals for wind farms where construction is starting within a couple of years; some baseline benthic studies are under way at these locations. These will be exclusion zones for all shipping and so will offer opportunities for protected areas and/or multi-function use areas (aquaculture, diving, etc.). International coordination and cooperation are required to consider their effects at a regional level: Belgium and Germany have licensed areas adjacent to Dutch waters where windfarms will not be built. A large multi-partner project (WE@SEA) will start in 2004 to address issues identified with offshore windfarm development (http://www.offshore-wind.nl). Jan van Dalfsen is the project leader for the environmental research programme.

Lene Buhl-Mortensen asked whether there were any studies that considered how the patterns of turbines (lines, blocks) affect the benthos. There have been studies that considered the effect on currents, but no direct studies on benthos.

15.4 Wave energy in Spain

Angel Borja mentioned there were plans to develop wave energy at stations off the NW and SW coasts of Spain. Structures will be built onto the benthos and so there will be some impact.

Action: Angel Borja will report to BEWG05 on wave energy in Spain.

16 Any other business

16.1 Oceanography and Marine Environment of the Basque Country

Angel Borja presented the book 'Oceanography and Marine Environment of the Basque Country', edited by A. Borja (AZTI) and M. Collins (SOC-SOES, Southampton), and published in Elsevier Oceanography Series (nº 70) in 2004. The book presents extensive information from the estuarine and coastal waters of the Basque Country, and it is divided into various sections: Introduction; Geography and Oceanography; Chemical Oceanography and Water Quality; Sediment Characteristics, Quality and Chemistry; Biomonitoring; Communities and Ecology; and Overall Assessment. The topics covered include: an historical review of marine research; the impact of human activities, during past centuries; geology, geomorphology and sediments; climate and meteorology; marine dynamics; hydrography; water mass characteristics; contaminants in the waters; microbiological quality; sedimentological characteristics; contaminants in sediments; biomonitoring of heavy metals and organic components, at tissue organism level and using cellular and molecular biomarkers; bacterioplankton and phytoplankton communities; zooplankton communities; benthic communities; seabirds; biodiversity and conservation; recovery of benthic communities; the polluted systems; and assessment of human impacts.

The interest for the BEWG comes from the chapter 18 (Benthos), which includes aspects as biogeography, communities from wetlands, soft- and hard-substrata (both intertidal and subtidal) and information about the monitoring of exploited benthic species. Chapter 22 is centred in the recovery of benthic communities from polluted estuaries, after sewerage works, including also soft- and hard bottom substrata.

16.2 UK Habitat Classification

Jon Davies described the recent work undertaken by the Joint Nature Conservation Committee (UK) to revise the UK Biotope classification. Sections on Littoral Rock, Littoral Sediment and Circalittoral Rock were published on the web in 2003 (http://www.jncc.gov.uk/marine/biotopes/default.htm). The remaining sections on Infralittoral rock and Subtidal sediment are complete and will be published on the web in Spring 2004. It is the intention that these revisions will be incorporated into the EUNIS classification (http://eunis.eea.eu.int/index.jsp) being developed by the European Environment Agency. The EUNIS scheme will be used to support the implementation of the EC Water Framework Directive for coastal and transitional waters.

16.3 Taxonomic guides

Mario de Kluijver announced that ETI identification guides in the series macrobenthos of the North Sea are now available online:
Crustacea http://ip30.eti.uva.nl/bis/crustacea.php
Pycnogonida http://ip30.eti.uva.nl/bis/pycnogonida.php
Echinodermata http://ip30.eti.uva.nl/bis/echinodermata.php
Anthozoa http://ip30.eti.uva.nl/bis/anthozoa.php
Tunicata http://ip30.eti.uva.nl/bis/tunicata.php

16.4 Upcoming symposia/conferences

ICES annual science conference will be held in Vigo, 2004. HyR urges the group to submit papers to the ASC by the deadline of 03 May, 2004: (abstract@ices.dk).
EMBS in Genoa (2004) and Vienna (2005).
Ocean Bioinformatics Meeting in Hamburg, November 2004.
GLOBEC meeting in Canada.
Climate change and aquatic systems, Plymouth 2004.
ICES meeting on Marine environmental indicators, 2007.
Iberian symposium on marine benthic studies, Canary Islands, 22–25 Septemeber 2004.

17 Recommendations and action list

The **Benthos Ecology Working Group** [BEWG] (Chair: H. Rumohr, Germany) will meet at ICES Headquarters, Copenhagen, from 18–22 April 2005 to:

a) review the state of benthic communities at sea mounts as presented by MarEco and other projects;

b) recognizing the ongoing importance of indicator development and its applications, review the status of indicator metrics for 2004 including the phytobenthos and hard-substrate benthos;

c) work with WGSAEM on testing the use of different statistical methods on specific data sets (for example, the 1986 North Sea Benthos Survey data);

d) work with WGSAEM to investigate the power of different monitoring programmes and their specific sampling schemes including the questions of substrate and change of methods;

e) review studies on long-term trends in benthic communities (including soft substrates, hard substrates, and phytobenthos) and establish working relations with other groups to identify any common patterns;

f) review the results of intersessional work on the compilation of biological criteria for the selection of dredged material disposal sites, to support the formulation of new biological criteria;

g) further review the environmental studies at wind energy locations at sea and make recommendations on means for a harmonized European approach to benthic ecosystem studies.

BEWG will report by 6 May 2005 for the attention of the Marine Habitat and the Fisheries Technology Committees, as well as ACE.

Supporting Information:

Priority	The current activities of this Group will lead ICES into various issues related to the role of marine benthos. There is a great demand by international forums, consequently these activities are considered to have a very high priority.
Scientific justification and relation to Action Plan	Action plan: 1.2.1, 2.2.1, 2.13, 4.12, 2.11 a) This is an issue of major conservation interest for ICES, OSPAR and the EU b) There is continuing demand from regulatory agencies for the production of reliable indicators of environmental change and the BEWG can make an important contribution through the expertise of members in benthic ecosystem studies c) This arises from the review of future activities of WGSAEM

	d) There is an ongoing discussion on sampling design and allocation of sampling effort where benthic ecologists need help from environmental statisticians. e) This will be an important and timely review which will contribute to the integrated assessment of the Regional North Sea Ecosystem planned for 2006 f) This will support efforts to improve the management of dredged material disposal with respect to the well-being of the benthic ecosystem g) There is a growing need for an harmonized approach to benthic studies in view of the rapid expansion of the interest in off-shore wind energy and the associated installation of wind-parks.
Resource requirements	N/A
Participants	Representatives from member Countries with experience in various aspects of benthic ecology.
Secretariat facilities	N/A
Financial:	None
Linkage to Advisory Committee	ACME, ACE
Linkages to other Committees or groups	WGECO, WGEXT, WGITMO, WGSAEM, WGMHM, SGQAE, SGQAB
Linkages to other organizations	OSPAR, HELCOM EEA
Secretariat Cost share	ICES 100%

Other recommendations

The BEWG endorses the activities of the SGNSBP Study Group and requests ICES to support the group during its lifetime.

Recommendation to WGSAEM: Review the advantages and pitfalls of different statistics methods in order to help biologists to achieve statistically sound data products.

Action List

- Hans Hillewaert update BEWG web page and make earlier WG reports available as pdf files.
- Heye Rumohr to update the BEWG history powerpoint and web page.
- Alex Schroeder to present new results of RESPONSE and BEOFINO projects.
- Henning Reiss update results of MAFCONS project.
- Susan Smith to report on further developments at artificial reefs in Gothenburg harbour.
- Henning Reiss to update results from EPICATCH project.
- Santiago Parra to provide an update on the effects of the Prestige oil spill on benthic communities.
- Steven Degraer to report on progress in BWZEE project.
- All, present data on trends in long-term series. Summaries and metadata (substrata, methods, biotic component etc) should be posted onto the website prior to the meeting.
- Frank Beuchel report on evaluation of 30 yrs fixed site images from the Arctic.
- Eike Rachor to contact Russian colleagues to request a report about long-term data series from the Barents Sea region for BEWG05.
- Angel Borja to report on Spanish wave energy installations and the impact on benthos fauna and flora.
- Les Watling to collect North American SOPs and recommendations on phytobenthos studies intersessionally and send them to Hans Kautsky.
- HH, HR, SS, AB, RC, WB and OTHERS, for dredged material disposal sites to:
  compile any available information on biological criteria for selecting sites
  select case studies at existing sites, representing good or bad selection retrospectively, and
  formulate new criteria for the selection of such sites
- Lene Buhl Mortensen to ask responsible data suppliers in DK (A. Josefson) for data supply to WGSAEM to test power of different monitoring programmes and their specific sampling schemes including the questions of substrate and change of methods

- Hans Hillewaert to put papers for BEWG05 onto the website ahead of the meeting.
- Ingrid Kroencke to report about the relationship between microbial and macrofaunal communities in the North Sea.

18 Closing of the meeting

The Chair closed the meeting and thanked AZTI for hosting the meeting and Angel Borja for all his work before and throughout the meeting.

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Annex 2 2004 Terms of reference

The **Benthos Ecology Working Group** [BEWG] (Chair: H. Rumohr, Germany) will meet in San Sebastian, Spain, from 19–22 April 2004 to:

a) review the report and activities of the Study Group on the North Sea Benthos Project 2000;

b) review the outcome of the 2003 Theme Session on "The Role of Benthic Communities as Indicators of Marine Environmental Quality and Ecosystem Change", and make recommendations on future developmental work;

collate information and recommend biological criteria for selection of dredged material disposal sites, including material from the Working Group on Marine Sediments in Relation to Pollution and the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem;

develop guidelines for phytobenthos sampling with a view to publication in the ICES TIMES series;

update and finalise guidelines for sampling of the epibiota for publication in the ICES TIMES series;

c) review progress in environmental assessments of offshore wind farms in relation to the underpinning regulatory rationale, and make recommendations concerning the role of benthic community studies;

d) review the outcome of the Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species for further use in formulating EcoQO's for the North Sea region;

e) consider output from the Working Group on the Statistical Aspects of Environmental Monitoring (Term of Reference a) for future studies;

f) determine priorities for assistance from the Working Group on the Statistical Aspects of Environmental Monitoring with statistical analyses and develop with this Working Group a plan for the necessary collaboration;

g) consider requests fromthe co-Chairs of the Study Group to Review Ecological Quality Objectives for Eutrophication for information in preparation for the Study Group;

h) start preparations to summarise the status of benthic communities in the North Sea for the period 2000–2004, and any trends over recent decades in these communities. Where possible, the causes of these trends should be outlined; for input to the Regional Ecosystem Study Group for the North Sea in 2006.

i) BEWG will report by 10 May 2004 for the attention of the Marine Habitat and the Oceanography Committees, ACME, and ACE.

Annex 3 Agenda for the Benthos Ecology Working Group (BEWG), San Sebastian, Spain, 19–22April 2004

1. Opening & Local Organisation
   1.1. Appointment of Rapporteur
   1.2. Terms of Reference
2. Adoption of Agenda
3. Report on ICES meetings and other meetings of interest
4. Report of co-operative studies and other studies relevant to ICES
5. Review the report and activities of the Study Group on the North Sea Benthos Project 2000
6. Start preparations to summarise the status of benthic communities in the North Sea for the period 2000–2004, and any trends over recent decades in these communities. Where possible, the causes of these trends should be outlined; for input to the Regional Ecosystem Study Group for the North Sea in 2006.
7. Review the outcome of the 2003 Theme Session on "The Role of Benthic Communities as Indicators of Marine Environmental Quality and Ecosystem Change", and make recommendations on future developmental work
8. Collate information and recommend biological criteria for selection of dredged material disposal sites, including material from the Working Group on Marine Sediments in Relation to Pollution and the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem
9. Consider output from the Working Group on the Statistical Aspects of Environmental Monitoring (Term of Reference a) for future studies;
10. Determine priorities for assistance from the Working Group on the Statistical Aspects of Environmental Monitoring with statistical analyses and develop with this Working Group a plan for the necessary collaboration
11. Develop guidelines for phytobenthos sampling with a view to publication in the *ICES TIMES* series;
12. Review the outcome of the Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species for further use in formulating EcoQO's for the North Sea region;
13. Consider requests from the co-Chairs of the Study Group to Review Ecological Quality Objectives for Eutrophication for information in preparation for the Study Group;
14. Update and finalise guidelines for sampling of the epibiota for publication in the *ICES TIMES* series
15. Review progress in environmental assessments of offshore wind farms in relation to the underpinning regulatory rationale, and make recommendations concerning the role of benthic community studies;
16. Report on the status quo of windpark research (macrozoobenthos)
17. Any other business
18. Upcoming symposia, etc., further theme sessions
19. Recommendations and Action List
20. Adoption of the report
21. Closing of the meeting

Annex 4 A summary of the MESH project

Project Summary

Project Title & Acronym	Development of a framework for **M**apping **E**uropean **S**eabed **H**abitats (MESH)
Project Registration Number	
Project type	Action
Measure applied under	5.2 Enhancing the maritime functions of NWE and promoting territorial integration across seas of NWE
Lead Partner organisation	Joint Nature Conservation Committee (JNCC)
Country of Lead Partner	UK
Total number of partners	12
Countries involved	The Netherlands, Belgium, France, Ireland, UK
Start date - End date	1 May 2003–30 April 2007
Project total budget	~€8.125m
ERDF applied for	~52%

Please enclose a two-page summary of your project application, briefly outlining the objectives of the project, the issues tackled, the actions and investments foreseen. Please put particular emphasis on the transnational and innovative character of your project.

The seas around north-west Europe support an exceptionally wide range of seabed habitats and rich biodiversity. These provide important food resources (fish, shellfish), contribute to essential ecosystem functioning (such as nutrient recycling) and yield valuable natural resources (oil, gas, aggregates). In addition the seabed is subject to increasing pressures from new developments, such as for renewable energy (e.g., windfarms) and coastal developments for leisure activities and coastal defences.

These multiple uses bring ever-growing pressures on our seas and coasts, leading to increased risk of conflict between users and a greater potential for degradation of the marine environment and the essential physical, chemical and biological processes that maintain our marine ecosystem. We are responding to this challenge through recognition of the need for much improved integrated spatial planning for our seas (where traditionally planning has been very piecemeal or sectoral), as reflected by the new requirement for Strategic Environmental Assessments (SEAs) and issues raised recently within the developing EU Marine Strategy, by the OSPAR Commission and by Governments (e.g., the UK's Marine Stewardship Report). Additionally there are new and increasing international commitments (from the EC Habitats Directive and OSPAR) to protect certain marine habitats, including through the designation of a network of marine protected areas, whilst the EC Water Framework Directive and OSPAR require periodic assessment of ecosystem health, including its seabed biological communities. The assessment of coastal sensitivity to oil spills is currently hampered by the lack of proper data on habitats, as has been shown by the recent *Prestige* case in France.

All this creates a substantial demand for information about intertidal and seabed habitats, but is set against a background of patchy, inconsistent and poorly collated information on their distribution, extent and quality. There are no national programmes (except in France) which collate such information and the information which is available is difficult to access, making very poor use of data which are expensive to collect. The recent increase in demand, coupled with advances in remote-sensing technologies over the past ten years, has led to a burgeoning of seabed mapping studies. These are undertaken using a variety of techniques, for a range of end needs (e.g., fisheries, commercial, nature conservation) and at various scales. The lack of international standards for these studies means the resulting data cannot readily be compared or aggregated and leads to an absence of regional, national and international perspectives on the seabed resource in spatial planning and decision-making.

MESH will address these issues in the following key ways:

- It will compile available seabed habitat mapping information across north-west Europe and harmonise it according to European habitat classification schemes (the European Environment Agency's EUNIS system and the EC Habitats Directive types) to provide the first seabed habitat maps for north-west Europe.
- Because the available information will be of variable quality and patchy in nature, habitat modelling will be developed to predict habitat distribution for unsampled areas, from the more widely available geophysical and hydrographic data. The final maps will be presented with confidence ratings so that end-users can determine their adequacy for their decision-making and future survey effort can be strategically directed.
- A set of internationally agreed protocols and standards for habitat mapping will be developed, drawing upon best available expertise across Europe and elsewhere, to help ensure that future mapping programmes yield quality assured data that can be readily exchanged and aggregated to further improve the initial maps. The protocols will be tested through a range of field-testing scenarios involving trans-national co-operation to ensure they are robust and the results repeatable.
- Both the protocols and the habitat maps will be made available via state of the art Internet-based GIS (Geographical Information Systems), providing ready access to the information for a wide range of end-users at local, regional, national and international levels (e.g., spatial planners and managers; governments and other regulatory authorities, research institutions, educa-

tional establishments).

- The wide spectrum of potential end-users will be engaged from the start of the project to better understand their end needs, to encourage the supply of relevant data and to encourage the improved use of the mapping information in spatial planning, management issues and for environmental protection. This network of stakeholders will be valuable in helping to forge strategies within each country for the maintenance and further improvement of the seabed maps beyond the end this three-year project.

A strong Partnership of highly skilled and experienced organisations has been developed to deliver this challenging project. The Partnership covers all five countries in the Interreg IIIb North-West Europe area, bringing with it a balanced mix of skills including scientific and technical habitat mapping skills, national data collation and management expertise and experience in the use of habitat mapping in management and regulatory frameworks. This blend of expertise from scientific/technical through to management and policy, with a focus on regional, national and international level delivery is felt to be essential to effectively deliver the required end products in a readily useable format.

Please list the major <u>concrete deliverables and outputs</u> which will have been produced by the end of your project. These can either be 'soft' deliverables (reports, maps, guides, training scheme, software, website, permanent network, database…**) or 'hard' small-scale physical investments** (specify what, i.e., a building, a cycle path, signposts…)

- The first collated and harmonised map of seabed habitats for the north-west Europe INTERREG-IIIB Area, presented in a Geographical Information System (GIS) according to the European Environment Agency's European EUNIS habitat classification system and the EC Habitats Directive types.
- Accompanying confidence maps, indicating the quality of mapping information in relation to its accuracy and precision at different scales of resolution.
- A meta-database of seabed mapping studies for north-west Europe, holding details on the location of each study, the mapping techniques employed and the range of data and end products generated.
- The first large-scale evaluation of the practical application of the EEA's EUNIS habitat classification and recommendations for its modification or improvement.
- A set of internationally agreed protocols and standards for marine habitat mapping. This will include guidance on mapping strategies, standards for undertaking remote-sensing and ground-truthing surveys for intertidal and subtidal mapping using a variety of techniques, and protocols for data storage, interpretation and presentation.
- A series of new mapping studies which test, evaluate and help improve the mapping protocols and standards.
- Models for the prediction of habitat type, based on physical and hydrographic information within different habitat areas and water depths.
- Case studies which demonstrate the political, economic and environmental use of marine habitat maps for spatial planning and management at local through to international scales.
- A website providing wide access to the products of the project, including interactive GIS seabed maps for north-west Europe.
- National networks of habitat mapping practitioners and end-users in management, regulatory and planning authorities.
- A framework within each country for the continued collation and improvement of habitat maps at national level and their compilation and aggregation at an international level.

Annex 5 EUMARSAND (European Marine Sand and Gravel Resources: Evaluation and Environmental Impact of Extraction)

Duration: 1/11/2002–1/11/2005
Research Training Network (Geo- and Environmental Sciences)
Funded by the European Commission within the 5th Framework Programme 'Improving the Human Research Potential and the Socio-economic Knowledge Base
Partners:

- AZTI Foundation (Technological Institute for Fisheries and Food), Marine Research Division, Spain (Dr. Wendy Bonne (wbonne@pas.azti.es), Dr. Adolfo Uriarte (aduriarte@pas.azti.es))
- SUSOES: School of Ocean and Earth Science - University of Southampton, United Kingdom (Dr. Erwan Garel (ezg@soc.soton.ac.uk), Prof. Michael Collins (mbc@soc.soton.ac.uk))
- RUG: Renard Centre of Marine Geology (RCMG) - Ghent University, Belgium (Dr. Valerie Bellec (Valerie.Bellec@UGent.be), Dr. Vera Van Lancker (Vera.VanLancker@UGent.be))
- NKUA: Department of Geography and Climatology - National & Kapodistrian University of Athens, Greece (Dr. Arnaud Ballay (aballay@geol.uoa.gr), Dr. Serafim Poulos (poulos@geol.uoa.gr))
- UOA: Marine Science Department - University of the Aegean, Greece, (Dr. Rolandas Radzevicius (rolandas.radzevicius@geo.lt), Prof. Adonis Velegrakis (afv@aegean.gr))
- MIG: Maritime Institute Gdansk, Poland (Dr. Nerijus Blažauskas (nb@geo.lt), M.S. Ingrida Bagdanaviciute (ingrida@geologin.lt), Mr. Juliusz Marek Gajewski (julgaj@im.gda.pl))
- ULCO: "Coastal Geomorphology and Shoreline Management Unit" (GeoDAL) - Université du Littoral-Côte d'Opale, Dunkerque, France (Dr. Stella Kortekaas (Stella.Kortekaas@univ-littoral.fr), Prof. Arnaud Hequette (hequette@univ-littoral.fr))
- UT: Civil Engineering Department - University of Twente, The Netherlands (Dr. Deborah Idier (until March 2004), Prof. Suzanne J.M.H. Hulscher (S.J.M.H.Hulscher@ctw.utwente.nl))
- IFG-CAU: Institute of Geosciences (IfG), Marine Geology, Coastal and Continental Shelf Research - Christian-Albrechts-University Kiel, Germany (Dr. Faustino Manso (fm@zaphod.gpi.uni-kiel.de), Dr. Klaus Schwarzer (kls@gpi.uni-kiel.de))

Tasks and achievements:
Task 1: Information compilation and management (co-ordinated by Kiel University (IFG-CAU)):
Compilation of all available information from national Regulatory Authorities, EU initiatives, industry associations and Non-Governmental Organisations on:

- Aggregate Usage (Leader: NKUA)
- Resource type and availability (Leader: IFG-CAU)
- Regulatory framework (Leader: UOA) The different licensing/regulatory regimes and their compatibility will be compared with the present European Environmental Legislation (e.g., EIA Directives, Habitats Directive, Water Quality Directives).
- Extraction techniques (Leader: UOA)
- Data management and integrated mapping of the occurrence and characterisation of marine aggregates, including coupling to a Geographical Information System (GIS) for various visualisation approaches (Leader: MIG)

The website structure to present the information has been defined and results will be posted in the future on http://www.azti.es/eumarsand/ under Project Progress.

Task 2: Marine aggregate prospecting (co-ordinated by Ghent University (RUG)):
Task 2.1 Review of geophysical instrumentation, survey and interpretative techniques presently in use for the location/evaluation of marine aggregate deposits (Leader: RUG).
This task is finished in June 2004.
Task 2.2 Field evaluation of MA prospecting techniques (Southern North Sea and Baltic Sea experimental sites): optimisation of survey strategies (including the deployment of 'state-of-the-art' geophysical instrumentation) and of sampling strategies, on the basis of geophysical data. (Leader: RUG)

- Kwintebank: side-scan sonar and multibeam data and seismic profiles have been gathered and analysed, video imagery has been acquired and ground truthing has been performed with Van Veen grabs and boxcores from the campaign in June 2003
- Baltic Sea: side-scan sonar data are successfully gathered and analysed of the Tromper Wiek area, a multibeam survey of the Tromper Wiek area has been performed as well

Task 2.3 Recommendations and formulation of research protocols (Leader: UOA)

Task 3: Assessment of the environmental impacts of marine aggregate (MA) extraction (co-ordinated by the University of Southampton (SUSOES)):

Task 3.1

Review and sensitivity of the hydro-sediment and morphodynamic models presently in use, to study mining-induced changes. This task is finished in June 2004.

Morphodynamic modelling of the experimental sites calibrated/validated against high-quality field observations (Leader: UT)

Performed idealized case morphodynamic modelling:

- The influence of bed roughness on the processes of sandwave and megaripple generation on sandbanks has been studied. Conclusion: mega-ripple generation is related to ripple roughness; sandwave generation to grain roughness.
- A new stability analysis has been performed including the influence of grain size on sandbank generation.
- It has been studied whether sandbanks result from interactions between sandwaves. However, no conclusion could be drawn yet regarding this statement.

Proposed modelling for the Kwintebank:

Idealized case modelling

- Grid sensibility of the sediment transport module, sandbank generation and saturation and sand extraction impact on flat bed / sandbanks with Delft3D

Field area modelling

- Existing regional hydro-sedimentary model of the Kwintebank (MUMM) providing boundary conditions for morphodynamical model with Delft3D
- Local morphodynamic model including tidal currents, waves, bedload and suspension

  2DH: only sandbank dynamics (grid size 100 m)
  3D: both sandbank and dune dynamics (grid size 10 m, no megaripples)

Task 3.2 Field observations of offshore (near-field) and coastal hydrodynamics/sediment dynamics (Leaders: SUSOES/ULCO)

- Wave, current and turbidity measurements of bottom and hull mounted ADCP and bottom mounted S4 on the Kwintebank have been successfully gathered in February 2004.
- Grids of sediment samples have been taken in September 2003 and February 2004 to be analysed with the McLaren & Bowles, 1985 (Gao & Collins, 1991) method to assess sediment transport paths

Task 3.3 Review of research protocols presently in use to monitor ecological changes at MA extraction sites. Field evaluation of the effectiveness and efficiency of these methods. Establishing the nature and vulnerability (to aggregate mining) of the benthic communities (Leader: AZTI)

- Benthic samples have been taken in June, September–December 2003 and February 2004 to assess the ecological impacts of extraction on the Kwintebank.

Task 4: Research Integration and Formulation of Guidelines (co-ordinated by AZTI):

Integration of the results from all previous tasks, resulting in the design of improved research protocols for MA resource prospecting and for the assessment of the environmental impacts of MA extraction.

Website: http://www.azti.es/eumarsand/

Annex 6 Assessment of Recovery Processes of the Macrobenthos on the Kwintebank

By Hans Hillewaert, Bart Maertens and Ine Moulaert
Sea Fisheries Department
Oostende, Belgium

Introduction

Possible effects of aggregate extraction on the marine environment may be: removal of substratum en it's associated benthic communities; alteration of the granulometry; enhancement of local turbidity; shifting of hydrodynamics and sediment transport; changing water quality (Posford Duvivier environment and Hill, 2001). The influence and the consequences of the impact are very site-specific and as such, a monitoring programme should be specifically aimed at and be suited to the local situation. On the Belgian Continental Shelf, two major zones are designated for licenses for sand extraction. Black box data have indicated that the majority of the extraction activity takes place in zone II on the Kwintebank. This study evaluates the current status of zone II with emphasis on the Kwintebank, based on macrobenthic and sedimentologic data. Macrobenthos being an ideal indicator for monitoring possible effects of sand extraction, due to it's intimate relationship with the sediment and it's low mobility (Boyd *et al*., 2003a). Furthermore the onset is given to a follow-up study, where recolonization is investigated after cessation of dredging on part of the Kwintebank.

Sampling

Twice a year, samples are taken on board the A962 “Belgica”. Macrobenthos, epibenthos and demersal fish are routinely sampled.

All samples were taken with a modified Van Veen grab, equipped with an extra 50 kg weight and a sampling surface of 0.1 m². The samples are subsequently stored on board in a 10% formalin solution and sieved after fixation, whereby the organisms are also stained with a 0.1% esosine solution. All biota are identified to the lowest taxon (species if possible) exept for Anthozoa and Nemertea (Adema, 1991; Hartmann-Schröder, 1996; Hayward and Ryland, 1990; Tebble, 1976; Emig, 1979; de Kluijver *et al*., 2000, 2001).

Four sampling stations (Zg1-Zg4) on the extraction Zone II were studied, of which 1 (Zg1) lays in an intensively dredged area. Additionally, two stations outside the extraction area were added to the initial analyses. (Figure 5).

Data analysis

Firstly a cluster analysis on all sampling points was performed. This indicated that differences between the stations are larger than those between the years. Three distinct groups can be distinguished: the reference points, the stations Zg3 and Zg4, and the stations Zg1 and Zg2.

Next, a non-metric multidimensional scaling was applied as an ordination technique. The same three groups were found (Figure 1).

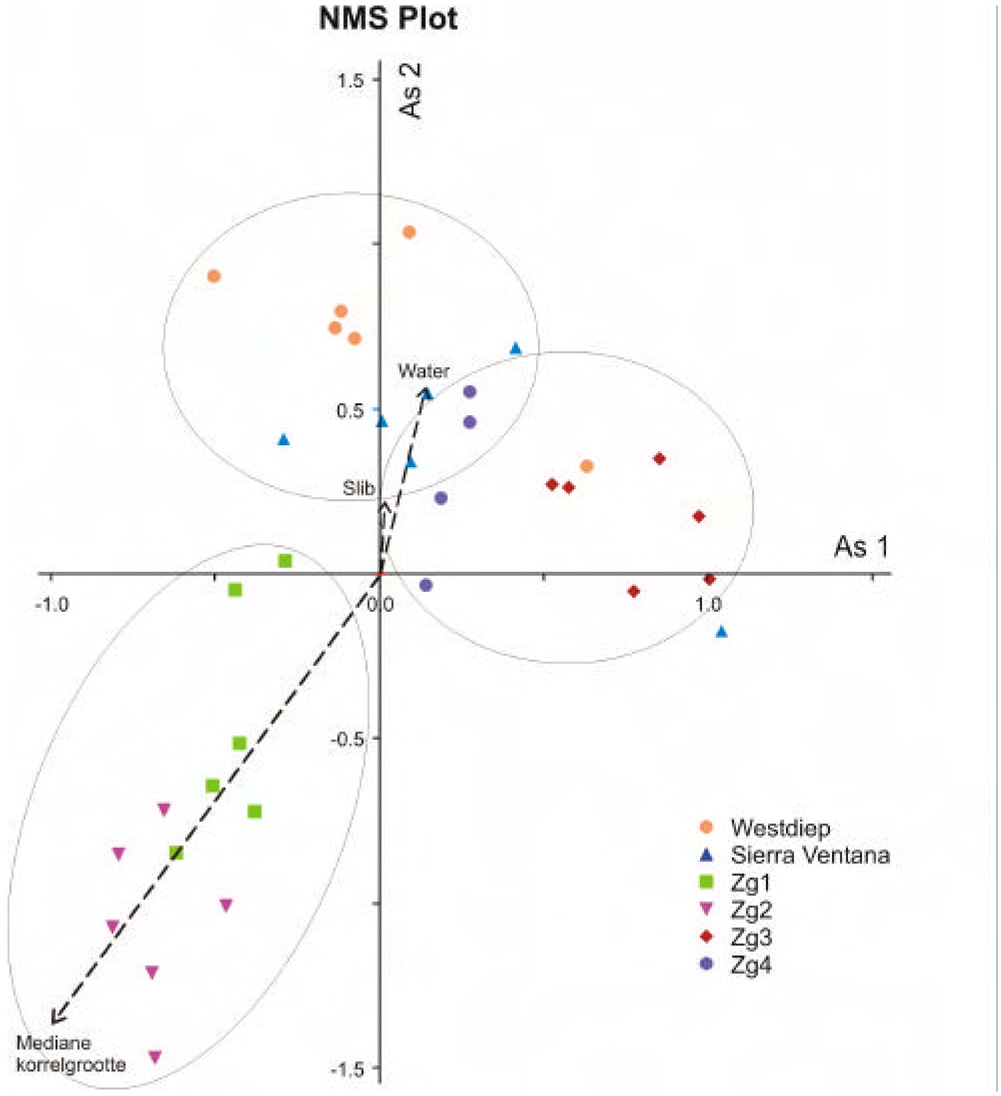

Figure 1. MDS plot with the three groups, and vector indicating environmental parameters.

This technique takes environmental parameters into account. Here, the parameters consist of median grain size, the amount of interstitial water and the granulometric fraction <64 µm.

The influence of the different parameters is visualised by vectors.

One notices that the median grain size is the largest discriminating factor: the stations Zg1 and Zg2 clearly separate from the other four points. Analysis showed them to have a coarser sediment.

The other four stations, in there turn, break apart again in two groups in response of the <64µ fraction and, closely correlated, the amount of interstitial water: on the one hand, a group with Zg3 and Zg4 is formed with the two remaining sand stations; on the other hand there are the Westdiep (120) and station Sierra Ventana (780).

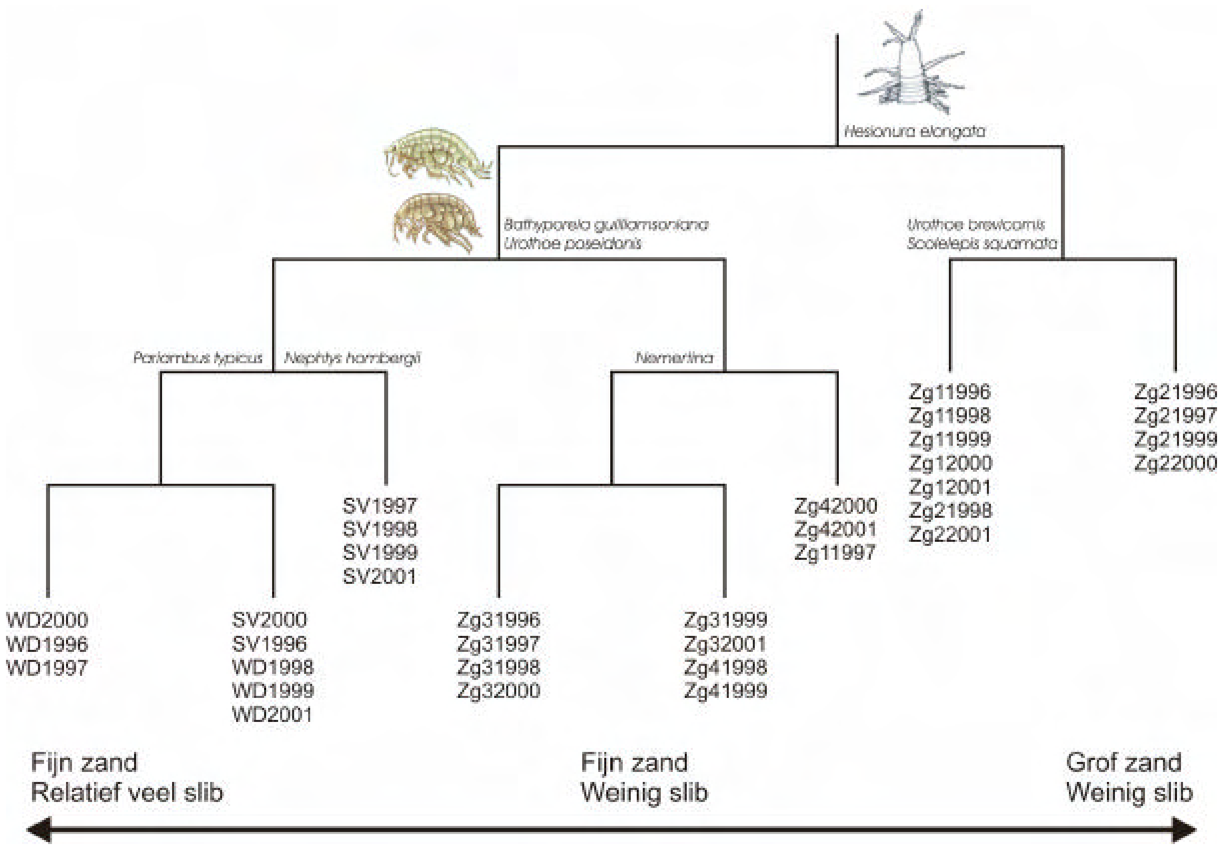

Figure 2. TWINSPAN with indicator species

Twinspan, a two-way indicator species analysis, is a splicing cluster analysis. The dataset is divided in consecutive smaller units according to the indicator species.

The first division is characterised by *Hesionura elongata*. This is a small interstitial polychaete living in coarse sands.

The next division is set apart by the amphipods *Bathyporeia guilliamsoniana* and *Urothoe brevicornis*. Stations with a higher silt content (3% to 10%) are separated from the more sandy locations (1% to 3% silt content).

Again the three groups surface, based on a gradient from coarse sand with low silt content to fine sand with a high silt content. This gradient validates the habitat model developed at the University of Ghent, Section Marine Biology.

The number of individuals/m² is at its lowest on Zg2 (where the aggregate extraction is negligible) followed by Zg1.

The reference stations and the points Zg3 and Zg4, located on the Kwintebank, have a higher number of individuals/m² (up to 3500 ind/m²).

The coarsest sands have the lowest number of species: 2 to 13 for Zg2 and 12 to 20 for Zg1. On other locations more then 40 different species are found.

The diversity on coarse sediments is generally lower then on fine sands with silt.

Station Zg1

The final part of the study focuses on station Zg1, which is situated closest to the northeastern part of the Kwintebank in an area of intensive extraction. Looking at the highest taxonomical levels, we see no temporal trends in the constitution of the macrobenthos.

Polychaetes (bristle worms) and Crustaceans (mainly amphipods), are the most abundant groups. Echinoderms (hart urchins en bristle stars) and the bivalve *Tellimya ferruginosa*, living in the holes of the hart urchin (*Echinocardium cordatum*), are found on a regular basis. Just once, Nemertinea (ribbon worms) and the lophophorate *Phoronis pallida* were found.

Between 1996 and 2001, a significant decrease in number of species is found on Zg1 (Figure 3), located closest to the major extraction site (northern edge of the Kwintebank). The decrease in number of individuals/m² and the Shannon-Wiener diversity do not prove to be significant at a 95% confidence interval.

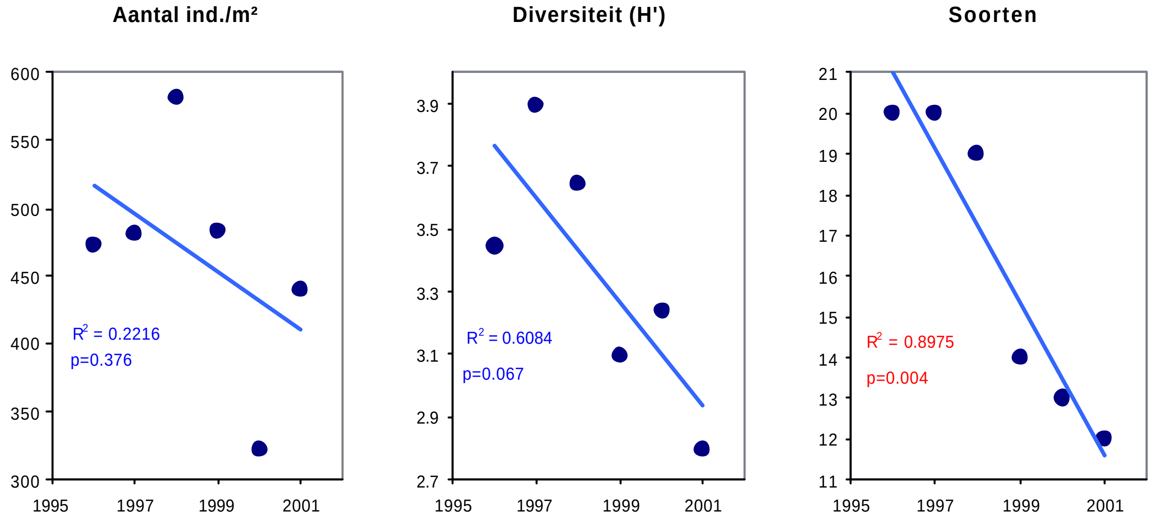

Figure 3. Trends of biological parameters on Zg1 (1996–2001).

A plausible explanation can be found when looking at the granulometric analysis.

We observe a significant increase in the fraction 500–1000 µm and a near to significant increase in the fraction 250–500 µm. An important decrease (significant again) in the 125–250 µm fraction is complementing these trends (Figure 4).

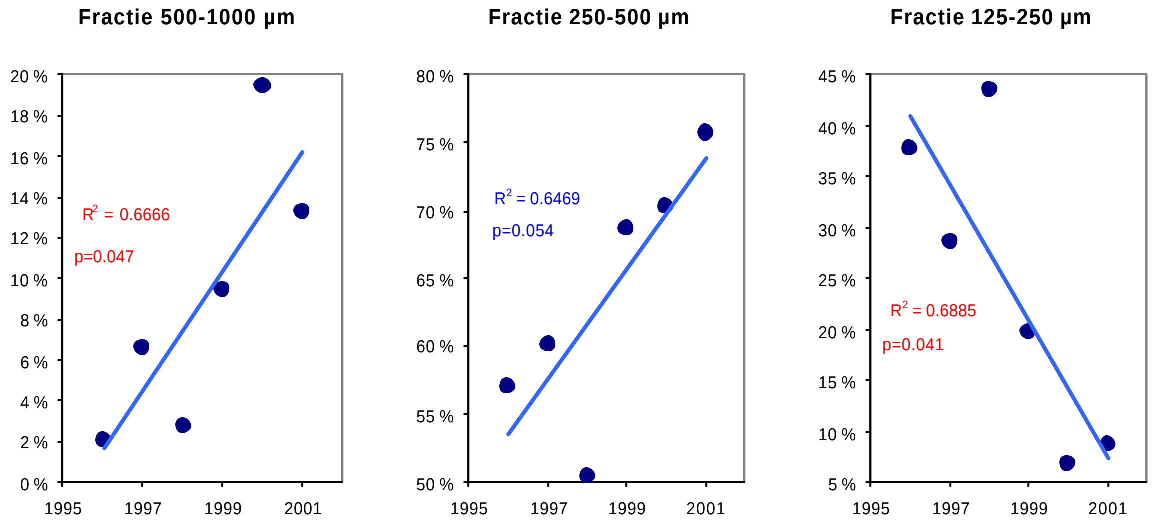

Figure 4. Trends of relevant granulometric fractions on Zg1 (1996–2001).

The conclusion may well be that there is a coarsening of the sediment, probably due to the intense, nearby, aggregate extraction. And, as shown by the TWINSPAN analysis previously, a coarser sediment carries a lower number of species. The non-significance of the diversity trend may be due to the absence of opportunistic, highly dominant organisms.

As mentioned above, there is a richer benthic fauna on fine and more silty sediments. Station Zg1 apparently evolves into a sediment similar to the one found on station Zg2: a larger median grain size with a smaller amount of more specialised species.

No significant trends were observed during the period 1996–2001 at the other stations.

Concluding we can state that median grain size, interstitial water and silt content are respectively the most important gradients to type the stations. The observed species form associations in accordance to the results of other studies (Habitat-model). Highest densities and diversities are found on fine sands with silt, lowest on pure coarse sands. Only station Zg1 showed significant trends due to a coarsening of the sand resulting in a decrease in the number of species. These effects are presumably driven by the intense, nearby aggregate extraction.

Recolonization study

The estimated time required for re-establishment of the benthic fauna following marine aggregate extraction may vary depending on:

- the nature of the habitat;
- the scale and duration of disturbance;
- hydrodynamics and associated bed-load transport processes;
- the topography of the area; and
- the degree of similarity of the habitat with that which existed prior to dredging (Boyd *et al*., 2003).

Other studies on recovery:

- Klaver Bank (van Moorsel, 1993): 1 year;
- RIACON Project, from Dutch and Danish waters (Essink, 1997; van Dalfsen & Essink, 1997; van Dalfsen *et al*., 2000): 2 years;
- Gravel extraction sites from the east coast of Britain (Kenny and Rees, 1994 & 1996 and Kenny *et al*. 1998): 3 years;
- Industrial extraction site off Dieppe (Deprez, 2000): Species richness has been fully restored after 16 months, while densities and biomass were still 40% and 25%, respectively, lower than in reference stations after 28 months.

Changes in the character of the sediment caused by aggregate dredging may not only lead to changes in the community structure in the short-term but may also have longer term implications. This is most likely if there is a change from the pre-dredging physical environment and therefore a readjustment of the biota rather than recovery to the pre-dredging condition.

Sampling design and sample collection:

- Van Veen grab (0.1 m²);
- Macrobenthos (1mm) + sediment samples;
- Sieved after fixation.

Reference site(s): should be identical in all respects to the dredged locations, save for the impact of marine aggregate extraction. However after dredging has taken place for many years, the benthos and sediment may have been structurally altered as a consequence of dredging. In this situation, it is difficult to reach a judgement as to whether a suitably located reference station, in the near vicinity of the dredged site, is representative of the likely pre-dredged status. The reference site in this study was chosen by taking account of the sedimentary characteristics and black box data.

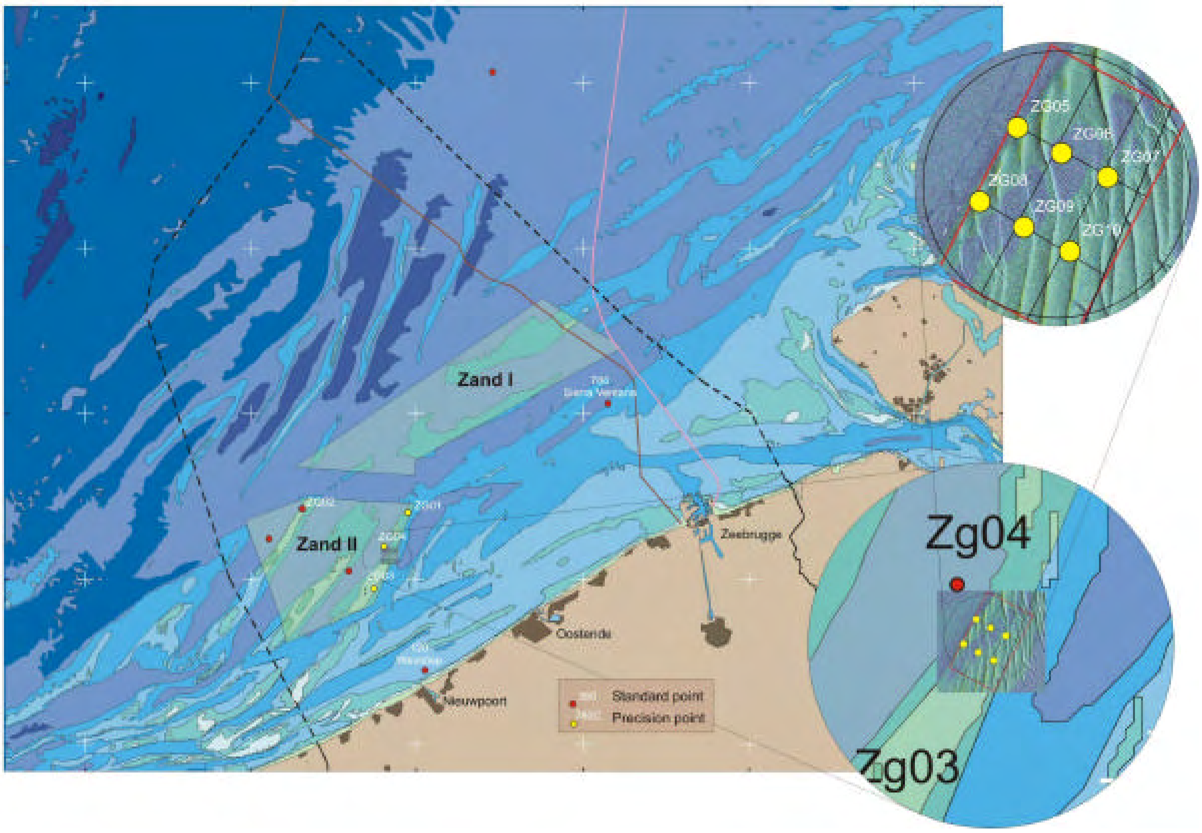

Figure 5. Situation of sand extraction areas with in the inset the recolonization programme.

A Grid with six points was selected (Figure 5)

- 3 times sampled in 2003 (March, June, September) (3 months interval);
- 2 times sampled in 2004 (March, September) (6 months interval);
- follow-up until after reopening of the site for extraction (2006).

Data analysis:

- Univariate measures: total abundance, numbers of species, species richness, diversity indices, biomass, rarefaction, etc.;
- Multivariate techniques such as non-metric multidimensional ordinations, twinspan, etc.;
- Relation between the different biological parameters and environmental parameters such as depth, sedimentary parameters (median grain size, different fractions, etc.);
- Comparison with other sampling points where extraction is still ongoing;
- Study of comparable areas where no extraction has ever taken place (reference points).

Preliminary results

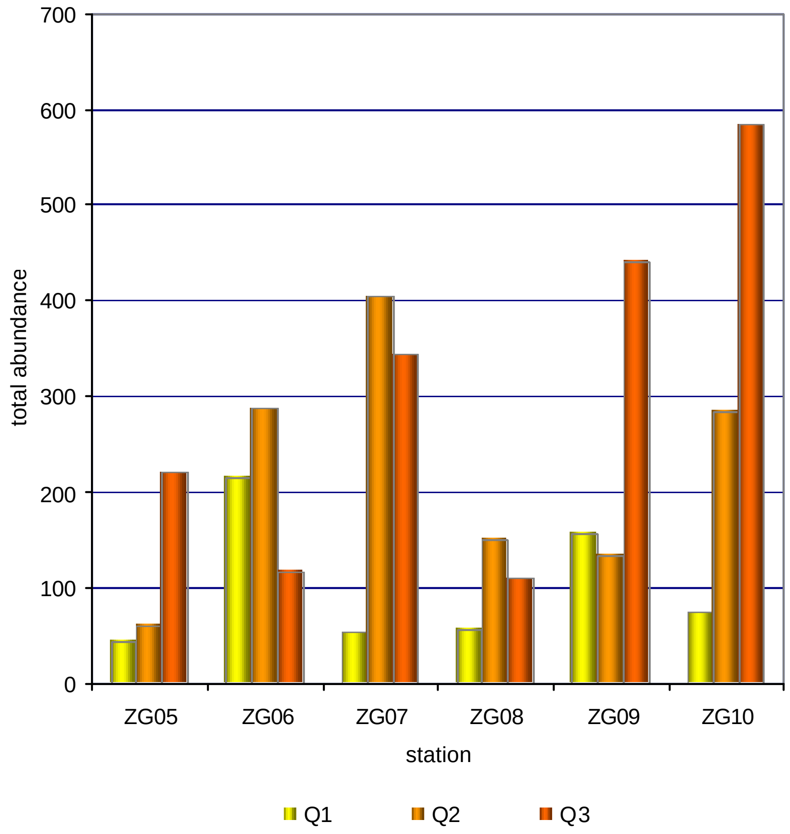

Figure 6.

Preliminary results hint at a fast recovery but may only be due to seasonal effects. More definite conclusions will be possible after assessment of two years of the restoration process.

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Annex 7 The impact of the *Prestige* oil spill on the benthic and demersal communities of the Continental Shelf off Galicia and in the Cantabrian Sea

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San Sebastián, Spain, April 2004 — Not to be cited without reference to author(s)

Introduction

During the course of events that led to the foundering and subsequent sinking of the enormous single-hulled tanker *Prestige* in November 2002, 130 miles off the coast of Muxía (La Coruña, Galicia), roughly 20,000 tons of fuel oil spilled into the sea, causing a vast black tide which has affected the entire coast of Galicia, especially devastating the *Costa de la Muerte*, spreading, months later throughout the Cantabrian Sea. The paper presented in 2003 in this working group provided general information on this oil spill, in addition to the actions carried out by the IEO towards the study of the impact of this oil spill on the continental shelf of Galicia and Asturias. This report offers new data on the evolution of the benthic and demersal communities of the shelf affected by the spill.

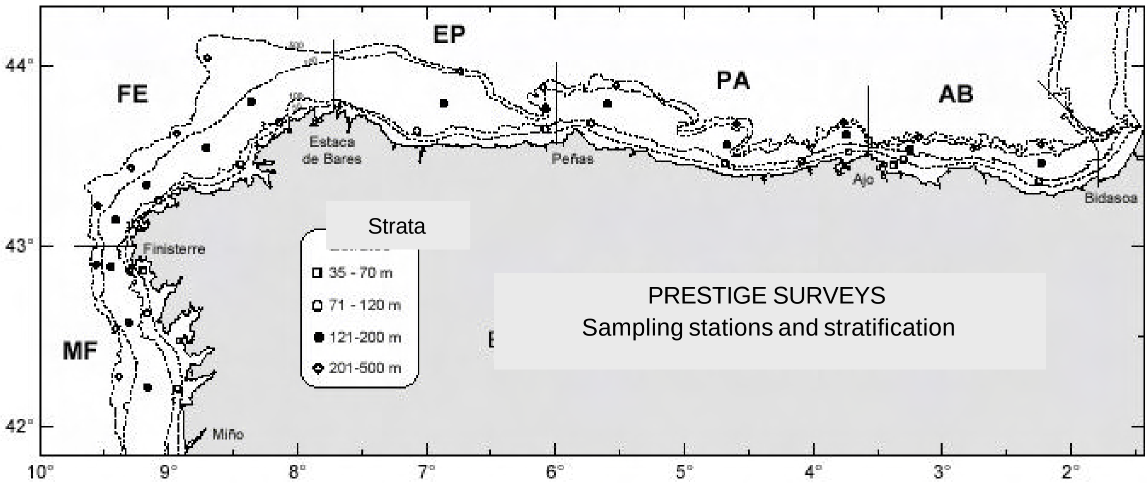

Figure 1. General view of sampling and bottom stations.

Material and methods

Samplings were carried out using several complementary systems to be able to quantify the different compartments of the bottom ecosystem (infauna, epifauna and megafauna) and to shed light on the state of its communities and resources. A sampling strategy was designed to include bottom stations arranged in a radial pattern and located in five geographic sectors (Miño-Finisterre, Finisterre-Estaca, Estaca-Peñas, Peñas-Ajo and Ajo-Bidasoa) and three depth strata (70–120 m, 121–200 m and 201–500 m), which correspond to those from the time series of IEO trawl surveys (Figure 1). In areas of great interest owing to the impact of the oil spill, special tows were carried out with the beam trawl and the *baca* gear.

The following samplings were conducted in each of the bottom stations:

- 4 *Bouma* type box corers covering a sampling area of 0.0175 m^2 (only in Galicia). Samples were collected for infaunal studies, sediment characteristics (granulometry, organic content, and Redox potential) and the concentration of hydrocarbons in the sediment.
- 1 hyperbenthic sled trawl (in only 1 radial). A stainless steel sled fitted with 3m length and 0.5 mm mesh plankton nets was used. The sampling surface of the nets was 0.450 m^2 for the lower net and 0.225 m^2 for the upper net. The trawl lasted approximately 2–3 minutes at a speed of 2 knots.
- 1 beam trawl. Targeting epibenthic invertebrates and small fishes (or juveniles). The 10 mm mesh net has a vertical opening of 65 cm and a horizontal opening of 350 cm. An effective 15-minute trawl was carried out at a constant speed of 2.5 knots. The mean distance covered along the bottom was 1022 ± 18.4 meters and the area swept per tow measured 3578 m^2.
- 1 *Baca* type trawl. Directed mainly at quantifying the biomass and size structure of demersal and benthic fish populations. 30 min. tows at a constant speed of 2.5 knots. The mean distance covered along the bottom was 2791 ± 14.9 meters and the area swept per tow measured 55227 m^2.

Preliminary results

Sediment characteristics

Table 2 (see Appendix) lists the sediment variables in the stations under study. In sector MF, in both winter and spring, 6 stations were studied – three located in the shallowest stratum (Stations 26, 5 and 1) and three in the deepest stratum (Stations 2, 6, and 8). Also sampled in sector MF were stations 4, but only in winter and 7, only in spring.

The sediment of the shallow stratum of sector MF is characterized by the presence of almost all sediment types, ranging from mud in stations 1 and 5 to coarse sand in station 26. For this reason the mean diameter varied in terms of space between relatively wide-ranging limits (from 36 to 1064 µm, Stations 27 and 26, respectively, Figure 2). The organic matter content was highly variable, ranging from low (1.86 %, Station. 26) and high (6.20 %, Station 1). The selection fluctuated between poor (Stations 1, 4 and 26) and moderate (Station 5). Relative to the temporal variation of the sediment between winter and spring, we did not observe any important changes (Figure 2; Table 2). The deep stratum of sector MF is characterized by the presence of sediments composed of very fine sands (103 µm, Station 8) or fine sands (163 µm and 153 µm, Stations 2 and 6 respectively, Figure 2), with an organic content ranging from low (1.85 %, Station 6) to moderate (3.75 %, Station 2). The selection fluctuated between moderate (Station 8) and moderately good (Stations 2 and 6; Table 2). In terms of time, between winter and spring, there was a slight increase in organic content in the three stations located in the deep stratum.

In both winter and spring seven stations were sampled in sector FE – five from the shallow stratum (Stations 11, 14, 15, 23, and 24) and three from the deep zone (Stations 10, 16 and 19). In the deep stratum of sector FE, we also sampled station 12 but only in winter as well as stations 28 and 29, these latter only in spring (Figure 2). The sediment of the shallow stratum of sector FE fluctuated between very fine sands (73 µm) and fine sands with low organic content from station 24 (162 µm, Table 2). Station 15 was very low in organic matter (1.14 %), fluctuating to the moderate limit of station 15 (3.88 %, Table 2). Sediment selection ranged between poor (Station 14) and moderately good (Station 15). The temporal variation of the sediment in the stations belonging to this stratum and sector was very small. The deepest stratum of sector FE also exhibited sandy sediments, ranging from very fine sands in station 19 (63 µm) and fine sands in station 29 (165 µm, Table 2). In terms of organic content, the values varied between 2.38 % in Station 29 and the moderate value of Station 19 (4.17 %, Table 2). The selection oscillated between poor (Stations 16 and 19) and moderate (Stations 10, 12, 28, and 29). In a temporal framework, between winter and spring, no major variations were found in sediment characteristics for the strata and sectors.

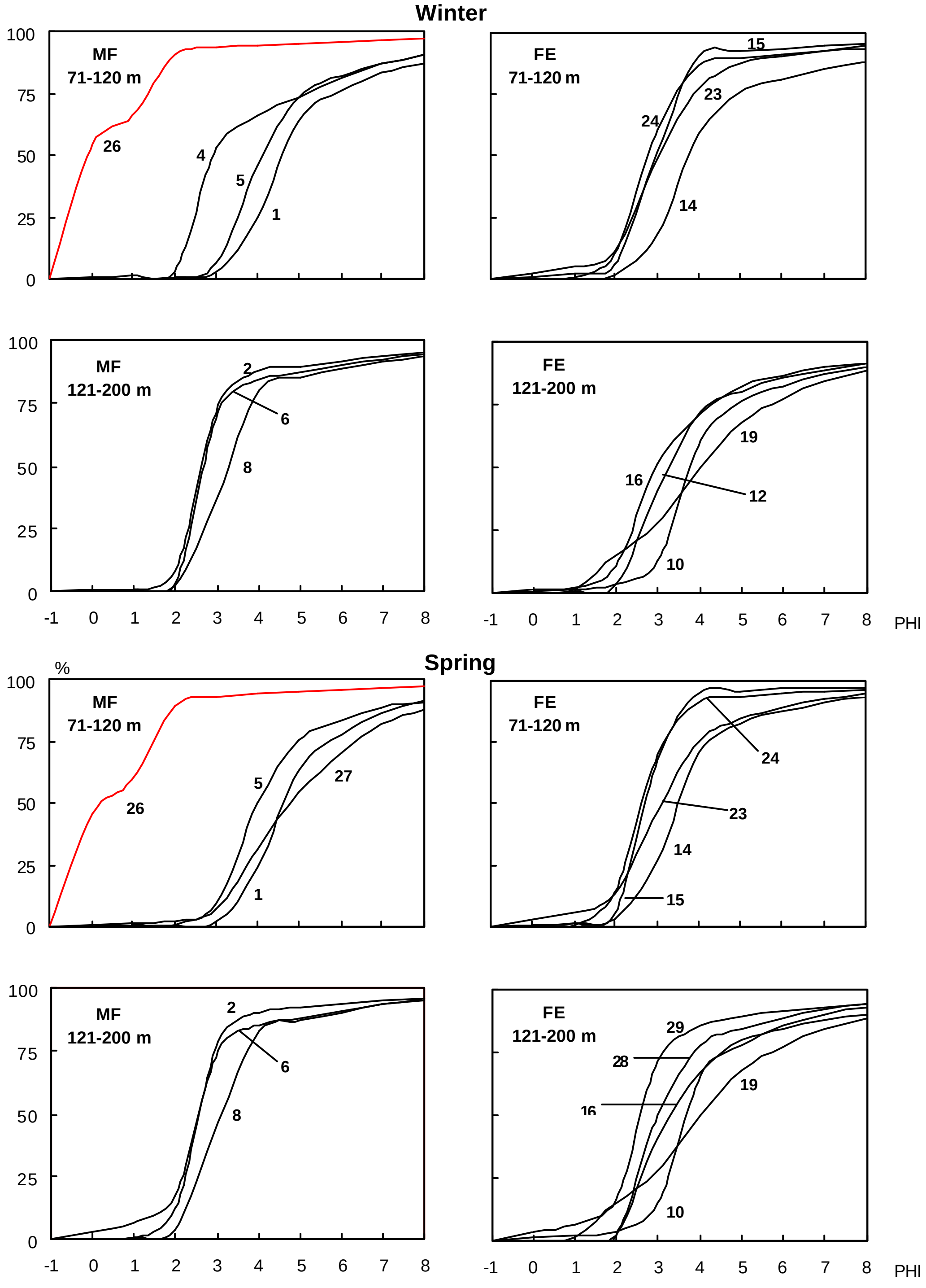

Figure 2. Granulometric curves of the sediment in the stations sampled during the winter and spring surveys, by sectors and depth strata. Station 26 (granulometric curve in red) is located in a shallower stratum than the one shown in the figure (60 m).

The redox potential indicates the chemical conditions of oxidation-reduction which determine the way in which the organic matter reacts and degrades in the sediment (Gray, 1981). Positive values are indicative of oxidizing conditions (good exchange of oxygen between the sediment and the free water), while negative values imply reductive conditions (build-up of organic matter on the surface and a slow rate of oxygen renovation in the interstitial water), which are dominated by anaerobic processes of degradation of organic matter.

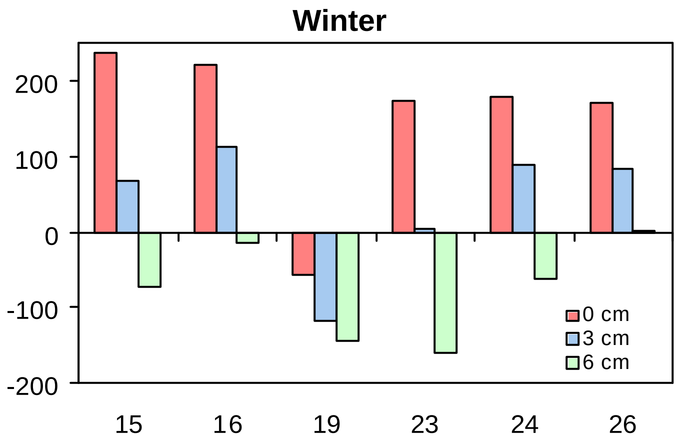

Figure 3. Variations in the Redox potential in the surface sediment of the stations sampled during the winter survey.

During the winter period it was only possible to measure the Redox potential on the *Prestige Plataforma 0103* oceanographic survey and the results obtained are detailed in Figure 3. The oxidation-reduction conditions observed in the stations sampled indicate that, in general, oxidation was good in the upper layers of the sediment, except in station 19, which had negative values even in the surface. In stations 15, 16, 24 and 26, the variation in the Redox potential relative to depth was very similar, reaching a depth of 3 cm in station 15, which was the highest negative potential value of the group. Station 23 exhibited a great fluctuation in the oxidation-reduction potential between the surface and the deepest measurement, where the highest negative value of all the samples analyzed was reached (- 160.7 mV).

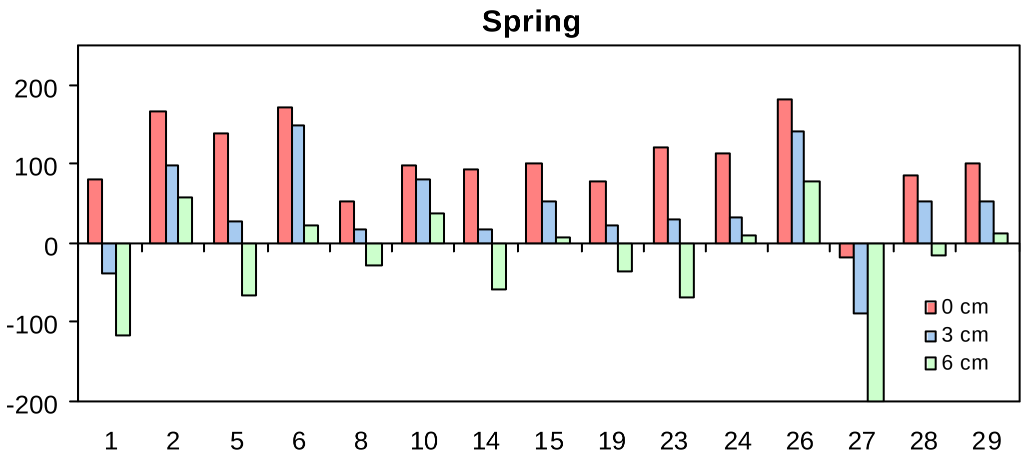

Figure 4. Variations in the Redox potential in the surface sediment of the stations sampled during the spring survey.

Figure 4 presents the variations in the Redox potential of the sediment in the stations sampled during the spring period. The oxidation-reduction conditions observed in the stations sampled point to a good oxidation in the upper layers of the sediment, except in station 27, which exhibited negative values even in the surface (- 19.2 mV). In stations 2, 6, 10, 24, 26 and 29, the variation in the Redox potential relative to depth was very similar and the sediments were oxidized even down to depths of 6 cm, reaching the highest oxidation value of the group at 6 cm (78.4 mV) in station 26. Stations 5, 8, 14, 19, 23, and 28 exhibited negative values at 6 cm depth, with a maximum of - 69.3 mV in station 23. Negative values were recorded in station 1 at 3 cm and 6 cm depth.

General characteristics of infaunal communities

In this section we will provide a brief description of the general faunal characteristics of the macroinfaunal communities under study by sector and depth stratum. In the stations that were sampled on a seasonal basis (winter and spring, Figure 5), only the dominant species will be cited. Further on, we will focus on the temporal variation of the community in relation to the possible effects of the oil spill. In the stations sampled only once, additional data are given on some of the community variables such as abundance, diversity and equitableness.

The fauna samples are still being processed, so, to date, we only have information from 8 stations from the Miño-Finisterre and Finisterre-Estaca sectors in winter and 6 in spring (Table 3, Appendix). In the depth stratum 71–120 m of sector MF we have analyzed a total of three stations (1, 4 and 5) characterized by sediments comprised of mud (stations 1 and 5) or fine sands (Station 4) with a moderate organic content. Stations 1 and 5 were sampled in winter and spring while, station 4 was only studied in winter. The most abundant zoological group in this stratum was the polychaetes (as high as 87 % in winter) while the other groups accounted for a mere 10 % (Figure 5 and 6). The communities are dominated by the spionid polychaete *Prionospio fallax*, which reached a mean abundance of 2042 ind m^{-2} in the stratum in winter (Table 5, Appendix). The species composition of the stratum is shown in Table 5 and the community variables in Table 4. Table 3 also details the community variables of each station studied.

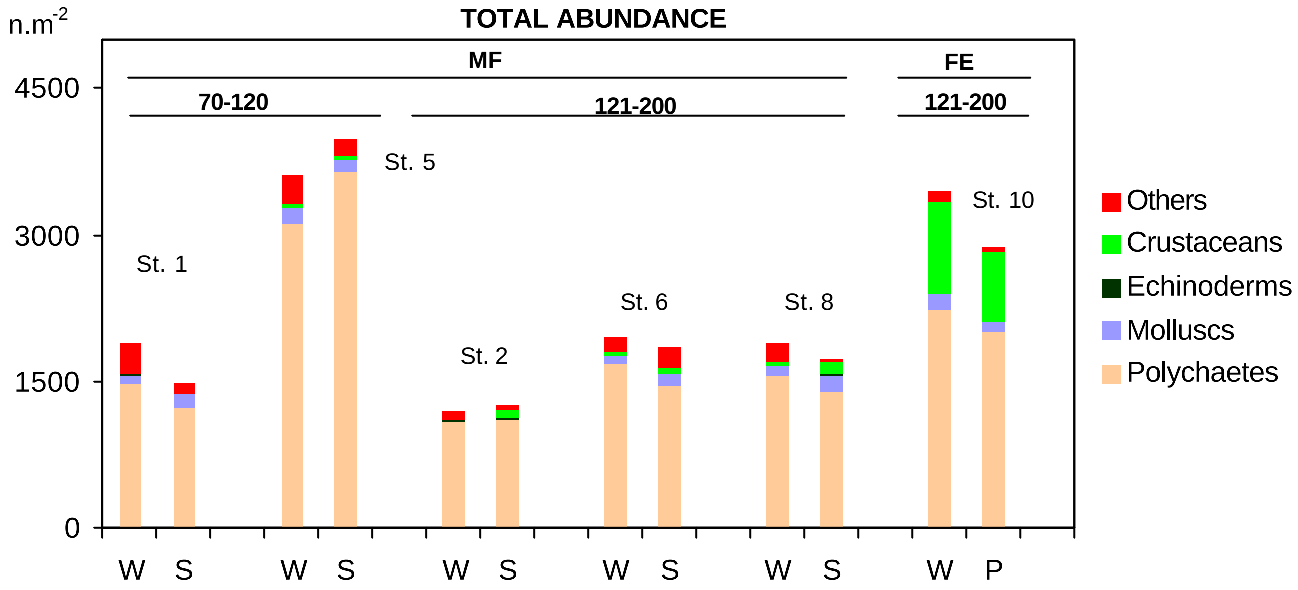

Figure 5. Total abundance (ind m^{-2}) by taxonomic group in the stations analyzed. Distribution is shown by sectors and depth strata.

In stratum 121–200 of sector MF three stations were studied (2, 6 and 8), in both winter and spring (Figure 5). These stations have a sediment made up of fine sands or very fine sands, with a moderately good selection. The polychaetes were the dominant zoological group in this stratum (89 % in spring, Figure 6). The infaunal communities were composed mainly of the polychaetes *Prionospio fallax*, *Monticellina dorsobranchialis* and *Aricidea* sp. The species composition in the stratum is listed in Table 5 and the community variables in Table 4. Table 3 also presents the community variables of each station studied.

To date we have only been able to analyze two stations (Stations 10 and 12) of sector Finisterre-Estaca (FE), both located in the 121–200 m depth stratum (Figure 5). Station 10 was sampled in winter and spring, while station 12 was only studied in winter. These stations exhibited a characteristic sediment consisting of very fine sands with a low organic content and moderate selection. The polychaetes were the most prevalent zoological group in this stratum (as high as 70 % in spring), followed by the crustaceans which accounted for 27 % of the fauna in winter (Figure 6). The characteristic species of this stratum were the peracarid crustacean *Ampelisca* sp. and the polychaetes *Prionospio fallax*, *P. steentrupii* and *Monticellina dorsobranchialis*. Species composition in the stratum is shown in Table 5 and the community variables in Table 4. Table 3 also details the community variables of each station studied.

Temporal evolution of the infaunal communities and the impact of the oil spill

In general, some minor variations were seen in the Miño-Finisterre (MF) sector between winter and spring. The most significant changes in spring were a slight decline in the total abundance and in the abundance of some of the less important groups, such as others (nemertines, sipunculids, etc) and a small increase in crustaceans, particularly in the deepest stratum (Figure 6). The species richness tended to decline, while the diversity and equitableness rose slightly in spring (Figure 7; Table 4).

In the 71–120 m depth stratum of sector MF a total of two stations (1 and 5) were analyzed in terms of time, and they were sampled in winter and spring. The temporal evolution of the infauna found in this stratum was characterized by a slight increase in the abundance of polychaetes, which was the dominant group of the community and a modest decline in the group of other species (nemertines, sipunculids, etc.; Figure 6). Moreover it is also possible to discern a decrease in the number of species in spring, down from 27 to 24. The total abundance underwent a slight decrease in spring (Figure 7). The dominant species is the polychaete *Prionospio fallax*, which reached a maximum of 2042 ind. m^{-2} in winter by sector and stratum. Diversity and equitableness rose but not substantially (Figure 7; Table 5).

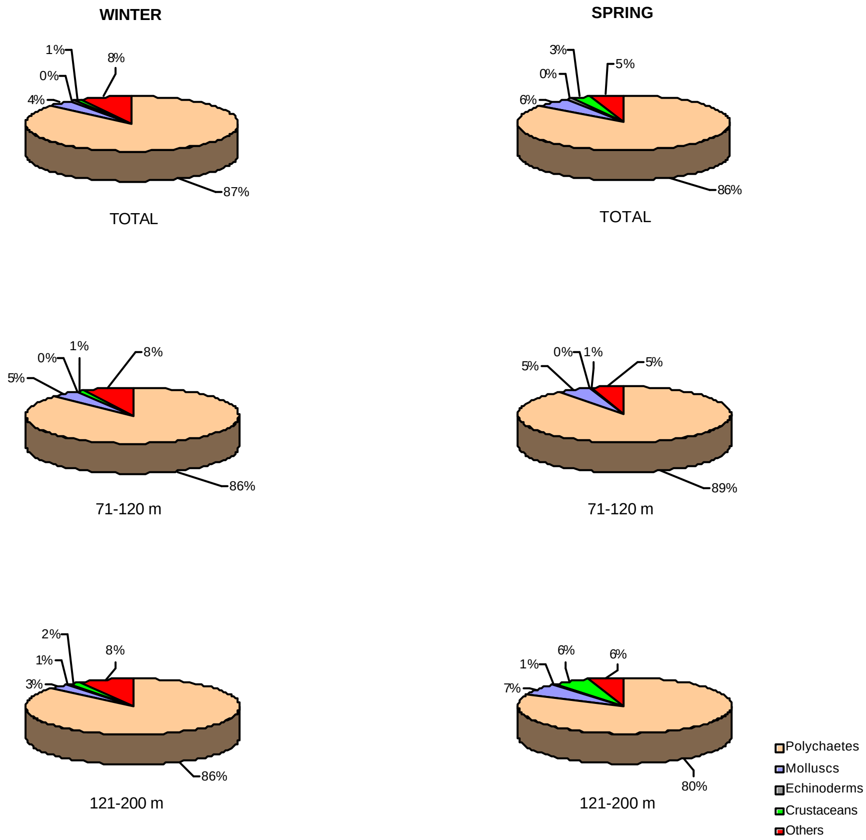

Figure 6. Percentage of total abundance shown by taxonomic group in sector MF, by depth strata.

In the 121–200 m depth stratum of sector MF three stations were studied (2, 6 and 8), in both winter and spring. In terms of species richness, the temporal evolution in this stratum was similar to the one described above, decreasing from 34 to 30 in spring. We did not detect practically any temporal variation in either total abundance or diversity in this stratum (Figure 7). The polychaete seen to dominate the community was *Prionospio fallax*, whose abundance decreased in spring, while the polychaetes *Aricidea* sp. and *P. steenstrupii* became slightly more abundant during the spring period (Table 5).

The only information available on the Finisterre-Estaca (FE) sector is from the stations located in the deepest stratum (121–200 m). Overall, there was a diminishing trend in all the community parameters, with the exception of diversity and equitableness, which showed a slight increase. The most notable decrease was in total abundance and in the crustacean group which went from 27.1 to 25.1 % of the total abundance. The main diminishing species was the amphipod crustacean *Ampelisca* spp.

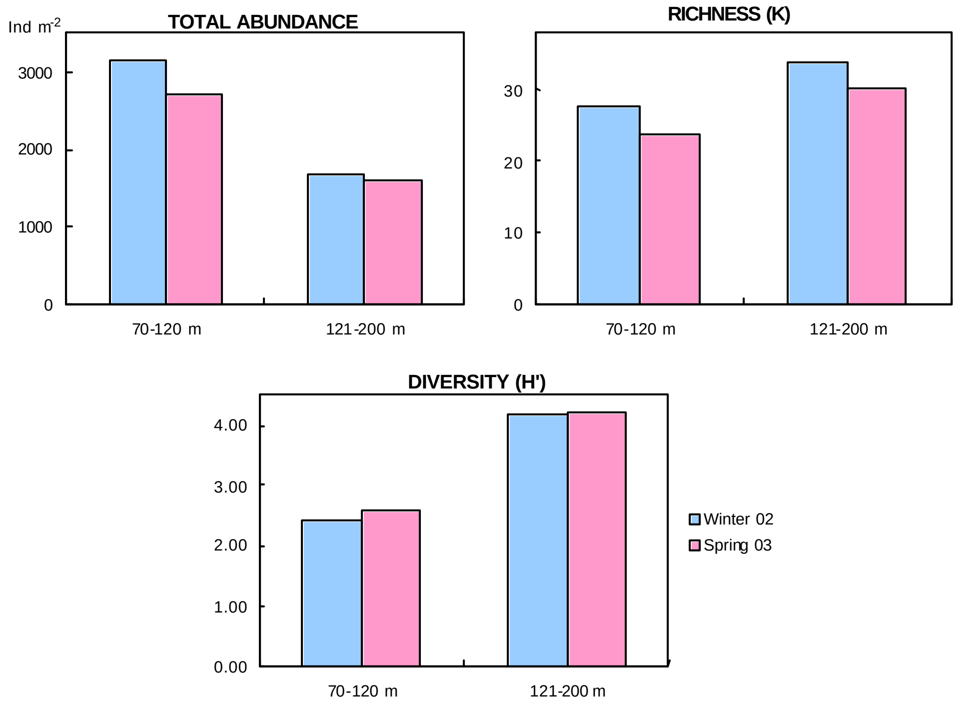

Figure 7. Temporal variation in total abundance, number of species and diversity in sector MF by depth stratum.

General characteristics of hyperbenthic communities

Similar to the data on infauna, this report offers preliminary results on the winter surveys. From the three stations together, each located at a different bathymetric stratum of the Finisterre-Estaca sector (FE; Figure 1), we collected a total of 6,530 specimens distributed among 9 zoological groups of varying proportions (Figure 8): amphipods (Amp, 27.6 %), mysidaceans (Mys, 31.4 %), cumaceans (Cum, 11.3 %), isopods (Iso, 2.8 %), tanaidaceans (Tan, <0.1 %), euphausiaceans (Eup, 10.9 %), decapods (Dec, 15.6 %), pycnogonids (Pyc, <0.1 %) and fishes (Pis, 0.4 %). The specific richness of each group is shown in Figure 9. In the 70–120 bathymetric stratum, the dominant groups in terms of abundance were the amphipods (267.1 ind 100m^{-2}), mysidaceans (257.7 ind 100 m^{-2}) and euphausiaceans (83.6 ind 100 m^{-2}). The dominant species in this bathymetric stratum were the amphipod *Amphilochoides boecki*, the mysidaceans *Leptomysis gracilis* and *Anchialina agilis* and the euphausiacean *Nyctiphanes couchi* (Table 7).

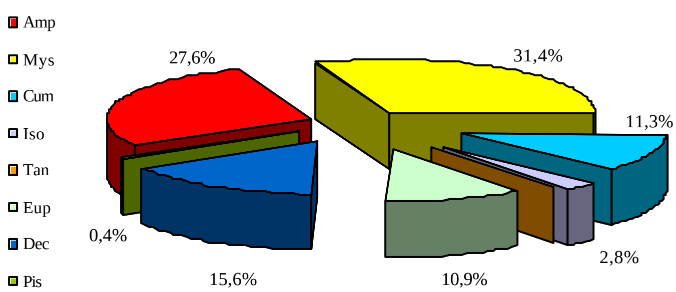

Figure 8. Abundance percentages of the main taxonomic groups of hyperbenthos (N= 6530 individuals). Abbreviations: Amp: amphipods; Mys: mysidaceans; Cum: cumaceans; Iso: isopods; Tan: tanaidaceans; Eup: euphausiaceans; Dec: decapods; Pis: fishes.

In the intermediate bathymetric stratum (121–200 m) the mysidaceans crustaceans (182.4 ind 100 m^{-2}), the amphipods (81.1 ind 100 m^{-2}) and the cumaceans (78.4 ind 100 m^{-2}) are the most abundant. The dominant species in this stratum are the mysidaceans *Anchialina agilis*, *Erythrops neapolitana* and *Leptomysis gracilis* and the euphausiacean *Nyctiphanes couchi* (Table 7). This bathymetric stratum presented the highest values for total abundance (422.9 ind 100 m^{-2}) and species richness (K = 71, Figure 9).

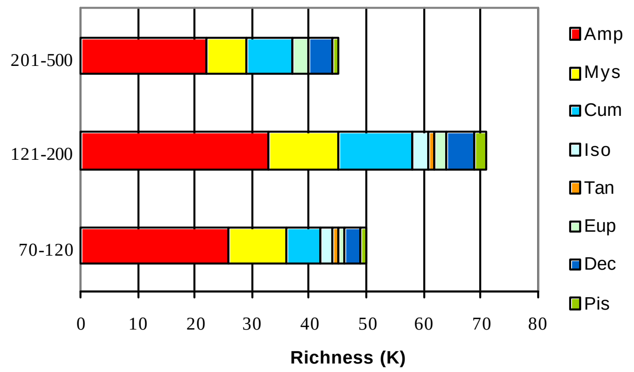

Figure 9. Species richness by zoological group in each of the stratum sampled. Abbreviations: Amp: amphipods; Mys: mysidaceans; Cum: cumaceans; Iso: isopods; Tan: tanaidaceans; Eup: euphausiaceans; Dec: decapods; Pis: fishes.

Of the 1,527 specimens collected in the deepest stratum (201–500 m) the most abundant groups were: decapods (142.3 ind $100m^{-2}$), amphipods (80.9 ind $100m^{-2}$) and euphausiaceans (26.7 ind $100m^{-2}$). The dominant species in this stratum were the decapod *Pasiphaea sivado*, the amphipods *Scopelocheirus hopei* and *Orchomenella nana* and the euphausiacean *Meganyctiphanes norvegica* (Table 7).

The vertical distribution of the hyperbenthic fauna is shown in figure 10. The highest values of species richness correspond to the lower web closest to the sediment, reaching a maximum of 70 species in the middle stratum (121–200 m). The values obtained for the lower web fluctuate between the minimum richness in the shallow and deep stratum (K = 7) and a maximum of 12 species in the middle stratum. As regards the type of communities, we may say that their structure is similar to what has been reported in other areas of the NE Atlantic continental shelf (Cunha *et al*., 1997; Sorbe, 1989).

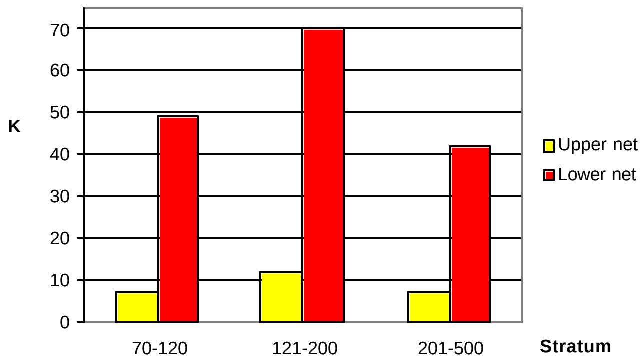

Figure 10. Vertical distribution of the hyperbenthic fauna in each stratum.

Temporal evolution of the hyperbenthic communities and the impact of the oil spill

In this section we will present the preliminary results of the temporal evolution of the hyperbenthic communities between the winter and spring samplings. Although the data from the spring period are still being analyzed, we offer here the changes recorded in the total abundance of the main groups of hyperbenthos in sector FE.

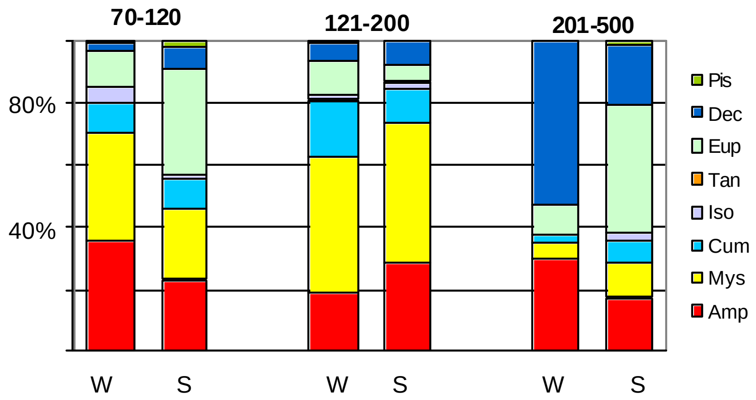

Figure 11. Variation in the percentage of total abundance of hyperbenthos by taxonomic group in sector FE. Also shown is the distribution by depth stratum and period. Abbreviations: W: winter; S: spring.

In the shallowest stratum there was a marked increase in the abundance of the group of euphausiaceans, up from 11 % to 34 % of the total abundance in spring. We also observed a major decline in the amphipods and mysidaceans, both of which decreased from over 30 % to 23 % of the total abundance in spring (Figure 11).

On the other hand, in the middle stratum, 121–200 m depth, where the community was dominated by the mysidaceans, there was a substantial increase in the number of amphipods in spring (up from 19 to 28 %) and a less important decrease in the cumaceans and euphausiaceans (Figure 11).

In contrast, in the deepest stratum, where the community was dominated by the decapods in winter, these animals decreased considerably (from 53 to 20 %), and this was accompanied by a rise in the number of euphausiaceans, which jumped from 10 % of the total abundance in winter to 41 % in spring, constituting the dominant group in the latter season. Similar to what occurred in the shallow stratum, the amphipods decreased in spring (down from 30 to 17 %, Figure 11).

General characteristics of the epibenthic communities

A total of 279 species belonging to 12 taxonomic groups were identified. Molluscs were the most abundant group, with 86 species, followed by the crustaceans (65), fishes (55), annelids (26), echinoderms (22), cnidarians (14), poriferans (5), nemertines (2) and Cephalochorda, tunicads, pycnogonids and sipunculids (1). The biomass indices stratified by species are shown in Table 10.

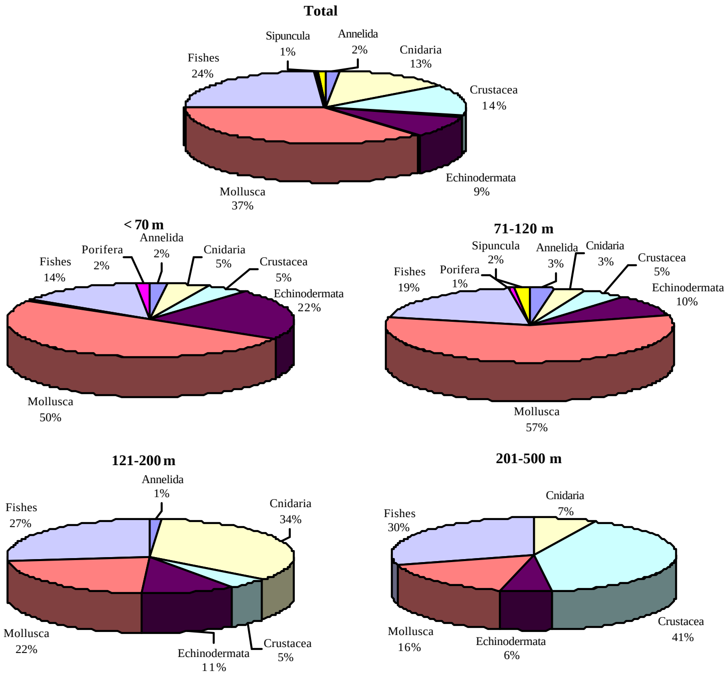

Figure 12. Percentages per stratum of mean composition gr/tow of principal taxa.

Molluscs exhibited the highest mean biomass (609.6 kg km^{-2}), followed by fishes (399.8 kg km^{-2}), crustaceans (233.6 kg km^{-2}) cnidarians (223.7 kg km^{-2}) and echinoderms (156.8 kg km^{-2}). The composition of the biomass did, however, change depending on the stratum (Figure 12).

In the shallowest strata (particularly lower than 70 m and stratum A, 71–120 m depth) molluscs were clearly the most prevalent, with abundances of 509.2 kg km^{-2} and 1414.2 kg km^{-2}, respectively. In stratum B the cnidarians (509.3 kg km^{-2}) made up the most dominant group, followed by the fishes and molluscs (399.4 and 316.1 kg km^{-2}). In stratum C, on the other hand, the crustaceans were the dominant taxa in biomass (532.9 kg km^{-2}), followed by fishes and molluscs (388.4 and 210.9 kg km^{-2}).

Temporal evolution of the epibenthic communities and the impact of the oil spill

Statistical tests were conducted to compare the values of the ecological indices (richness, biomass, density and diversity) by station between winter and spring for each depth stratum (A, B and C). In order to do this, we used the tows common to each period. None of the 15 comparisons, involving five ecological indices and three depth strata, exhibited significant differences that would imply important alterations in the structure of the communities observed (Figure 13).

Figure 14 shows the abundance differences in number between the two periods for some of the groups known to be sensitive to contamination by fuel oil (e.g., Suchanek, 1993) such as bivalves, large gastropods, large crabs (Crustacea Decapoda Reptantia), echinoderms and polychaetes. The Mann-Whitney test was used to compare abundance per tow between the two periods for each group. No significant differences were found in any of the cases.

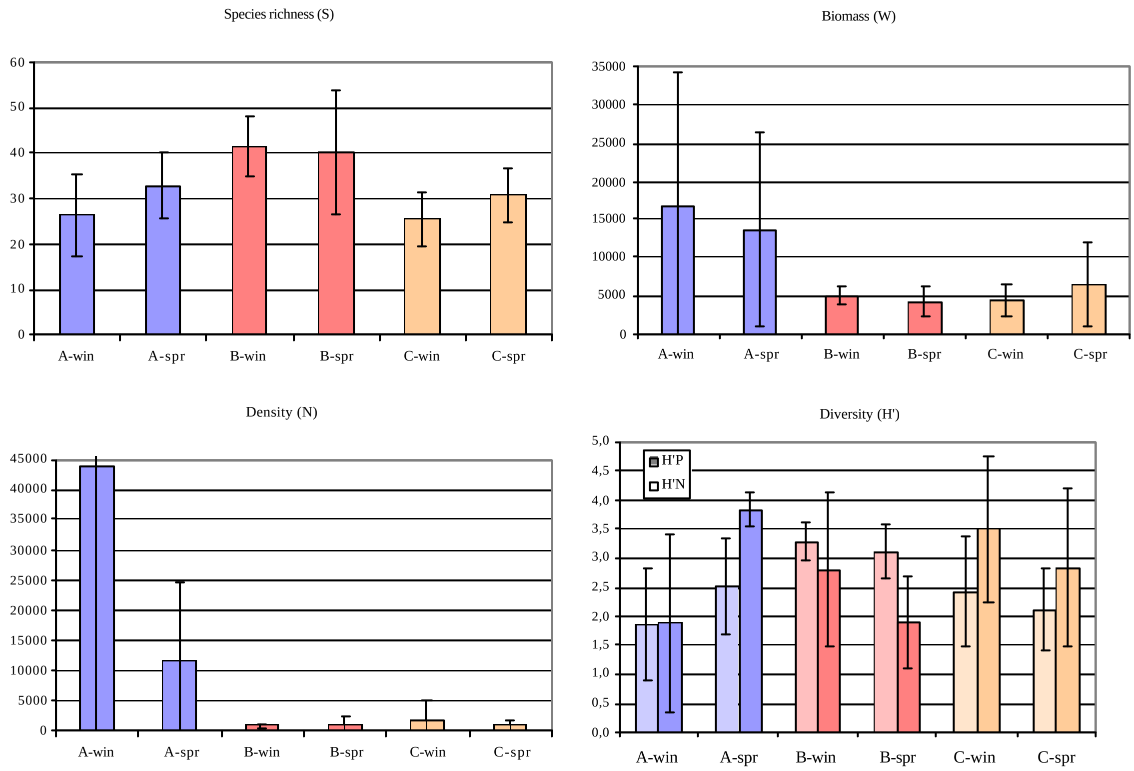

Figure 13. A comparison of the index values between winter and spring for common tows in the two surveys. A, B, and C are the 3 depth strata studied .

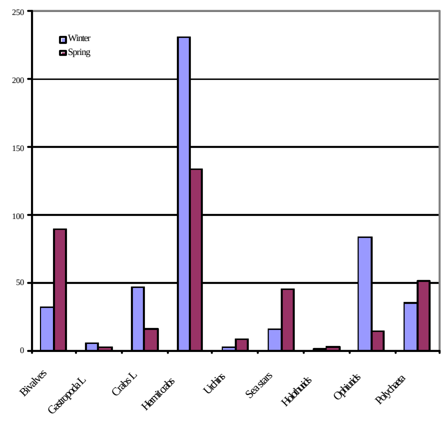

Figure 14. A comparison of the abundance in number of specimens per tow between winter and spring for some indicator groups. Gastropods and Crabs L = large-sized species.

No differences were found in the structure of the epibenthic communities as compared to recent studies. The indices for richness, biomass and diversity described are similar to those obtained using the same sampling methodology on the Cantabrian shelf in the years prior to the oil spill (Serrano *et al*., in press; Sánchez *et al*., 2003). The specific composition follows the same patterns defined for equivalent environmental conditions on the Galician and Cantabrian shelf (López-Jamar *et al*., 1992; Sánchez *et al*., 2003; Serrano *et al*., in press). We did not detect the dominance of opportunistic species as reported in sediments contaminated by fuel oil (Plante-Cuny *et al*., 1993; Parra & López-Jamar, 1997). In the multivariate analyses, carried out with the data from these oceanographic surveys, the importance of bathymetry was observed as a determinant of structure, in keeping with the findings of previous studies (Olaso, 1990; Sánchez, 1993; Sánchez *et al*., 2003; Sánchez & Serrano, 2003; Serrano *et al*., in press). An analysis is currently underway to study the effect of the sediment characteristics on the structure of the communities, which we expect will become a factor of the first order. Nevertheless, these preliminary reports must be considered as tentative studies in a monitoring process that will only fall into place once we have gained the perspective of several annual cycles. A large part of the changes detected are seasonal and the importance of this will be assessed in future surveys.

General characteristics of the megabenthic communities and commercial species

The sampling conducted with the *baca* type gear provided information on a total of 177 species, of which 73 were fishes, 34 crustaceans, 30 molluscs, 18 echinoderms and 22 from other groups. The biomass indices stratified by species are listed in the Appendix (Table 11). The stratified abundance indices obtained for the principal species of commercial interest in spring are given in Table 8, with a comparison to those obtained during the survey conducted in October. These data refer to the whole Galicia + Cantabrian zone, although we must point out that the October survey had greater coverage (120 tows) than the cruise conducted in spring (45 tows). The most abundant species on the shelf was the horse mackerel, accounting for 41.2 kg/tow, followed by the blue whiting.

Temporal evolution of the megabenthic communities and commercial species and the impact of the oil spill: This section presents a comparative study of the oceanographic surveys *Demersales 02* (Autumn) and *Prestige 0403* (Spring). The tows selected were common to the two research cruises, to eliminate the heterogeneity caused by differences in sampling effort and spatial variations. Owing to the great importance that the season has on the distribution and abundance of the species in this zone (Olaso, 1990; Sánchez, 1993), it is necessary to interpret this preliminary approach under the assumption that the major cause of any variability observed would be seasonal. For this reason, monitoring will be conducted mainly taking into account the ecological indices and the abundance of indicator taxa sensitive to the presence of hydrocarbons.

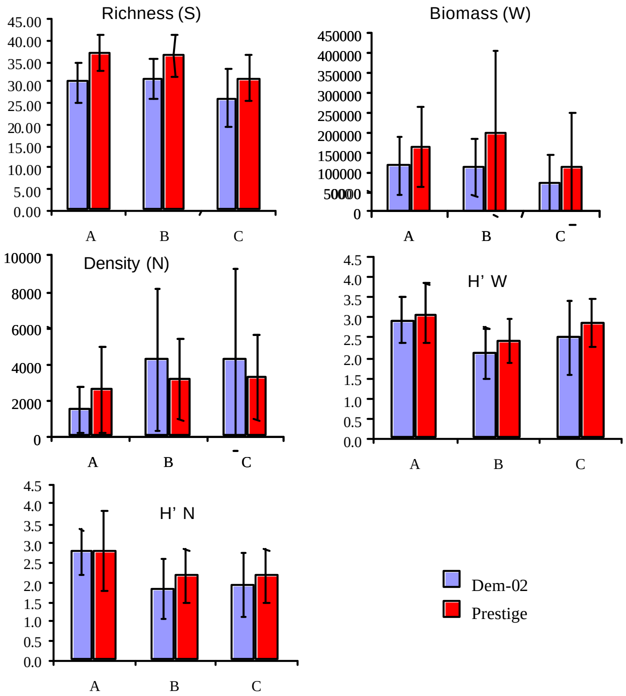

Figure 15. Average values of the ecological indices by stratum (A, B and C) and survey (*Demersales 0902* and *Prestige 0403*). The vertical lines indicate standard deviation (SD).

A comparison of the ecological indices between the oceanographic surveys by depth stratum (Table 9 and Figure 15) shows an overall increase in all of these during the spring survey *Prestige 0403* versus the *Demersales 0902*. An analysis of the indices by stratum shows that the average richness in the 70–120 m stratum of the *Prestige 0403* survey is significantly higher than in the index from the *Demersales 0902* survey (t= - 3.56, p<0.01). The same is true in depth stratum 121–200 m (t = - 2.94, p<0.01). In contrast, there were no significant differences in the average richness between the two surveys in the deepest stratum (p> 0.01). As regards the other indices, we did not find significant differences in biomass (P), number of specimens (N), diversity in weight (H'P) or diversity in number (H'N) between the surveys.

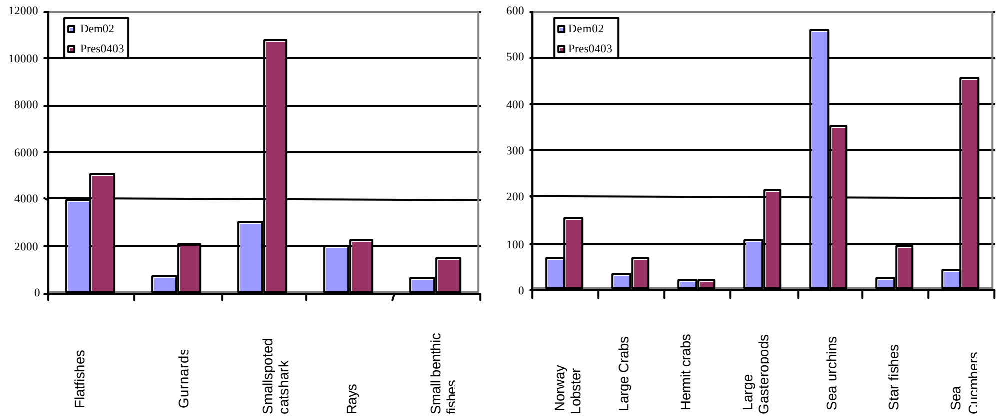

Figure 16. A comparison of the abundance in biomass (kg/tow) between the oceanographic surveys, *Demersales 0902*, and *Prestige 0403*, for some indicator groups. Gastropods and L Crabs = megafaunal, large-sized species.

Figure 16 shows the changes in abundance of some of the indicator groups between the autumn and spring surveys. There is a general increase in all the groups, with the exception of the sea urchins. However, according to the Mann-Whitney test, significant differences were only found in starfish ($T = 927.5$; $p<0.0001$), large gastropods ($T = 1076.5$; $p<0.0001$), holothurians ($T = 1080.0$; $p = 0.0084$) and small benthic fishes ($T = 1061.0$; $p = 0.0045$), all having 36 degrees of freedom. The sole purpose of this comparison is to give us a general idea during the early stages of monitoring, since the seasonal differences (autumn–spring) prevent us from drawing conclusions on the possible effects of the oil spill caused by the tanker *Prestige*.

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Appendix Tables

Table 1. Location of the stations sampled and number of samples of the different variables measured. Abbreviations: W: winter survey; S: spring survey; levels A, B and C: for the vertical distribution study of the infauna (A: 0–5 cm; B: 5–10 cm; C: 10–15 cm); MO/PHI/Hb: sample for the organic content study, granulometry and hydrocarbon concentration in the sediment.

Station	Season	LatitudeN	LongitudeW	Depth.(m)	No. of samples Infauna	Levels	MO/PHI/Hb	Redox
1	W	42º 14,7’	8º 58,8’	102	5	A, B	1	1
	S	“	“	100	3	-	1	1
2	W	42º 11,9’	9º 10,2’	155	4	A, B, C	1	-
	S	“	“	156	3	-	1	1
4	W	42º 24,7’	9º 02,5’	96	5/-	-/-	1/-	-
	S	-	-	-	-	-	-	-
5	W	42º 36,7’	9º 13,7’	101	5	A, B, C	1	1
	S	“	“	100	3	-	1	1
6	W	42º 30,2’	9º 17,1’	138	5	A, B	1	1
	S	“	“	133	3	-	1	1
8	W	42º 51,9’	9º 25,6’	157	5	A, B	1	1
	S	“	“	154	3	-	1	1
10	W	43º 11,0’	9º 26,8’	166	5	A, B, C	1	1
	S	“	“	168	3	-	1	1
12	W	43º 21,2’	9º 05,0’	155	5	A, B, C	1	1
	S	-	-	-	-	-	-	-
14	W	43º 21,6’	8º 45,4’	88	5	A, B	1	1
	S	“	“	86	3	-	1	1
15	W	43º 26,5’	8º 28,7’	91	5	A, B	1	1
	S	“	“	88	3	-	1	1
16	W	43º 35,5’	8º 32,0’	150	5	A, B, C	1	1
	S	“	“	154	2	-	1	-
19	W	43º 28,1’	8º 46,8’	148	5	A, B, C	1	1
	S	“	“	149	3	-	1	1
23	W	43º 14,1’	9º 07,5’	90	5	A, B	1	1
	S	“	“	88	3	-	1	1
24	W	43º 07,7’	9º 16,1’	72	5	A, B	1	1
	S	“	“	80	3	-	1	1
26	W	42º 51,3’	9º 11,5’	60	5	A, B, C	1	1
	S	“	“	58	3	-	1	1
27	W	-	-	-	-	-	-	-
	S	42º 49,2’	9º 16,1’	105	3	A,B,C,D	1	1
28	W	-	-	-	-	-	-	-
	S	43º 22,1’	9º 03,1’	151	3	A,B,C,D	1	1
29	W	-	-	-	-	-	-	-
	S	43º 47,8’	8º 16,8’	176	3	A,B,C	1	1

Table 2. Sediment variables. Symbols: % O.M.: organic content; Q_{50}: mean diameter; Q_{25}: first quartile; Q_{75}: third quartile; S_0: sorting coefficient; CS: coarse sand; FS: fine sand; VFS: very fine sand; M: mud; P: poor sorted; Mod: moderately sorted; modW: moderately well sorted.

Sta.	Season	Type	% O.M.	Q_{50} (phi)	Q_{50} (mm)	Q_{25} (phi)	Q_{75} (phi)	S_o	Selection
1	W	M	4.07	4.60	0.041	4.00	5.85	1.90	P
	S	M	4.42	4.65	0.040	4.08	5.73	1.78	Mod
2	W	FS	3.36	2.62	0.163	2.30	3.02	1.28	modW
	S	FS	3.75	2.58	0.167	2.22	2.91	1.27	modW
4	W	FS	3.40	2.91	0.133	2.45	5.20	2.59	P
	S	-	-	-	-	-	-	-	-
5	W	M	3.23	4.11	0.058	3.50	5.08	1.73	Mod
	S	M	3.15	4.00	0.063	3.42	5.00	1.73	Mod
6	W	FS	1.85	2.68	0.156	2.37	3.11	1.29	modW
	S	FS	2.97	2.53	0.173	2.18	3.00	1.33	modW
8	W	VFS	1.90	3.28	0.103	2.69	3.81	1.47	Mod
	S	VFS	2.13	3.10	0.117	2.52	3.72	1.52	Mod
10	W	VFS	3.12	3.76	0.074	3.30	4.88	1.73	Mod
	S	VFS	3.56	3.68	0.078	3.22	4.62	1.62	Mod
12	W	VFS	2.79	3.28	0.103	3.30	4.88	1.73	Mod
	S	-	-	-	-	-	-	-	-
14	W	VFS	3.86	3.77	0.073	3.20	5.00	1.87	P
	S	VFS	3.88	3.50	0.088	2.92	4.20	1.56	Mod
15	W	FS	1.14	2.97	0.128	2.48	3.52	1.43	Mod
	S	FS	1.13	2.70	0.154	2.36	3.10	1.29	modW
16	W	FS	3.04	2.95	0.129	2.39	4.30	1.94	P
	S	VFS	3.58	3.30	0.102	2.62	4.53	1.94	P
19	W	VFS	4.17	4.00	0.063	2.86	5.73	2.70	P
	S	VFS	3.69	3.42	0.093	2.40	4.56	2.11	P
23	W	VFS	3.26	3.02	0.123	2.40	3.89	1.68	Mod
	S	VFS	2.98	3.11	0.116	2.40	4.00	1.74	Mod
24	W	FS	2.93	2.79	0.145	2.35	3.43	1.45	Mod
	S	FS	3.37	2.63	0.162	2.22	3.12	1.37	Mod
26	W	CS	1.86	-0.09	1.064	-0.58	1.39	1.98	P
	S	CS	2.44	0.20	0.871	- 0.50	1.50	2.00	P
27	W	-	-	-	-	-	-	-	-
	S	M	6.20	4.80	0.036	4.76	6.40	1.77	Mod
28	W	-	-	-	-	-	-	-	-
	S	VFS	3.60	3.00	0.125	2.51	3.89	1.61	Mod
29	W	-	-	-	-	-	-	-	-
	S	FS	2.38	2.60	0.165	2.20	3.12	1.38	Mod

Table 3. Community variables in the stations studied. Symbols: N m^{-2}: total abundance (ind. m^{-2}); % P: % of polychaetes; % M; % of molluscs; % E: % of echinoderms; % C: % of crustaceans; % O: % others; K: number of species; H': diversity; J': evenness.

			Abund.							
Sta.	Season	Nm-2	% P	% M	% E	% C	% O	K	H'	J'
1	W	1897	77.11	5.42	0.60	0.00	16.87	22	2.84	0.64
	S	1482	82.89	10.53	0.00	0.00	6.58	18	2.54	0.61
2	W	1186	91.57	0.00	1.20	1.20	6.02	28	4.12	0.86
	S	1257	87.88	1.52	1.52	6.06	3.03	27	4.05	0.85
4	W	4035	91.22	4.25	0.00	0.85	3.68	25	1.27	0.27
	S	-	-	-	-	-	-	-	-	-
5	W	3601	86.67	4.76	0.00	0.95	7.62	36	3.15	0.61
	S	3962	92.31	2.88	0.00	0.96	3.85	30	2.62	0.53
6	W	1955	86.55	3.51	0.58	1.75	7.60	30	3.89	0.79
	S	1848	78.35	7.22	0.00	3.09	11.34	35	4.57	0.89
8	W	1897	82.53	4.22	0.60	2.41	10.24	44	4.48	0.82
	S	1734	80.22	9.89	1.10	7.69	1.10	29	4.00	0.82
10	W	3552	65.23	4.30	0.00	27.15	3.31	37	3.80	0.73
	S	2877	70.20	3.31	0.00	25.17	1.32	34	4.01	0.79
12	W	2617	76.80	7.42	0.00	5.68	13.10	45	4.5	0.82
	S	-	-	-	-	-	-	-	-	-
Mean	W	2592	82.21	4.24	0.37	5.00	8.56	33	3.51	0.69
	S	2193	81.98	5.89	0.44	7.16	4.54	29	3.63	0.75
Max.	W	4035	91.57	7.42	1.20	27.15	16.87	45	4.50	0.86
	S	3962	92.31	10.53	1.52	25.17	11.34	35	4.57	0.89
Min.	W	1186	65.23	0.00	0.00	0.00	3.31	22	1.27	0.27
	S	1257	70.20	1.52	0.00	0.00	1.10	18	2.54	0.53

Table 4. Mean total abundance value, by zoological group and indices of richness (K), diversity (H') and evenness (J') for each stratum in sectors Miño-Finisterre (MF) and Finisterre-Estaca (FE).

				Abund.							
Sector	**Stratum**	**Season**	**Nm^{-2}**	**% P**	**% M**	**% E**	**% C**	**% O**	**K**	**H'**	**J'**
MF	**70-120**	W	3161	86.67	4.68	0.12	0.72	7.81	28	2.42	0.51
		S	2724	89.74	4.97	0.00	0.70	4.59	24	2.58	0.57
MF	**121-200**	W	1674	86.30	2.91	0.72	1.81	8.26	34	4.16	0.82
		S	1598	81.37	6.74	0.79	5.55	5.55	30	4.21	0.85
MF	**Total**	W	2418	86.49	3.79	0.42	1.26	8.04	31	3.29	0.67
		S	2161	85.56	5.86	0.40	3.12	5.07	27	3.39	0.71
FE	**121-200**	W	3552	65.23	4.30	0.00	27.15	3.31	37	3.80	0.73
		S	2877	70.20	3.31	0.00	25.17	1.32	34	4.01	0.79

Table 5. Abundance indices (ind.m^{-2}) of the species belonging to the infaunal communities by depth stratum and season for sector MF. Abbreviations: W: winter; S: spring.

Species	W 70-120	S 70-121	W 121-200	S 121-201	W Total	S Total
Polychaetes						
Prionospio fallax	2042.33	1610.00	364.67	260.33	979.74	755.15
Aricidea sp.	64.67	76.00	130.33	184.33	106.26	144.62
Prionospio steenstrupii	144.67	106.00	86.67	114.33	107.93	111.28
Monticellina dorsobranchialis	49.67	85.50	164.67	88.67	122.50	87.51
Paraonidae indet.	87.67	143.50	42.00	44.33	58.74	80.69
Magelona cf. *wilsoni*	61.00	124.50	48.00	63.33	52.77	85.76
Ampharetidae indet.	7.33	0.00	77.00	82.67	51.46	52.36
Mediomastus fragilis	30.33	38.50	67.00	38.00	53.56	38.18
Galatowenia oculata	7.33	9.50	62.00	31.67	41.96	23.54
Lumbrineris gracilis	0.00	29.00	0.00	38.00	0.00	34.70
Paraonidae indet. 2	0.00	0.00	57.00	0.00	36.10	0.00
Cirratulidae indet.	3.67	19.00	19.00	19.00	13.38	19.00
Hyalinoecia brementi	0.00	0.00	11.33	44.33	7.18	28.08
Prionospio multibranchiata	45.67	0.00	15.33	0.00	26.45	0.00
Glycera rouxii	11.33	9.50	23.00	12.67	18.72	11.51
Gyptis capensis	3.67	19.50	8.33	19.00	6.62	19.18
Lumbrineris sp.	0.00	0.00	46.67	0.00	29.56	0.00
Archiannelida indet.	0.00	9.50	0.00	31.67	0.00	23.54
Poecilochaetus serpens	15.00	19.50	9.67	0.00	11.62	7.15
Nephtys hombergi	0.00	0.00	25.00	12.67	15.83	8.02
Prionospio sp.	0.00	19.00	0.00	19.00	0.00	19.00
Chaetopteridae indet.	3.67	0.00	11.33	19.00	8.52	12.03
Hesionidae indet.	11.33	0.00	3.67	19.00	6.48	12.03
Terebellidae indet.	3.67	19.50	12.33	0.00	9.16	7.15
Sternaspis scutata	26.67	9.50	0.00	0.00	9.78	3.48
Notomastus latericeus	18.67	10.00	0.00	0.00	6.84	3.67
Spiophanes bombyx	11.33	9.50	0.00	6.33	4.16	7.49
Maldanidae indet.	0.00	10.00	15.00	0.00	9.50	3.67
Cossura sp.	7.33	19.00	0.00	0.00	2.69	6.97
Polychaeta indet.	0.00	0.00	20.00	0.00	12.67	0.00
Ammotrypane cylindricaudatus	0.00	0.00	0.00	19.00	0.00	12.03
Ampharete finmarchica	0.00	0.00	0.00	19.00	0.00	12.03
Nephtys sp.	3.67	9.50	0.00	6.33	1.34	7.49
Pista cristata	0.00	0.00	3.67	12.67	2.32	8.02
Paraonis gracilis	19.00	0.00	0.00	0.00	6.97	0.00
Terebellides stroemi	0.00	0.00	15.33	0.00	9.71	0.00
Paradoneis lyra	3.67	10.00	3.67	0.00	3.67	3.67
Capitellidae indet.	0.00	0.00	8.33	6.33	5.28	4.01
Goniada maculata	3.67	0.00	3.67	6.33	3.67	4.01
Glycera sp.	0.00	0.00	0.00	12.67	0.00	8.02
Magelona alleni	0.00	0.00	0.00	12.67	0.00	8.02
Paradoneis sp.	0.00	0.00	0.00	12.67	0.00	8.02
Sphaerosyllis sp.	0.00	9.50	3.67	0.00	2.32	3.48
Chaetozone sp.	7.67	0.00	3.67	0.00	5.13	0.00
Ninoe armoricana	0.00	0.00	3.67	6.33	2.32	4.01
Spio sp.	0.00	0.00	3.67	6.33	2.32	4.01
Cirratulus sp.	0.00	0.00	9.67	0.00	6.12	0.00
Glycera sp.	0.00	0.00	9.67	0.00	6.12	0.00
Lumbrineris gracilis	11.33	0.00	0.00	0.00	4.16	0.00
Pherusa sp.	0.00	10.00	0.00	0.00	0.00	3.67
Praxillella sp.	0.00	9.50	0.00	0.00	0.00	3.48
Polynoinae indet.	3.67	0.00	3.67	0.00	3.67	0.00
Glycinde nordmanni	7.67	0.00	0.00	0.00	2.81	0.00
Spio decoratus	7.67	0.00	0.00	0.00	2.81	0.00
Sthenolepis yhleni	7.67	0.00	0.00	0.00	2.81	0.00
Asychis biceps	0.00	0.00	0.00	6.33	0.00	4.01
Brada villosa	0.00	0.00	0.00	6.33	0.00	4.01
Malacoceros sp.	0.00	0.00	0.00	6.33	0.00	4.01
Nereis sp	0.00	0.00	0.00	6.33	0.00	4.01
Sabellidae indet.	0.00	0.00	0.00	6.33	0.00	4.01
Armandia sp.	0.00	0.00	4.67	0.00	2.96	0.00
Chaetozone gibber	0.00	0.00	4.67	0.00	2.96	0.00
Onuphis quadricuspis	0.00	0.00	4.67	0.00	2.96	0.00
Paraonidae indet. 1	0.00	0.00	4.67	0.00	2.96	0.00

Table 5 (continued)

Species	W 70-120	S 70-121	W 121-200	S 121-201	W Total	S Total
Syllidia armata	0.00	0.00	4.67	0.00	2.96	0.00
Ammotrypane sp.	0.00	0.00	3.67	0.00	2.32	0.00
Exogone sp.	0.00	0.00	3.67	0.00	2.32	0.00
Hyalinoecia sp.	0.00	0.00	3.67	0.00	2.32	0.00
Magelona filiformis	0.00	0.00	3.67	0.00	2.32	0.00
Ophiodromus flexuosus	0.00	0.00	3.67	0.00	2.32	0.00
Polydora sp.	0.00	0.00	3.67	0.00	2.32	0.00
Pseudocapitella sp.	0.00	0.00	3.67	0.00	2.32	0.00
Sthenelais limicola	0.00	0.00	3.67	0.00	2.32	0.00
Aonides sp.	3.67	0.00	0.00	0.00	1.34	0.00
Lumbrineris sp. 1	3.67	0.00	0.00	0.00	1.34	0.00
Molluscs						
Thyasira sp.	61.00	19.50	22.67	19.00	36.72	19.18
Abra sp.	0.00	87.50	0.00	19.00	0.00	44.11
Tellina fabula	57.00	9.50	3.67	0.00	23.22	3.48
Abra alba	11.33	0.00	7.67	19.00	9.01	12.03
Opistobranquio indet.	0.00	0.00	3.67	19.00	2.32	12.03
Venus striatula	7.67	9.50	3.67	0.00	5.13	3.48
Parvicardium sp.	0.00	0.00	3.67	6.33	2.32	4.01
Turritella communis	0.00	9.50	0.00	0.00	0.00	3.48
Bivalvo indet.	0.00	0.00	0.00	6.33	0.00	4.01
Epilepton sp.	0.00	0.00	0.00	6.33	0.00	4.01
Nudibranquio indet.	0.00	0.00	0.00	6.33	0.00	4.01
Timoclea ovata	0.00	0.00	0.00	6.33	0.00	4.01
Nuculana fragilis	0.00	0.00	3.67	0.00	2.32	0.00
Myrtea spinifera	3.67	0.00	0.00	0.00	1.34	0.00
Prosobranquio indet.	3.67	0.00	0.00	0.00	1.34	0.00
Venus sp.	3.67	0.00	0.00	0.00	1.34	0.00
Echinoderms						
Amphiuridae indet.	0.00	0.00	8.33	0.00	5.28	0.00
Echinoidea indet	0.00	0.00	0.00	6.33	0.00	4.01
Leptosynapta inhaerens	0.00	0.00	0.00	6.33	0.00	4.01
Leptosynapta sp.	0.00	0.00	3.67	0.00	2.32	0.00
Cucumaria elongata	3.67	0.00	0.00	0.00	1.34	0.00
Crustaceans						
Harpinia sp.	0.00	9.50	0.00	19.00	0.00	15.52
Callianassas subterranea	0.00	0.00	0.00	25.33	0.00	16.05
Ampelisca sp.	7.67	0.00	3.67	6.33	5.13	4.01
Orchomenella nana	0.00	0.00	3.67	6.33	2.32	4.01
Tanaidacea indet.	0.00	0.00	3.67	6.33	2.32	4.01
Alpheus glaber	0.00	0.00	8.33	0.00	5.28	0.00
Bodotria scorpioides	0.00	9.50	0.00	0.00	0.00	3.48
Perioculodes longimanus	3.67	0.00	3.67	0.00	3.67	0.00
Euphausiaceo indet.	7.67	0.00	0.00	0.00	2.81	0.00
Isopoda indet.	0.00	0.00	0.00	6.33	0.00	4.01
Leucon siphonatus	0.00	0.00	0.00	6.33	0.00	4.01
Lysianassidae indet.	0.00	0.00	0.00	6.33	0.00	4.01
Ostracoda indet.	0.00	0.00	0.00	6.33	0.00	4.01
Anfípodos indet.	0.00	0.00	3.67	0.00	2.32	0.00
Eudorella truncatula	0.00	0.00	3.67	0.00	2.32	0.00
Upogebia sp.	3.67	0.00	0.00	0.00	1.34	0.00
Others						
Undet. Nemertines	122.00	86.00	44.67	38.00	73.02	55.60
Undet. Oligochaete	110.33	19.50	23.00	0.00	55.02	7.15
Onchnesoma steenstrupii	3.67	0.00	23.00	44.33	15.91	28.08
Golfingia vulgaris	3.67	0.00	38.00	0.00	25.41	0.00
Phoronis sp.	0.00	10.00	0.00	6.33	0.00	7.68
Undet. Sipunculids	0.00	0.00	9.67	0.00	6.12	0.00
Golfingia sp.	0.00	9.50	0.00	0.00	0.00	3.48
Phascolion strombus	7.33	0.00	0.00	0.00	2.69	0.00

Table 6. Location of the hyperbenthic stations sampled (beginning and end of trawl), depth and duration of trawl. Abbreviations: W: winter; S: spring.

Sta..	Season	Beginning of trawl			End of trawl			Trawl duration
		Latitude N	Longitude W	Depth	Latitude N	Longitude W	Depth	
15	W	**43º 26,90'**	8º 29,48'	97	43º 26.97'	8º 29,62'	98	2'
	S	43º 26,72'	8º 29,27'	96	43º 26.79'	8º 29,38'	97	2'
16	W	43º 35,96'	8º 31,24'	150	43º 35,85'	8º 31,45'	158	2'
	S	43º 36,30'	8º 30,80'	153	43º 36,22'	8º 30,97'	153	2'
17	W	43º 42,59'	8º 43,45'	290	43º 42,67	8º 43,50'	290	2'
	S	43º 42,50'	8º 43,60'	300	43º 42,54	8º 43,60'	295	2'

Table 7. Specific composition of the hyperbenthic communities by stratum in the winter period (Abundance: ind. 100m^{-2}).

Species	70-120	121-200	201-500
Pycnogonids			
Anoplodactylus petiolatus	-	0.2	-
Amphipods			
Ampeliscidae indet.	1.0	14.9	2.5
Amphilochoides boecki	187.4	-	-
Amphilochoides serratipes	-	0.3	0.5
Amphilochus neapolitanus	5.8	-	-
Paramphilochoides odontonyx	-	1.6	-
Lembos sp.	-	0.5	-
Aoridae indet.*	-	-	0.2
Argissa hamatipes	0.3	-	0.2
Siphonoecetes striatus	5.8	-	-
Atylus vedlomensis	1.9	-	-
Apherusa bispinosa	1.3	3.9	0.2
Apherusa henneguyi	-	0.2	-
Apherusa ovalipes	0.3	1.4	0.4
Apherusa spp.*	-	-	0.9
Eusirus longipes	9.4	10.4	3.0
Rhachotropis integricauda	-	8.4	4.6
Gammaropsis sophiae	0.3	1.7	0.2
Photis longicaudata	1.0	-	-
Microjassa sp. A	0.6	0.2	-
Leucothoe lilljeborgi	0.3	1.4	0.9
Liljeborgia pallida	-	0.3	-
Hippomedon denticulatus	0.6	-	-
Ichnopus spinicornis	-	0.3	0.2
Orchomenella nana	1.9	5.1	26.5
Scopelocheirus hopei	23.0	3.6	29.5
Trischizostoma nicaeense	-	-	0.5
Tryphosites longipes	-	0.3	-
*Lysianassidae indet.**	-	-	0.2
Megaluropus agilis	1.0	-	-
Melphidippella macra	4.5	1.7	0.2
Halicreion aequicorn is	-	0.2	-
Monoculodes sp.*	-	-	0.2
Perioculodes longimanus	5.5	17.4	6.2
Pontocrates altamarinus	6.2	-	-
Synchelidium haplocheles	1.0	0.3	-
Synchelidium maculatum	2.9	0.2	-
Westwoodilla caecula	-	0.6	0.5
Westwoodilla rectirostris	-	0.8	0.2
Halice walkeri	-	0.9	-
Harpinia antennaria	-	0.6	-
Harpinia laevis	-	0.2	-
Phoxocephalidae indet.*	-	0.2	-

Table 7 (continued)

Species	70-120	121-200	201-500
Stenopleustes malmgreni	-	0.6	0.4
Bathyporeia tenuipes	0.3	-	-
Stegocephaloides christianensis	-	-	0.2
Stenothoe marina	0.3	1.4	0.4
Gammaridea indet.*	-	-	2.1
Caprella sp.	-	0.2	-
Pariambus typicus	3.9	0.3	-
Pseudoprotella phasma	-	0.3	-
Mysidaceans			
Phronima sedentaria	-	-	0.2
Lophogaster typicus	0.3	0.5	-
Boreomysis megalops	-	-	7.6
Boreomysis sp. (juv.)	1.6	0.6	-
Siriella jaltensis	1.6	0.3	-
Anchialina agilis	72.9	66.3	1.2
Gastrosaccus sp. (juv.)	20.1	2.0	-
Haplostylus lobatus	5.5	1.7	-
Haplostylus normani	0.3	-	-
Haplostylus sp.*	0.3	-	-
Erythrops elegans	10.0	7.3	-
Erythrops neapolitana	-	48.7	1.4
Hypereythrops sp.	-	0.2	0.4
Parerythrops sp.	-	2.6	-
Pseudomma calloplura	-	-	0.2
Leptomysis gracilis	89.8	33.8	0.2
Leptomysis megalops	-	3.3	-
Leptomysis spp. (juv.)	16.5	-	-
Leptomysis spp.*	-	3.4	0.2
Mysideis parva	22.0	3.0	-
Mysidopsis angusta	0.6	4.0	1.2
Schistomysis ornata	5.2	-	-
Undet. Mysidacea *	10.7	4.7	1.9
Cumaceans			
Bodotria arenosa	17.2	1.6	-
Bodotria pulchella	14.6	-	-
Iphinoe serrata	-	0.8	0.5
Diastylis rugosa	-	0.2	-
Diastyloides biplicata	3.2	32.2	1.1
Diastyloides serrata	-	3.7	0.7
Ekleptostylis walkeri	-	0.5	-
Leptostylis macrura	-	-	0.2
Leptostylis sp.	-	1.1	-
Vemakylindrus sp.	-	7.9	-
Lamprops sp.	-	-	0.2
Eudorella truncatula	-	0.8	-
Leucon siphonatus	-	24.4	0.5
Campylaspis glabra	9.1	4.0	0.2
Campylaspis sulcata	-	-	2.1
Cumella pygmaea	-	1.1	-
Pseudocuma longicornis	20.1	-	-
Pseudocuma similis	1.3	-	-
Pseudocuma sp.	-	0.2	-
Isopods			
Arcturella sp.	-	0.8	-
Gnathia spp. (praniza ?)	2.3	-	-
Munna sp.	39.9	7.0	-
Paramunna bilobata	-	0.5	-
Tanaidaceans			
Leptognathia brevimana	-	0.3	-
Typhlotanais brevicornis	0.3	-	-
Euphausiaceans			
Meganyctiphanes norvegica	-	-	21.2
Nyctiphanes couchi	83.6	46.4	5.1

Table 7 (continued)

Species	70-120	121-200	201-500
Stylocheiron longicorne	-	0.5	0.4
Decapods			
Alpheus glaber	-	0.9	-
Athanas nitescens	-	0.2	-
Philocheras bispinosus	5.5	19.6	1.2
Undet. Crangonidae (juv.)	1.6	0.2	-
Pasiphaea sivado	-	-	0.2
Pasiphaea sivado (juv.)	14.3	1.9	137.7
Processa canaliculata	-	0.2	0.2
Polybius henslowi	1.0	-	3.0
Fishes			
Aphia minuta (juv.)	0.6	0.5	-
Pomatochistus sp.	-	0.5	-
Undet. Juveniles	1.6	1.6	0.2
Total Abundance	741.0	422.9	269.9

Table 8. Stratified biomass indices for some of the principal commercial species. Yst is expressed in kg/30 minutes trawl and SD is the standard deviation.

	October 2002		***Spring 2003***	
Species	***Yst***	***SE***	***Yst***	***SE***
Hake	*1.91*	*0.23*	*3.44*	*0.51*
Blue whiting	*51.82*	*7.65*	*38.84*	*5.73*
Megrim L. boscii	*2.22*	*0.23*	*3.37*	*0.59*
Megrim L. whiffiagonis	*1.27*	*0.24*	*1.31*	*0.49*
Black anglerfish	*0.26*	*0.09*	*0.53*	*0.16*
White anglerfish	*1.34*	*0.21*	*3.70*	*1.42*
Horse mackerel	*11.23*	*1.76*	*41.31*	*10.31*
Norway lobster	*0.04*	*0.01*	*0.08*	*0.05*

Table 9. Ecological indices by depth stratum and survey (mean value and standard deviation, SD). S = no. of species; P = biomass (Kg/tow)

	70- 120 m		***121- 200 m***		***201- 500 m***	
	Demersales	***Prestige 0403***	***Demersales***	***Prestige 0403***	***Demersales***	***Prestige 0403***
S	*30.00*	*37.00*	*30.92*	*36.19*	*26.33*	*30.87*
DS_S	*4.90*	*4.11*	*4.54*	*5.00*	*6.81*	*5.45*
P	*116.73*	*164.08*	*113.68*	*198.25*	*73.41*	*110.29*
DS_P	*75.16*	*100.60*	*72.88*	*209.16*	*71.98*	*142.34*
N	*1519.78*	*2613.33*	*4289.85*	*3214.44*	*4315.50*	*3318.53*
DS_N	*1236.84*	*2363.17*	*3946.49*	*2287.84*	*5031.17*	*2406.91*
H'P	*2.93*	*3.10*	*2.12*	*2.43*	*2.50*	*2.86*
$DS_{H'P}$	*0.57*	*0.74*	*0.62*	*0.54*	*0.91*	*0.58*
H'N	*2.78*	*2.82*	*1.84*	*2.17*	*1.93*	*2.16*
$DS_{H'N}$	*0.58*	*1.03*	*0.77*	*0.66*	*0.81*	*0.67*

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Table 10. Epibenthic communities biomass index (kg km^{-2}), sampled with a 3.5 beam trawl. Empty cells: no presence; cells with 0.00: biomass<0.01.

SPECIES	70-120	121-200	201-500	Total
Fishes				
Lophius piscatorius	54.44	21.82	267.05	98.21
Arnoglossus laterna	163.40	117.26	2.78	93.05
Lepidorhombus boscii	5.66	69.93	138.12	75.23
Gadiculus argenteus	2.89	35.65	134.49	56.59
Microchirus variegatus	72.46	74.41	10.16	54.94
Lophius budegassa		29.08	55.83	30.34
Chelidonichthys gurnardus	21.57	44.35	12.81	30.16
Scyliorhinus canicula	40.38	35.25	10.18	28.82
Lepidorhombus whiffiagonis	2.45	37.79	7.62	21.44
Merluccius merluccius	13.16	25.99	2.55	16.38
Callionymus maculatus	5.39	24.17	2.24	13.76
Raja clavata	16.37	20.32		13.50
Trisopterus luscus	61.79	1.08		13.41
Trachurus trachurus	6.94	19.79		11.27
Conger conger	3.32	15.15	3.74	9.28
Scorpaena scrofa		16.56		8.22
Callionymus lyra	35.35	1.38		8.05
Solea vulgaris	33.64			7.01
Chelidonichthys cuculus	21.66	3.52		6.26
Micromesistius poutassou	14.08	4.09	2.13	5.57
Lesueurigobius friesii	11.18	6.36		5.49
Arnoglossus imperialis	24.66	0.36		5.32
Gaidropsarus macrophthalmus		4.50	10.60	5.25
Raja montagui	24.83			5.17
Galeus melastomus		5.38	8.03	4.96
Argentina sphyraena	1.71	8.50	0.48	4.72
Chelidonichthys obscurus	21.09			4.39
Solea lascaris	16.98			3.54
Cepola rubescens	11.56	2.21		3.51
Helicolenus dactylopterus		2.31	8.01	3.42
Trisopterus minutus	15.02			3.13
Trachinus draco	14.36			2.99
Phycis blennoides	0.49	2.40	4.47	2.57
Pomatoschistus sp.	3.06	1.84	0.05	1.56
Blennius ocellaris	0.53	2.30		1.25
Malacocephalus laevis			2.65	0.75
Buglossidium luteum	3.37			0.70
Serranus cabrilla	2.92			0.61
Boops boops	2.38			0.50
Capros aper	0.06	0.80		0.41
Trigla lucerna	1.56			0.33
Deltentosteus quadrimaculatus	0.09	0.12		0.08
Pomatoschistus microps	0.14	0.07		0.06
Notoscopelus kro eyerii			0.21	0.06
Echiichthys vipera	0.23			0.05
Zeus faber	0.14	0.02		0.04
Crystallogobius linearis	0.16			0.03
Sygnathus acus	0.03			0.01
Crustaceans				
Munida sarsi	0.11	0.80	405.03	115.74
Polybius henslowi	152.48	25.41	237.16	111.91
Plesionika heterocarpus		0.95	203.30	58.36
Goneplax rhomboides	18.30	26.97	1.41	17.60
Munida intermedia	0.02	0.28	41.52	11.96
Pagurus prideaux	22.46	7.95	0.21	8.69
Munida iris		0.02	24.46	6.97
Liocarcinus depurator	25.96	1.32	0.32	6.16
Alpheus glaber	9.41	4.68	2.23	4.92
Chlorotocus crassicornis	0.96	8.05	0.25	4.27
Solenocera membranacea	10.38	2.49	1.99	3.97
Pagurus excavatus	6.36	3.84	0.24	3.30
Nephrops norvegicus	2.80		8.46	2.99
Pontophilus spinosus	1.19	2.03	5.82	2.92

SPECIES	70-120	121-200	201-500	Total
Scalpellum scalpellum	2.14	4.28	0.02	2.58
Anapagurus laevis	8.42	0.70	1.67	2.58
Processa canaliculata	0.73	3.57	0.20	1.98
Dichelopandalus bonnieri			5.46	1.56
Philocheras echinulatus		0.30	2.64	0.90
Macropipus tuberculatus		0.82	1.25	0.77
Processa macrophthalma	1.39	0.34	0.99	0.74
Ebalia cranchii	2.76	0.24	0.02	0.70
Macropodia longipes	0.23	1.11	0.16	0.65
Processa nouveli	2.59	0.00	0.00	0.54
Pagurus alatus	0.28	0.09	1.53	0.54
Lophogaster typicus	0.36	0.26	0.37	0.31
Eurynome aspera	0.22	0.39	0.04	0.25
Liocarcinus marmoreus	0.93			0.19
Galathea dispersa	0.08	0.28	0.09	0.18
Parapenaeus longirrostris			0.46	0.13
Pasiphaea sivado			0.42	0.12
Rissoides desmaresti	0.03	0.06	0.21	0.10
Pagurus bernhardus	0.44			0.09
Ebalia deshayesi	0.43	0.00		0.09
Galathea strigosa		0.17		0.08
Pagurus cuanensis	0.33			0.07
Atelecyclus rotundatus	0.17	0.02	0.06	0.06
Inachus dorsettensis	0.05	0.06	0.06	0.06
Heterocrypta maltzani	0.25			0.05
Anapagurus bicorniger	0.25			0.05
Philocheras sculptus	0.01	0.00	0.15	0.05
Macropodia tenuirrostris	0.13	0.00	0.03	0.04
Polycheles typhlops			0.11	0.03
Liocarcinus pusillus	0.09	0.02		0.03
Monodaeus couchii		0.01	0.07	0.03
Ebalia tuberosa	0.02	0.03		0.02
Cirolanidae indet.			0.06	0.02
Bathynectes maravigna			0.04	0.01
Inachus leptochirus		0.00	0.03	0.01
Macropodia deflexa		0.01	0.01	0.01
Pandalina brevirostris		0.01	0.00	0.00
Iphimedia obesa		0.01		0.00
Scyllarus arctus	0.01			0.00
Ebalia nux		0.00	0.00	0.00
Galathea intermedia	0.01			0.00
Eualus occultus	0.01			0.00
Cymodoce truncata		0.00		0.00
Philocheras bispinosus		0.00		0.00
Processa sp.	0.00			0.00
Molluscs				
Turritela communis	881.43	1.84	0.02	184.55
Eledone cirrhosa	138.80	139.23	103.42	127.50
Aporrhais pespelicani	39.66	26.92	14.61	25.79
Aporrhais serresianus	44.32	17.42	21.93	24.13
Neptunea contraria	16.99	31.35	1.24	19.46
Scaphander lignarius	5.43	11.02	9.52	9.31
Astarte sulcata	2.43	12.87	1.57	7.34
Nassaridae indet.	25.47	1.38	2.73	6.77
Calliostoma granulatum	4.84	7.56	2.33	5.43
Argobuccinum olearium		2.50	13.18	4.99
Nucula sulcata	14.29	3.59	0.79	4.99
Rossia macrosoma	0.75	5.86	5.38	4.60
Charonia lampax		7.86		3.90
Galeodea rugosa	4.23	3.22	4.74	3.83
Coralliophila squamosa		6.74	1.47	3.77
Venus striatula	17.32		0.02	3.61
Glycimeris glycimeris	15.87			3.31
Colus gracilis	9.40	1.15	1.54	2.97
Lunatia fusca	0.40	1.32	7.04	2.74
Octopus salutii			7.87	2.24
Sepia elegans	1.53	3.07	0.03	1.85
Timoclea ovata	6.82	0.20	0.05	1.53

SPECIES	70-120	121-200	201-500	Total
Sepietta oweniana	0.10	0.23	4.10	1.30
Todaropsis eblanae	0.60	0.84	2.37	1.22
Octopus vulgaris	5.76			1.20
Rondeletiola minor	0.98	0.46	0.92	0.70
Bathypolipus sponsalis			2.38	0.68
Buccinum humphreysianum		1.12	0.24	0.63
Sepiola sp.	0.61	0.65	0.56	0.61
Semicassis saburon		1.14		0.56
Alloteuthis sp.	1.11	0.59	0.05	0.54
Illex coindetii		1.02		0.51
Pseudamussium septenradiatum	0.02	0.45	0.87	0.48
Corbula gibba	0.41	0.39		0.28
Sepia orbignyana	0.74	0.21	0.02	0.26
Cuspidaria cuspidata	0.20	0.32	0.18	0.25
Gari costulata	1.06			0.22
Alloteuthis media		0.42		0.21
Pteria hirundo	0.26	0.30		0.21
Pygnodontha cochlear	0.53	0.13		0.17
Arcopagia balaustina	0.02	0.27	0.03	0.15
Venus casina	0.67			0.14
Arminia tigrina		0.26		0.13
Comarmondia gracilis	0.41	0.03	0.06	0.12
Epitonium clathrus	0.48	0.02		0.11
Spisula eliptica	0.41			0.08
Hinia reticulata	0.31			0.06
Abra alba	0.17	0.04	0.00	0.06
Pandora pinna	0.19	0.01	0.00	0.04
Roxania utricolis	0.06	0.04	0.02	0.04
Lunatia alderi	0.15			0.03
Poromya granulata		0.05		0.02
Dosinia exoleta	0.11			0.02
Antalis entalis	0.07	0.01		0.02
Cuspidaria rostrata		0.02	0.02	0.02
Opistobranquio		0.01	0.04	0.02
Chlamyx varia	0.03	0.01		0.01
Tellina fabula	0.07			0.01
Bela sp.	0.06	0.00		0.01
Ocenebra erinaceus	0.05			0.01
Raphitoma sp.	0.03	0.00	0.00	0.01
Fusinus rostratus	0.01	0.00	0.00	0.00
Cuspidaria abbreviata			0.01	0.00
Myrtea spinifera	0.01			0.00
Palliolum striatum	0.02			0.00
Chlamyx opercularis	0.01			0.00
Aperiovula adriatica	0.01			0.00
Epitonium trevelyanum		0.00		0.00
Pectinidae indet.	0.01			0.00
Capulus ungaricus		0.00		0.00
Lunatia alderi		0.00		0.00
Crassopleura maravignae	0.01			0.00
Nuculana commutata			0.00	0.00
Echinoderms				
Astropecten irregularis	49.13	54.77	25.23	44.61
Stichopus regalis	73.04	26.70	7.72	30.67
Echinus acutus	54.77	29.31	1.85	26.49
Ophiura ophiura	4.28	14.62	7.03	10.15
Ophiura affinis	0.15	7.06	10.49	6.52
Brissopsis lyrifera	14.04	3.34	0.74	4.79
Marthasterias glacialis	3.66	4.75		3.12
Anseropoda placenta	0.03	1.38	5.29	2.19
Echinocardium cordatum	0.61	1.65	0.03	0.95
Ophiura albida		1.74	0.02	0.87
Spatangus purpureus	2.90	0.22	0.38	0.82
Luidia sarsi	0.24	0.65	0.19	0.43
Trachythyone tergestina	1.15	0.10		0.29
Ophiothrix fragilis	0.05	0.45	0.03	0.24
Amphiura chiajei	0.03	0.42		0.21
Leptometra celtica		0.06	0.48	0.17

SPECIES	70-120	121-200	201-500	Total
Leptosynapta inhaerens	0.07	0.13	0.20	0.13
Trachythyone elongata	0.28			0.06
Echinocyamus pusillus	0.02	0.03		0.02
Leptosynapta bergensis	0.04	0.01		0.01
Psammechinus miliaris	0.02	0.01		0.01
Annelids				
Hyalinoecia tubicola	17.66	10.73	0.52	9.16
Sternaspsis scutata	41.48	0.93		9.10
Aphrodita aculeata	15.64	7.92		7.19
Nepthys sp.	0.14	0.05	0.04	0.07
Chloeia venusta			0.15	0.04
Sigalionidae indet.	0.10	0.02	0.00	0.03
Laetmonice filicornis		0.01	0.08	0.03
Glycera sp.	0.04	0.02		0.02
Eteone barbata		0.02		0.01
Maldanidae indet.		0.02		0.01
Sabella pavonina	0.04			0.01
Nereis sp.		0.01	0.00	0.01
Ampharetidae indet.		0.00	0.01	0.00
Nephtys hombergi			0.01	0.00
Pontobdella municata	0.01			0.00
Polynoidae indet.		0.00		0.00
Lumbrineris sp.	0.00	0.00		0.00
Lagis koreni	0.01			0.00
Eunicidae indet.			0.00	0.00
Nereis fucata			0.00	0.00
Phyllodoce groenlandica			0.00	0.00
Cnidarians				
Actinauge richardi	0.00	400.48	7.57	201.01
Pennatula rubra	0.11	63.92	0.00	31.76
Epizoanthus incrustatus	6.29		88.74	26.58
Caryophyllia smithii	0.61	8.02	7.90	6.36
Adamsia carcinopados	14.17	2.23		4.06
Calliactis parasitica	6.55	4.24		3.47
Lytocarpia myriophyllum	2.21	1.84	0.06	1.39
Funiculina quadrangularis		0.56	1.93	0.83
Alcyonium sp.		1.51	0.00	0.75
Pteroeides griseus	3.37			0.70
Ceriathus lloydi		0.49	0.50	0.39
Alcyonum glomeratum	1.28			0.27
Serturalella sp.	0.04	0.32	0.16	0.21
Nemertesia ramosa		0.36		0.18
Nemertina				
Nemertina indet.	0.03	0.01		0.01
Cerebratulus sp.	0.07			0.01
Pycnogonids				
Anoplodactylus petiolatus	0.00			0.00
Poriferans				
Axinella sp.	9.15			1.91
Suberites sp.	1.40			0.29
Phakelia ventilabrum	0.74		0.27	0.23
Adreus fascicularis	0.07			0.01
Sipunculids				
Phascolion strombii	37.80	0.98	0.04	8.37
Tunicata				
Corella paralelograma	1.12	0.74		0.60

Table 11. Biomass indices (kg km^{-2}) by stratum of the species belonging to the megafauna and commercial species.

SPECIES	70-120	121-200	201-500	Total
Fishes				
Trachurus trachurus	925.815	882.087	377.895	746.229
Micromesistius poutassou	271.516	1052.257	410.470	703.243
Scyliorhinus canicula	432.814	135.369	74.855	180.582
Lophius piscatorius	50.066	84.288	48.962	66.924
Merluccius merluccius	65.855	76.955	34.150	62.306
Lepidorhombus boscii	18.324	72.646	72.102	61.057
Capros aper	9.796	106.488	2.263	56.150
Boops boops	80.468	22.779	47.422	42.008
Raja clavata	164.974	7.044	0.000	38.260
Argentina sphyraena	50.301	45.286	2.300	33.969
Scomber scombrus	26.961	33.045	31.235	31.235
Gadiculus argenteus	0.000	1.159	95.986	28.193
Chimaera monstrosa	0.000	52.945	0.000	26.563
Trisopterus luscus	94.175	5.233	8.166	24.807
Lepidorhombus whiffiagonis	12.277	33.697	14.558	23.684
Conger conger	30.583	12.385	22.054	18.994
Helicolenus dactylopterus	0.127	14.196	40.632	18.831
Pagellus acarne	77.788	3.223	1.774	18.505
Microchirus variegatus	15.826	13.997	17.926	15.518
Aspitrigla cuculus	70.545	1.177	0.036	15.445
Zeus faber	50.392	8.148	0.000	14.703
Mullus surmuletus	15.482	9.796	10.303	11.136
Galeus melastomus	0.000	0.036	34.005	9.796
Lophius budegassa	9.253	6.482	15.536	9.669
Trisopterus minutus	43.946	0.163	0.000	9.325
Spondyliosoma cantharus	41.049	0.000	0.000	8.637
Cepola rubescens	11.751	11.353	0.000	8.166
Trigla lucerna	29.859	2.281	0.000	7.442
Raja montagui	32.122	0.000	0.000	6.754
Arnoglossus laterna	16.785	6.066	0.272	6.663
Phycis blennoides	0.000	2.100	19.049	6.537
Eutrigla gurnardus	7.062	5.595	1.847	4.835
Callionymus lyra	16.876	0.561	0.000	3.839
Pagellus bogaraveo	2.318	1.213	9.542	3.839
Trachinus draco	14.866	0.869	0.000	3.567
Solea vulgaris	10.031	2.173	0.000	3.205
Malacocephalus laevis	0.000	0.000	10.575	3.042
Arnoglossus imperialis	13.218	0.217	0.000	2.897
Sardina pilchardus	9.977	1.503	0.091	2.879
Trigla lyra	0.000	5.197	0.652	2.788
Blennius ocellaris	0.525	3.694	0.235	2.028
Mustelus asterias	0.000	3.784	0.000	1.901
Pagellus erythrinus	8.438	0.000	0.000	1.774
Scorpaena scrofa	0.000	2.553	0.000	1.286
Aspitrigla obscura	4.454	0.235	0.000	1.050
Mustelus mustelus	0.000	0.000	2.698	0.779
Hexanchus griseus	3.259	0.000	0.000	0.688
Raja naevus	3.060	0.054	0.000	0.670
Molva dipterygia	0.000	0.000	1.068	0.308
Lepidotrigla cavillone	0.923	0.036	0.000	0.217
Serranus cabrilla	0.742	0.000	0.000	0.163
Lepidopus caudatus	0.235	0.109	0.000	0.109
Sphoeroides pachygaster	0.507	0.000	0.000	0.109
Alosa fallax	0.398	0.000	0.000	0.091
Buglossidium luteum	0.308	0.000	0.000	0.072
Petromyzon marinus	0.000	0.145	0.000	0.072
Solea lascaris	0.344	0.000	0.000	0.072
Callionymus maculatus	0.072	0.072	0.018	0.054
Crystallogobius linearis	0.217	0.000	0.000	0.054
Scyliorhinus stellaris	0.235	0.000	0.000	0.054

SPECIES	70-120	121-200	201-500	Total
Antonogadus macrophthalmus	0.000	0.054	0.054	0.036
Bathysolea profundicola	0.000	0.000	0.127	0.036
Lesueurigobius friesii	0.000	0.054	0.000	0.036
Macroramphosus scolopax	0.000	0.054	0.054	0.036
Ophidion barbatum	0.000	0.054	0.000	0.036
Acantholabrus palloni	0.000	0.036	0.000	0.018
Ammodytes tobianus	0.091	0.000	0.000	0.018
Chlorophthalmus agassizii	0.018	0.000	0.054	0.018
Cyttopsis roseus	0.000	0.000	0.036	0.018
Rhinonemus cimbrius	0.000	0.000	0.072	0.018
Echiodon dentatus	0.000	0.018	0.000	0.000
Lampanyctus crocodilus	0.000	0.000	0.018	0.000
Pomatoschistus sp.	0.000	0.000	0.000	0.000
Crustaceans				
Munida sarsi	0.036	0.000	207.616	59.735
Polybius henslowi	51.696	9.108	84.180	39.673
Munida intermedia	0.000	0.000	32.738	9.416
Plesionika heterocarpus	0.000	0.253	19.320	5.686
Nephrops norvegicus	1.123	0.272	3.839	1.467
Polycheles typhlops	0.000	1.865	0.000	0.942
Liocarcinus depurator	1.774	0.561	0.543	0.815
Munida iris	0.000	0.000	1.811	0.525
Cancer pagurus	0.000	0.000	1.557	0.453
Pagurus excavatus	0.706	0.326	0.036	0.326
Solenocera membranacea	0.978	0.000	0.109	0.235
Dichelopandalus bonnieri	0.000	0.000	0.598	0.181
Maja squinado	0.833	0.000	0.000	0.181
Pagurus prideaux	0.072	0.127	0.018	0.091
Scalpellum scalpellum	0.000	0.181	0.000	0.091
Macropodia longipes	0.000	0.145	0.000	0.072
Chlorotocus crassicornis	0.018	0.091	0.018	0.054
Macropipus tuberculatus	0.000	0.000	0.091	0.036
Pagurus bernhardus	0.163	0.000	0.036	0.036
Goneplax rhomboides	0.018	0.018	0.000	0.018
Processa macrophthalma	0.054	0.000	0.000	0.018
Alpheus glaber	0.018	0.000	0.000	0.000
Galathea sp.	0.000	0.000	0.000	0.000
Galathea striposa	0.000	0.000	0.000	0.000
Inachus dorsettensis	0.000	0.000	0.000	0.000
Pagurus alatus	0.000	0.000	0.018	0.000
Pagurus cuanensis	0.018	0.000	0.000	0.000
Palaemon serratus	0.000	0.000	0.000	0.000
Parapenaeus longirrostris	0.000	0.000	0.000	0.000
Pasiphaea sivado	0.000	0.000	0.018	0.000
Philocheras echinulatus	0.000	0.000	0.000	0.000
Pontophilus spinosus	0.000	0.000	0.000	0.000
Processa canaliculata	0.000	0.000	0.000	0.000
Processa sp.	0.000	0.000	0.000	0.000
Molluscs				
Eledone cirrhosa	32.231	60.297	83.166	60.967
Illex coindetii	5.921	9.868	7.297	8.293
Todaropsis eblanae	4.201	5.957	13.291	7.696
Octopus vulgaris	10.955	8.510	0.000	6.573
Loligo vulgaris	13.725	6.084	0.000	5.939
Loligo forbesi	0.181	3.259	0.634	1.847
Rossia macrosoma	0.000	2.444	1.449	1.648
Alloteuthis sp.	5.722	0.471	0.036	1.449
Neptunea contraria	1.014	0.724	1.593	1.032
Charonia lampax	4.291	0.000	0.398	1.014
Alloteuthis subulata	1.883	0.416	0.018	0.616
Sepia elegans	1.430	0.616	0.036	0.616
Argobuccinum olearium	0.199	0.127	0.960	0.380
Galeodea rugosa	0.199	0.217	0.688	0.344

SPECIES	70-120	121-200	201-500	Total
Octopus salutii	0.000	0.000	0.742	0.217
Sepia orbignyana	0.362	0.091	0.000	0.127
Aplysia punctata	0.489	0.000	0.000	0.109
Sepia officinalis	0.380	0.018	0.000	0.091
Scaphander lignarius	0.000	0.127	0.036	0.072
Sepietta oweniana	0.000	0.000	0.145	0.054
Buccinum humphreysianum	0.000	0.018	0.091	0.036
Lunatia fusca	0.000	0.091	0.000	0.036
Rondeletiola minor	0.036	0.018	0.054	0.036
Aporrhais pespelicani	0.018	0.036	0.018	0.018
Opistobranquio	0.000	0.000	0.054	0.018
Pteria hirundo	0.091	0.018	0.000	0.018
Sepiola sp.	0.072	0.018	0.018	0.018
Alloteuthis media	0.000	0.000	0.000	0.000
Calliostoma granulatum	0.018	0.000	0.000	0.000
Pygnodontha cochlear	0.036	0.000	0.000	0.000
Echinoderms				
Stichopus regalis	18.976	6.482	1.901	7.786
Echinus acutus	18.234	3.603	0.471	5.776
Stichopus tremulus	6.392	0.652	0.362	1.774
Astropecten irregularis	1.793	1.630	1.575	1.648
Marthasterias glacialis	0.435	0.616	0.000	0.398
Echinus melo	0.000	0.290	0.000	0.145
Anseropoda placenta	0.000	0.091	0.199	0.109
Ophiura ophiura	0.054	0.145	0.018	0.091
Luidia sarsi	0.127	0.054	0.054	0.072
Spatangus purpureus	0.217	0.000	0.000	0.054
Asteronyx loveni	0.000	0.054	0.000	0.018
Echinocardium cordatum	0.000	0.000	0.036	0.018
Luidia ciliaris	0.091	0.000	0.000	0.018
Ophiothrix fragilis	0.000	0.018	0.000	0.018
Brissopsis lyrifera	0.000	0.018	0.000	0.000
Leptometra celtica	0.000	0.000	0.000	0.000
Leptosynapta inhaerens	0.000	0.000	0.018	0.000
Nymphaster arenatus	0.000	0.000	0.018	0.000
Others				
Funiculina quadrangularis	0.000	2.426	0.000	1.213
Actinauge richardi	0.000	1.141	1.249	0.923
Epizoanthus sp.	2.843	0.000	0.670	0.779
Dendrophyllia ramea	0.000	0.435	0.000	0.217
Calliactis parasitica	0.543	0.163	0.000	0.199
Aphrodita aculeata	0.308	0.145	0.072	0.163
Pennatula rubra	0.000	0.091	0.018	0.054
Lytocarpia myriophyllum	0.036	0.018	0.054	0.036
Phakelia ventilabrum	0.000	0.000	0.091	0.036
Porifero	0.000	0.072	0.000	0.036
Alcyonium sp.	0.000	0.054	0.000	0.018
Epizoanthus paguriphilus	0.000	0.000	0.072	0.018
Hyalinoecia tubicola	0.036	0.000	0.000	0.018
Suberites sp.	0.054	0.000	0.000	0.018
Adamsia carcinopados	0.000	0.000	0.018	0.000
Bathypathes patula	0.000	0.000	0.000	0.000
Caryophyllia smithii	0.000	0.000	0.000	0.000
Ceriathus lloydi	0.000	0.000	0.000	0.000
Corella paralelograma	0.000	0.018	0.000	0.000
Laetmonice filicornis	0.000	0.000	0.000	0.000
Sabella pavonina	0.000	0.000	0.000	0.000
Sipunculus nudus	0.000	0.000	0.000	0.000

Annex 8 Benthos, AMBI (AZTI Marine Biotic Index) and the Water Framework Directive

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In recent years, several benthic biotic indices have been proposed for use in estuarine and coastal waters in order to determine the natural and man-induced impacts. One of them, named AMBI (AZTI Marine Biotic Index), was created by Borja *et al*. (2000) and has been applied to different European geographical areas, under various impact sources (Borja *et al*., 2003a). The AMBI offers a 'pollution classification' of a particular site, representing the benthic community 'health' (*sensu* Grall and Glémarec, 1997). The theoretical basis of AMBI is that of the ecological adaptative strategies of the *r*, *k* and *T* (Pianka, 1970) and the progressive steps in stressed environments (Pearson and Rosenberg, 1978).
The species should be classified into five ecological groups, based upon sensitivity/tolerance to pollution (or disturbance): (i) Group I: Species very sensitive; (ii) Group II: Species indifferent; (iii) Group III: Species tolerant; (iv) Group IV: Second order opportunistic species; and (v) Group V: First order opportunistic species. A formula (see Borja *et al*., 2000) permits the derivation of a series of continuous values, based upon the proportions amongst the five ecological groups.

The AMBI has been verified successfully in relation to a very large set of environmental impact sources (38), both physical and chemical, including drill cutting discharges, submarine outfalls, harbour and dyke construction, heavy metal inputs, eutrophic processes, engineering works, diffuse pollutant inputs, recovery in polluted systems under the impact of sewerage schemes, dredging processes, mud disposal, sand extraction and oil spills (Borja *et al*., 2000, 2003a, 2003b; Caselli *et al*., 2003; Forni and Occhipinti Ambroggi, 2003; Bonne *et al*., 2003; Muxika *et al*., 2003; Gorostiaga *et al*., 2004; and Salas *et al*., in press).

The most recently impacts checked were (Muxika *et al*., submitted): (i) the relationships with anoxy processes in Sweden; (ii) the good gradient show in oil-based mud drilling impact, in the North Sea (with a high significant correlation with total hydrocarbons); and (iii) harbour dredging impact.
The AMBI is very easy to use, having freely-available software, including a continuously updated species list, incorporating more than 2,700 taxa (http://www.azti.es/ingles).

Further, the European Water Framework Directive (WFD; Directive 2000/60/EC) develops the concept of Ecological Quality Status (EcoQ) for the assessment of the quality of water masses (Borja *et al*., 2004a). Recently, an equivalence between the AMBI values and the 'Ecological Status' classification has been proposed (Borja *et al*., 2003b, 2004b). It has been based upon the interpretation of the normative definitions in the WFD, for the ecological status of coastal and transitional waters, in relation to the benthic invertebrate fauna (see Borja *et al*., 2004b).

On the other hand, Borja *et al*. (2004a) have developed a new approach in the determination of biological quality based upon the macroalgae element (*sensu* WFD). This first approach has been improved, including different indicators, which should be determined (see Table 5 in Borja *et al*., 2004a, and the next table):

Indicator	Score		
	1	3	5
1-Richness	<1	2-5	>6
2- Pollution indicator species (mean coverage)	>70%	20%-70%	<20%
3- Mean phanerogams coverage	<1%	1%-7%	>7%
4- Mean macroalgae coverage (without indicator sp.)	<5%	6%-30%	>30%
5- Ratio (coverage) green algae/remainder of the macroalgae and phanerogams	>3,1	1,1-3	<1

Table. Macroalgae indicators in the Basque Country, with their asigned ratings. Classification: High (22 to 25), Good (18 to 21), Moderate (14 to 17), Poor (10 to 13) and Bad (5 to 9).

The criteria followed, in order to determine indicator pollution species, are based upon Orfanidis *et al*. (2001) and adapted for the characteristics of the Basque estuaries. Hence, as indicator species *Cyanophyta*, *Lyngbya* sp., *Microcoleus lyngbyaceus*, *Blidingia minima*, *Cladophora coelothrix*, *Enteromorpha* sp., *Rhizoclonium tortuosum*, *Ulothrix* sp., *Ulva* sp., *Ulva lactuca*, *Capsosiphon*, *Vaucheria* sp., *Lola* sp., *Bostrychia scorpioides*, *Catenella caespitosa*, *Polysipho-*

nia sp., *Polysiphonia lanosa* and *Fucus ceranoides*, were considered. As not indicators (or sensitive) *Spartina marítima, Zostera noltii, Gracilaria* sp., *Gracilaria compressa, Porphyra umbilicalis, Gelidium pusillum, Fucus spiralis spiralis, Fucus spiralis limitaneus, Fucus* sp., *Fucus vesiculosus, Ascophylum nodosum* and *Pelvetia canaliculata*, were considered.

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Annex 9 Background paper on benthic EcoQOs

Assessing the suitability of OSPAR EcoQOs vs ICES Criteria

A UK working paper to the ICES Study Group to Review Ecological Quality Objectives for Eutrophication (SGEUT) May 2004.

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1. SUMMARY

Ecological Quality Objectives (EcoQOs) form an important framework for applying the ecosystem approach to the management of human activities affecting estuarine and coastal waters. Five Ecological Quality elements have been agreed (Bergen Declaration 2002) for monitoring nutrient enrichment and potential eutrophication effects in the marine environment (North Sea and OSPAR-wide). Desired levels (EcoQOs) have been proposed for each of these elements, *viz.* winter nutrient concentrations (t[1]), phytoplankton chlorophyll *a* (q[1]), phytoplankton indicator species (r[1]), oxygen concentrations (u[1]) and changes/kills in zoobenthos (m[1]). These EcoQOs incorporate attributes which are considered to be most representative of water quality, and which are easily observed, amenable to quantitative analysis, and provide the first indication of biological response to nutrient enrichment.

The objective of this report is to provide a preliminary evaluation of the suitability of the EcoQOs for the coastal and offshore waters of England and Wales. The evaluation is based on ICES criteria that good indicators should be easy to understand, should show a cause-effect relationship with manageable human activities (*i.e.* should be sensitive to, tightly linked to, and primarily responsive to these activities), and should be relatively easy to measure and monitor.

In principle, the agreed EcoQOs for eutrophication are easy to understand, but recent shifts in our conceptual understanding of eutrophication indicate complex responses to nutrient inputs, which may compromise the suitability of the measures of ecological quality. Quantitative monitoring of water quality criteria in marine waters around England and Wales started on an *ad hoc* basis in the 1960s, providing some time-series for data analysis. While long-term trends in anthropogenic nutrient inputs are evident in the data, few (if any) studies have been able to provide unequivocal evidence of a link with the consequences of nutrient enrichment. This is particularly true for offshore environments. It is therefore difficult to provide conclusive evidence of the sensitivity of biological responses to manageable human activities. Monitoring of nutrient inputs and eutrophication effects is generally feasible and in place (*e.g.* through OSPAR and various directives), but insufficient long-term data-sets are available for the setting of reliable reference points, especially on a regional basis. There is still an urgent need to improve the frequency and spatial coverage of (quality assured) monitoring of nutrients and the direct and indirect effects of nutrient enrichment.

Detailed evaluations of the five agreed Ecological Quality elements in terms of the ICES criteria suggest that the best of the EcoQOs is the concentration of winter nutrients. This is particularly true for coastal environments, where it is feasible that all of the ICES criteria may be met. For offshore waters, it is less likely that all the criteria will be met, as nutrient concentrations are primarily responsive to other processes (*e.g.* due to hydrodynamics) and not directly to human activity. Concentrations of phytoplankton chlorophyll *a* also appear to be a good indicator in environments which are susceptible to nutrient enrichment (*e.g.* clear coastal water). In water bodies which are less susceptible to the impacts of nutrient enrichment, this EcoQO may not meet any of the criteria for demonstrating cause and effect relationships. Reduced susceptibility may be due to factors which limit or control phytoplankton growth, for example light, advective losses and grazing pressure. The EcoQO for zoobenthos (or fish) kills potentially meets all the

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[1] OSPAR and ICES notation for the current integrated set of ecological quality elements used to assess eutrophication effects

ICES criteria for a good indicator although it is difficult to establish unequivocal links with nutrient enrichment.

Detailed evaluations of the EcoQOs for phytoplankton indicator species, oxygen concentrations and zoobenthos changes suggest that these elements do not meet sufficient ICES criteria to be considered good indicators. In specific cases where human activities are clearly evident, it may be easy to demonstrate localised cause and effect relationships between the ecological quality element and human activity, but on a broader (*e.g.* regional) scale this may be more problematic. Indicator species, oxygen concentrations and zoobenthos are easy to monitor, but relatively few data sets are available for regional analyses.

Consideration of specific examples for each EcoQO indicates that greater emphasis needs to be placed on (a) identifying seasonal effects of nutrient inputs and the responses of the phytoplankton community, *e.g.* during the entire growth season (*vs* the spring bloom) summer nutrient concentrations are also important, (b) assessing the natural susceptibility of different water bodies, (c) distinguishing between coastal and offshore environments, and (d) development of longer (>20 y) time-series of data for assessing the significance of anthropogenic inputs versus natural variability. Other potential elements to be considered for EcoQOs include indices of greenness from the Continuous Plankton Recorder and the "Phytoplankton Trophic Index" currently under development through CEFAS.

2. INTRODUCTION

Over the past decade Ecological Quality Objectives (EcoQOs) have been developed to facilitate the development of an ecosystem approach to fisheries and environmental management. One of the key issues in environmental management is the assessment of the risks and impacts of eutrophication in estuarine and coastal waters. Within the EU, a common legislative definition of eutrophication is the "enrichment of water by nutrients especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned" (Urban Wastewater Treatment Directive, 1991).

Five Ecological Quality elements have been identified for monitoring nutrient enrichment and potential eutrophication effects in coastal waters (Table 1). For each element, desired levels (Ecological Quality Objectives, EcoQOs) have been defined in order to assess potentially negative impacts of eutrophication. These EcoQOs form the basis of assessments under OSPAR and EU directives, such as the Water Framework Directive (WFD). They have been tested during recent and ongoing studies in Europe (*e.g.* Baan and van Buuren 2003, Nielsen *et al.* 2003), and are currently under review by ICES. As agreed by Ministers at the 5th North Sea Conference, the EcoQOs will be tested and developed further in a pilot project for the North Sea. Progress will be reviewed in 2005 and reported to North Sea Ministers. Additional EcoQOs for eutrophication may include riverine and direct nutrient inputs (RID), transboundary fluxes (nutrient budgets), shifts from long-lived macrophytes, including macroalgae, to short-lived nuisance species (*e.g.* Ulva, OSPAR EUC 03/5/2-E (L)). Under its 'Safeguarding our Seas' strategy, DEFRA is committed to testing and reviewing these EcoQOs for the coastal waters of England and Wales. Additional work contributing towards an improved understanding of the linkages between nutrient enrichment and eutrophication is likely to form the basis for further development of these and other EcoQOs.

The objective of this report is to provide a preliminary evaluation of the suitability of the EcoQOs for indicating the risks and impacts of eutrophication in coastal and transitional waters of England and Wales. Within the context of EU directives, a good indicator should respond to anthropogenic influences, be generally present in coastal waters, be measurable with high accuracy and precision, have well-defined reference conditions, be cost-effective, and be easy to communicate to the public. These criteria form the basis of the review currently being undertaken by ICES (see Table 2). For this report, each of the indicators in Table 1 was evaluated against the ICES criteria.

Available data from previously reported work were synthesised and reviewed, and appropriate figures are used here to demonstrate the results of this work. Data on coastal and offshore waters were taken from the First Application of the OSPAR Comprehensive Procedure to waters around England and Wales (Malcolm *et al.* 2002), and from a recent study on the risks and impacts of eutrophication in estuaries (Painting *et al.* 2003). The data used in these studies was obtained from a number of sources including the National Marine Monitoring Programme, the Environment Agency estuary and coastal water surveillance and monitoring programmes, CEFAS research programmes, Port Erin Marine Laboratory surveys of the north-east Irish Sea, and other data held in the ICES databases. The spatial coverage and the temporal coverage of the data varies from year to year, making comparison of trends over time difficult.

For the OSPAR Comprehensive Procedure, assessments were made of the eutrophic status of offshore waters of the southern and central North Sea, the coastal waters of North East England, South East England (Humber to Norfolk, Norfolk to Thames), the Irish Sea/ Liverpool Bay

Region and the Bristol Channel. Estuaries assessed included the Humber, the Wash, the Thames, the Severn and the Mersey. For the study on the risks and impacts of eutrophication in estuaries, additional data were obtained for approximately 40 other estuaries in England and Wales.

Table 1. Ecological Quality Elements and Objectives for monitoring and assessing the biological response to nutrient enrichment (from the Bergen Declaration, 2002).

Ecological quality element	**Ecological quality objective**
(m) Changes/kills in zoobenthos in relation to eutrophication	• There should be no kills in benthic animal species as a result of oxygen deficiency and/or toxic phytoplankton species.
(q) Phytoplankton chlorophyll *a*	• Maximum and mean chlorophyll *a* concentrations during the growing season should remain below elevated levels, defined as concentrations > 50% above the spatial (offshore) and/or historical background concentration
(r) Phytoplankton indicator species for eutrophication	• Region/area - specific phytoplankton eutrophication indicator species should remain below respective nuisance and/or toxic elevated levels (and increased duration)
(t) Winter nutrient concentrations (Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphate (DIP)	• Winter DIN and/or DIP should remain below elevated levels, defined as concentrations > 50% above salinity related and/or region-specific natural background concentrations
(u) Oxygen	• Oxygen concentration, decreased as an indirect effect of nutrient enrichment, should remain above region-specific oxygen deficiency levels, ranging from 4-6 mg oxygen per liter

Note: The Scheveningen workshop (Skjoldal *et al.* 1999) defined Ecological Quality (EcoQ) as *an overall expression of the structure and function of the aquatic systems*, and Ecological Quality Objectives (EcoQOs) as *the desired level of the EcoQ relative to the reference level*. Reference level was defined as *the level of the EcoQ where the anthropogenic influence on the ecological system is minimal*.

Table 2. Criteria for good Ecological Quality metrics (ICES 2001)

To be useful for management, indicators should be:

1. Relatively easy to understand by non-scientists and other users;
2. Sensitive to a manageable human activity;
3. Relatively tightly linked in space and time to that activity;
4. Responsive primarily to a human activity, with low responsiveness to other causes of change
5. Easily and accurately measured, with a low error rate;
6. Measurable over a large proportion of the area over which the EcoQO element is to apply;
7. Based on an existing body or time series of data to allow a realistic setting of objectives

3. BIOLOGICAL RESPONSE TO NUTRIENT ENRICHMENT (RATIONALE BEHIND INDICATORS)

The general concept of eutrophication assumes a simple dose-response relationship between nutrient input and ecosystem response in terms of the growth of phytoplankton and higher forms of plant life. In general terms, nutrient input is assumed to result in the rapid growth of opportunistic fast growing primary producers and the accumulation of extra biomass which may have a negative impact on the ecosystem. Attributes considered to be symptoms of negative impacts of nutrient enrichment in many ecosystems include blooms of toxic algae, increased growth of epiphytic algae, the growth of macroalgae, the loss of submerged vegetation due to shading, the development of hypoxic (and anoxic) conditions due to decomposition of the accumulated biomass, and changes in the community structure of benthic animals due to oxygen deficiency or the presence of toxic phytoplankton species. The Ecological Quality elements and Objectives for monitoring and assessing the biological response to nutrient enrichment in Table 1 incorporate those attributes considered to be most representative of water quality, and which are easily observed, are amenable to quantitative analysis, and provide the first indication of biological response to nutrient enrichment.

Relatively recent shifts in our conceptual understanding of eutrophication (Cloern 2001) indicate complex responses to nutrient inputs, including both direct and indirect responses, and the role of 'filters' in moderating the response or determining the sensitivity to unwanted effects. These filters include factors such as the light climate and advective losses, which affect the susceptibility of different water bodies to nutrient enrichment. Region- or site- specific reference levels are therefore essential for sensible application of the EcoQOs. This will require considerable effort to improve our knowledge and understanding of the responses of different ecosystems to nutrient enrichment.

Within any given region, *e.g.* the southern North Sea, temporal variability in physical factors plays an important role in limiting or controlling the biological response to nutrient enrichment. This has been incorporated into the current EcoQOs, which propose season-specific reference levels for nutrients and phytoplankton chlorophyll *a,* albeit loosely. Spatial variability also plays a critical role in determining susceptibility to nutrient enrichment, both alongshore and in near-shore *vs* offshore waters. Nutrient inputs and biological responses in coastal waters adjacent to river mouths or sewage outlets, for example, are likely to be different from those in coastal waters which are not strongly influenced by river run-off or point sources. Similarly, nutrient inputs and biological responses in coastal waters are likely to be significantly different from those in offshore waters, where the influence of freshwater inputs is weakest and the temporal variability in hydrographic and biological processes is high. Clearly defined local or salinity-specific reference levels may therefore also be essential for sensible application of the EcoQOs. To some extent, these have been incorporated into the current EcoQOs, but insufficient emphasis has been placed on this point. Certainly, the suitability of the EcoQOs based on the ICES criteria (Table 2) is far more difficult to evaluate for offshore waters than for coastal waters.

Future shifts in our understanding of eutrophication are likely to indicate even greater complexity in the biological response to nutrient enrichment, with multiple stressors (*e.g.* nutrient input, climate change, fish harvesting, toxic contaminants and aquaculture), multiple factors determining sensitivity, and complex feedbacks between the different biological responses in an ecosystem (Cloern 2001). This may compromise the suitability of the measures of Ecological Quality, as defined in Table 2.

4. SETTING ASSESSMENT STANDARDS

The crucial step in making assessments of the eutrophic status of different water bodies is obtaining adequate information about the background and reference values to be applied in the case of each EcoQO. Where there is good historic data for a given area this is a simple process. However, in most European waters the historic record is limited and either proxy evidence or derived values have to be used to set assessment standards (Hartnoll *et al.* 2001, Rodhe *et al.* in prep.). This may have a significant impact on the suitability of the Ecological Quality Objectives as indicators of the risks and impacts of eutrophication.

Setting background and reference levels for estuarine and coastal waters around the UK requires adequate long-term data-sets for each of the EcoQOs, and an understanding of the linkages between nutrient inputs and ecosystem response. For some offshore and coastal sites, data may be available although the linkages are poorly understood. Data series are generally limited, and do not lend themselves to robust assessments of reference levels. Deriving suitable reference levels for use in estuaries and other coastal waters where there is a gradient is even more problematic in the absence of good historical information. This is currently being addressed under the WFD.

For the initial application of the OSPAR Comprehensive Procedure it was assumed that Atlantic water, which enters the shelf seas of northern Europe provides a suitable background condition from which to derive standards for assessment. This assumption was used to set background concentrations and reference levels for nutrient concentrations, nutrient ratios, chlorophyll concentration and potential primary production. In estuaries and coastal waters with defined mixing gradient concentrations, dissolved substances were normalised to salinity 30 and judged against the Atlantic derived standard. For particulate material, such as chlorophyll a concentration, this was not possible and appropriate statistical treatments were applied to the whole water body.

Estuarine data have been analysed in an attempt to identify the key causal processes linking nutrient loadings with biological effect in a number of different estuarine categories, and to develop category-specific standards or thresholds for each of the attributes. Robust relationships could not be easily identified from the available data. A simple model was therefore developed to calculate rates of nutrient input resulting in consequences for which there are already defined criteria such as different levels of primary production (Nixon, 1995) and changes in dissolved oxygen (CSTT, 1994, 1997). The model was based on the approach adopted by the Comprehensive Studies Task Team (CSTT, 1994, 1997), and was used to investigate the growth of phytoplankton in each of the estuarine categories in response to physico-chemical characteristics. The predicted magnitude of primary production in the different estuary types was used in conjunction with Nixon's (1995) scale to set standards or thresholds for assessing likely trophic status in the different estuary categories.

5. IMPLEMENTATION AND EVALUATION OF ECOLOGICAL QUALITY OBJECTIVES

5.1. Winter nutrient concentrations

Table 3. Ecological Quality Objective for monitoring winter nutrient concentrations (from the Bergen Declaration, 2002).

Ecological quality element	Ecological quality objective
(t) Winter nutrient concentrations (Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphate (DIP)	• Winter DIN and/or DIP should remain below elevated levels, defined as concentrations > 50% above salinity related and/or region-specific natural background concentrations

The availability of nutrients (and the appropriate ratios of different nutrient species such as nitrogen and phosphorus) is one of the key environmental variables controlling the growth of phytoplankton and other primary producers in coastal waters. Other key factors include the availability of light in the water column, and a suitable temperature regime. In UK coastal and estuarine waters, nutrient concentrations are highest in winter, when agricultural run-offs are highest due to increased precipitation. In addition, growth rates of algae and other plants are slow due to poor availability of light and low water temperatures. Monitoring studies indicate that nutrients tend to accumulate in coastal waters during winter months (November to February).

For the OSPAR Comprehensive Procedure, mean DIN and DIP concentrations during winter were compared with mean winter (January/February) nutrient concentrations in Atlantic seawater, *viz.* 7.20 µM for nitrogen and 0.45 µM for phosphorus (Gowen *et al.* 2002). Elevated concentrations were judged to be those that exceed the background concentration by 50% (10.8 µM for nitrogen and 0.68 µM for phosphorus)

For the different areas assessed, the spatial and temporal coverage of the data was highly variable from year to year, making comparison of trends over time difficult. In most eastern regions, monitoring started in the 1960's, providing a reasonable time series for analysis. Along the west and south coasts time series are considerably shorter, but still span approximately 10 years or more. Figures 1 and 2 shows interannual trends in the mean winter concentrations of DIN and DIP along the south east coast, from Norfolk to the Thames. In common with all the areas assessed, winter nutrient concentrations indicate marked temporal variability, which was considered to be due to variability in river run-offs. Variability between assessment areas was also high, presumably due to spatial variability in hydrology and nutrient loading. In general, comparison of winter nitrogen and phosphorus concentrations with the background concentrations assumed for Atlantic water indicated that winter nutrient concentrations were elevated in all the coastal areas assessed, but not in the offshore central and southern North Sea areas. This may indicate that the relative impact of anthropogenic nutrient inputs is higher in coastal waters, as might be expected. It may also indicate that the assumed background concentrations were not appropriate for all the assessment areas. More realistic background concentrations may be calculated from the existing time series of data for each region.

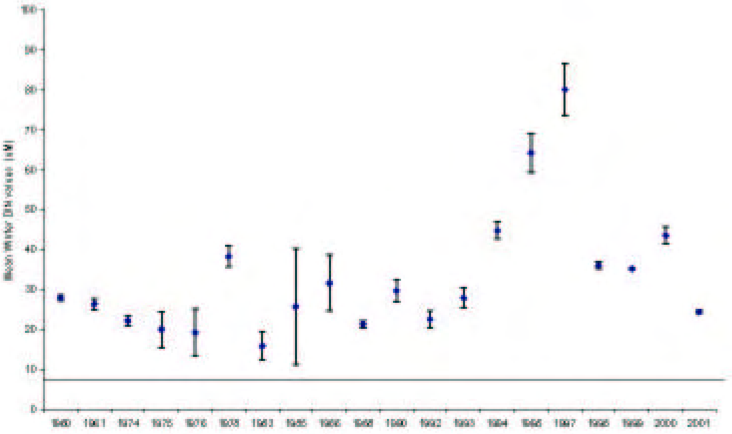

Figure 1. Mean winter DIN concentration (µM) in the Norfolk to Thames Coastal Water Area from 1960 – 2001. The line indicates the reference level (Malcolm *et al* 2002).

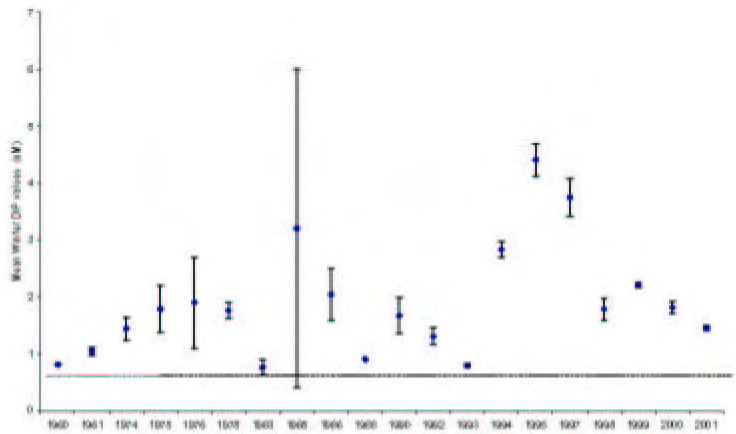

Figure 2. Mean winter DIP concentration (µM) in the Norfolk to Thames Coastal Water Area from 1960 – 2001. The line indicates the reference level (Malcolm *et al* 2002).

In terms of the ICES criteria for good indicators of ecological quality, the use of winter nutrient concentrations as an EcoQO (Table 4) is easy to understand. Cause and effect relationships are easy to demonstrate for coastal waters, but less so for offshore waters. Available data indicate that winter nutrient concentrations in coastal waters are relatively closely linked in space and time to diffuse and point source inputs of nutrients, and are responsive to a large extent to human activities. In offshore waters, linkages of nutrient concentrations (and therefore responsiveness) to human activities are weaker. Consequently, winter nutrient concentrations in estuarine and coastal waters are likely to be sensitive to management of nutrient inputs, but less so in offshore waters.

In situ concentrations of winter nutrients are easy to measure with a low error rate, but it is difficult to distinguish between anthropogenic and natural sources. With a considerable degree of effort, nutrient concentrations are measurable over a large proportion of the area over which the

EcoQO is to be applied. At present, the main limitation to the use of this EcoQO is the availability of long-term data for quantifying the natural variability, and for the realistic setting of objectives, particularly on a regional basis (see Hartnoll *et al.* 2001).

Table 4. Evaluation of the EcoQO for winter nutrient concentrations against those features considered to be qualities of good EcoQOs. Y = Yes, M = Moderate, N = No.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
Winter nutrient concentrations (DIN and DIP)	Y	Y	Y	Y (coastal areas) N (offshore areas)	Y	Y	Y (critical areas) N (other areas)

5.2. Phytoplankton chlorophyll a

Table 5. Ecological Quality Objective for monitoring phytoplankton chlorophyll *a* (from the Bergen Declaration, 2002).

Ecological quality element	**Ecological quality objective**
(q) Phytoplankton chlorophyll *a*	• Maximum and mean chlorophyll *a* concentrations during the growing season should remain below elevated levels, defined as concentrations > 50% above the spatial (offshore) and/or historical background concentration

The primary biological response to nutrient enrichment in aquatic environments, given suitable environmental conditions (such as light availability and water temperatures), is the growth of phytoplankton and higher plants. Assessment of the magnitude of the response should ideally be based on estimates of primary production rates of the different plant groups. For numerous reasons (including limited financial and human resources), measurements of primary production are not included in routine surveys for monitoring water quality in coastal environments. For phytoplankton, it is assumed that biomass may be used as a proxy for net production. Concentrations of chlorophyll *a* in water samples are used as an index of phytoplankton biomass.

Maximum and mean chlorophyll *a* concentrations during the growing season (March to September) are the basic parameters required to assess chlorophyll *a* as an estimate of plant biomass. In the temperate waters of the UK, maximum concentrations are expected to occur in the early part of the season during the spring bloom. The timing of the spring bloom is predictable in most areas.

For the OSPAR Comprehensive Procedure, appropriate standards for assessing chlorophyll *a* concentration were derived from the background nutrient concentrations by making some reasonable assumptions about nutrient conversion to plant biomass. There was considerable uncertainty in the calculated background level due to the wide range of factors that could be used to convert carbon to chlorophyll. From practical experience the UK has adopted 10 $\mu g\ l^{-1}$ chlorophyll *a* as a guide for assessment. It was therefore proposed that for

* offshore waters **10 µg l^{-1} chlorophyll *a*** is adopted as the reference value (implying background value of 6.7 µg l^{-1} and a reasonable C:Chl factor of 0.012) and for
* nearshore waters, where the level of production may be expected to be higher, **15 µg l^{-1} chlorophyll *a*** is adopted as the reference value (implying a background value of 10 µg l^{-1} chlorophyll *a* and a C:Chl factor of 0.02).

The NERC North Sea project described the annual cycle of phytoplankton growth in the offshore southern North Sea. The spring bloom occurs during April and May with peak chlorophyll *a* concentrations exceeding 10 mg m^{-3}. Chlorophyll concentrations decrease to levels of about 2 mg m^{-3} during the summer. Very low concentrations occur during the winter. The maximum spring chlorophyll *a* concentration varied between 2.12 and 12.63 µg l^{-1} and the mean chlorophyll *a* concentration during the growing season varied between 0.66 and 4.18 µg l^{-1} in the period from 1993 to 2000. There was no statistically significant trend in peak chlorophyll a concentrations over time (linear regression, $P > 0.05$). Results showed that in one year (1999) in four the peak chlorophyll *a* concentration exceeded the reference value of 10 µg l^{-1} and that mean summer concentrations were low and below the Atlantic background concentration (Howarth *et al.* 1994)

Similar patterns in the annual pattern of growth and maximum chlorophyll levels were observed from the Smartbuoy *in situ* measurements at the Outer Gabbard in the Offshore Southern North Sea (Fig. 3, CEFAS, unpubl. NMP data).

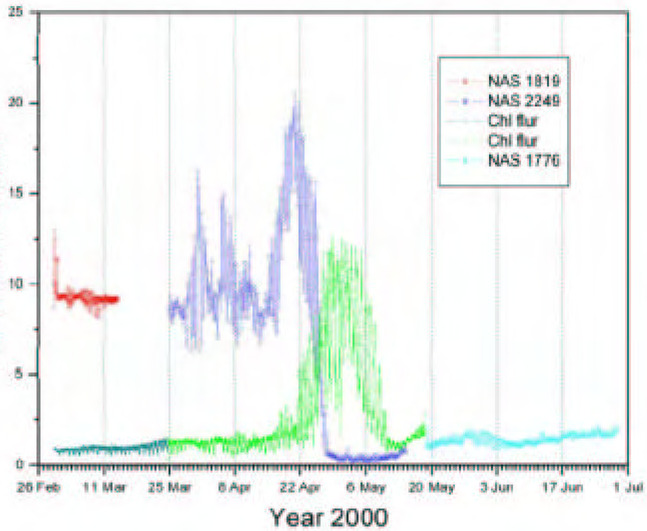

Fig. 3. Smartbuoy data from the Outer Gabbard station in the southern North Sea (CEFAS, unpubl. data). Maximum chlorophyll levels (mg m^{-3}, from chlorophyll fluorescence) peak after nitrate levels (µmol^{-1}, NAS data) have been depleted in early May.

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Figures 4 and 5 show changes in chlorophyll *a* concentrations in two regions of England (from Malcolm *et al.* 2002). For the area from the Humber to the Wash (Fig. 4) the maximum spring growing season chlorophyll *a* concentrations were significantly higher than the reference level (15 µg/l) in two of the seven years for which there was good data. The growing season mean chlorophyll *a* concentrations were below the Atlantic offshore background concentration. It was concluded that chlorophyll *a* concentrations are not elevated in the area. Data from the Bristol Channel (Fig. 5) indicate that the reference levels have not been exceeded since 1990.

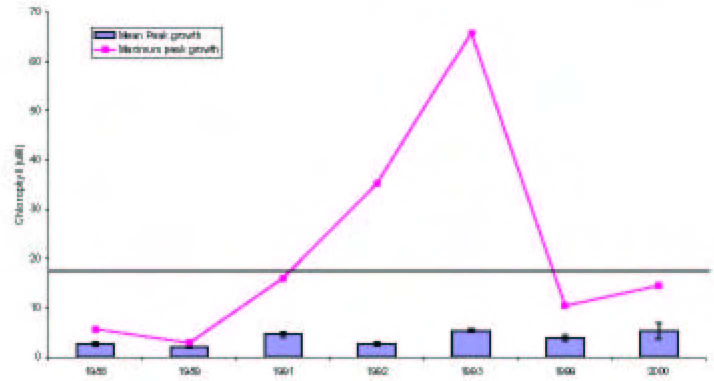

Figure 4. Mean growing season and maximum peak chlorophyll *a* concentration (µg/l) in the Humber to Norfolk coastal water area from 1988-2001. The line represents reference value (15 µg/l).

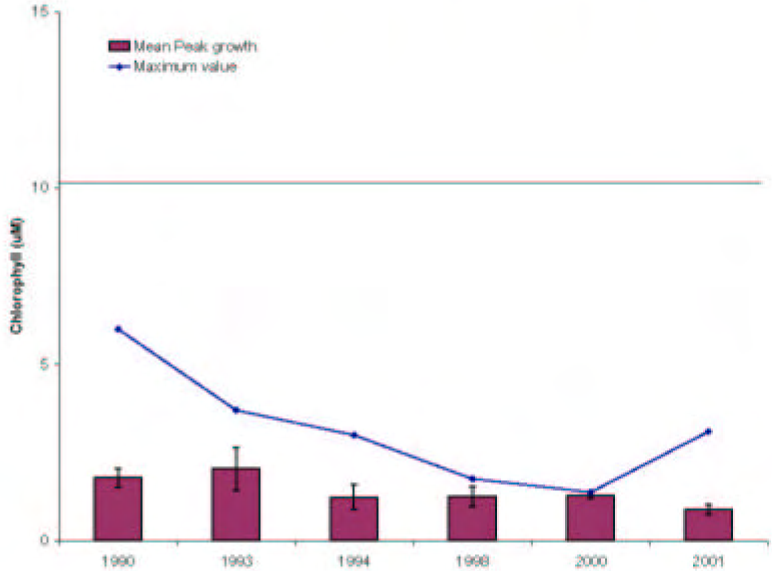

Figure 5. Mean annual and maximum peak chlorophyll *a* concentration (µg/l) in the Bristol Channel from 1993 – 2001. (ICES, CEFAS and NMP data). The line represents lower reference value.

In terms of the ICES criteria for good indicators of ecological quality, the use of chlorophyll *a* concentrations as an EcoQO (Table 6) is easy to understand. In relatively clear coastal and offshore waters, chlorophyll concentrations are likely to show sensitivity to the management of nutrient inputs. In more turbid coastal and estuarine waters, however, this sensitivity is likely to be lower. Available data indicate that chlorophyll concentrations are relatively closely linked in space and time to availability of nutrients in water bodies when other factors, such as light and temperature, are not limiting. Where other factors limit (such as light) or control (such as grazing) phytoplankton growth, linkages are weak. Phytoplankton chlorophyll *a* concentrations in relatively clear coastal and offshore waters are likely to be sensitive to management of nutrient inputs, but less so in water bodies where phytoplankton growth is limited or controlled.

In situ concentrations are easy to measure with a low error rate and, with a considerable degree of effort, are measurable over a large proportion of the area over which the EcoQO is to be applied. At present, the main limitation to the use of this EcoQO is the availability of data for the realistic setting of objectives, particularly on a regional basis.

Table 6. Evaluation of the EcoQ for phytoplankton chlorophyll *a* against those features considered to be qualities of good EcoQOs. Y = Yes, M = Moderate, N = No.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
Phytoplankton chlorophyll *a*	Y	Y (clear coastal) N (turbid coastal and offshore)	Y (no other limiting factors) N (limiting or cont-rolling factors present)	Y (no other limiting factors) N (limiting or cont-rolling factors present)	Y	Y	Y (critical areas) N (other areas)

5.3. Phytoplankton indicator species

Table 7. Ecological Quality Objective for monitoring phytoplankton indicator species (from the Bergen Declaration, 2002).

Ecological quality element	Ecological quality objective
(r) Phytoplankton indicator species for eutrophication	• Region/area - specific phytoplankton eutrophication indicator species should remain below respective nuisance and/or toxic elevated levels (and increased duration)

The presence of certain species of phytoplankton in a given area may be indicative of eutrophication concerns but due to the dynamic nature of the plankton communities, and in many areas the relative lack of consistent data, it is not yet possible to fully use this factor in the assessment. Where good data exist, it is possible to provide an overall description of the community, and how it changes in the growing season, as well as information about the presence and levels of potentially nuisance and toxic species. There are no readily applicable standards.

The Continuous Plankton Recorder Survey can provide useful information over a long time period for many areas. In particular, the relative abundance of diatoms and flagellates in the phytoplankton community may be used as an indicator of change and if the change favours flagellates this may be deemed undesirable because of consequences for the food web. However, these changes may be the result of wider regional climatic change rather than the consequence of nutrient input.

The seasonal cycle of phytoplankton in the North Sea usually consists of a spring bloom dominated by diatoms, a summer period during which biomass is generally lower and production is dominated by flagellates, followed, in some areas, by an autumn bloom (Reid *et al.*, 1990; Gowen *et al.*1995). The Continuous Plankton Recorder (CPR) Survey has shown some significant changes over time.

In the southern North Sea, for example, large spring and autumn diatom blooms were typical from 1958 to 1965 (Fig. 6). After 1966 the autumn diatom bloom declined significantly while the overall growth season extended. It is unclear whether this change is linked to anthropogenic

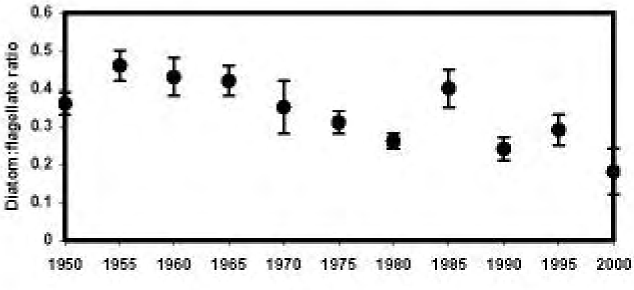

Figure 6. Growing season diatom:flagellate ratios for the offshore southern North Sea from 1950 to 2000.

nutrient inputs or to changes in the transport of Atlantic water into the North Sea in response to climatic shifts.

Mean (growing season) diatom to flagellate ratios reflects the change described above. It would be difficult to conclude whether this apparent change is the result of nutrient input or to wider scale regional changes in response to climatic forcing. The nutrient data (covering a shorter time period) suggests that there has been little change in nutrient concentration though it should be noted that there is a tendency to higher N:Si ratios in 1990's.

In terms of the ICES criteria for good indicators of ecological quality, the use of phytoplankton indicator species as an EcoQO (Table 8) is relatively easy to understand where the impacts of these species may be observed (*e.g.* due to colour changes, foaming on beaches, or noxious odours). In general, the concept is complex and not easy to understand. The growth of indicator species has not been shown to be responsive primarily to human activities. Except in specific cases, it is difficult to demonstrate sensitivity to the management of nutrient inputs, or linkages in space and time to the availability of anthropogenic nutrients.

Indicator species are easy to measure with a low error rate but require considerable effort, and are not routinely measured over a large proportion of the area over which the EcoQO is to be applied. At present, the main limitation to the use of this EcoQO is the availability of data for the realistic setting of objectives, particularly on a regional basis.

Table 8. Evaluation of the EcoQ for phytoplankton indicator species against those features considered to be qualities of good EcoQOs. Y = Yes, M = Moderate, N = No.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
Phytoplankton indicator species	Y and N	N (in general) Y (in specific cases)	N (in general) Y (in specific cases)	N	Y	Y	N

5.4. Degree of oxygen deficiency

Table 9. Ecological Quality Objective for monitoring the degree of oxygen deficiency (from the Bergen Declaration, 2002).

Ecological quality element	Ecological quality objective
(u) Oxygen	• Oxygen concentration, decreased as an indirect effect of nutrient enrichment, should remain above region-specific oxygen deficiency levels, ranging from 4-6 mg oxygen per liter

Decomposition of excess primary production (and biomass) which accumulates in response to nutrient enrichment may result in the development of hypoxic conditions in the water column, or near the bottom. These low oxygen concentrations may, in turn, result in changes in fish behaviour or kills in zoobenthos and/or fish species. These problems are exacerbated in areas subject to organic enrichment.

OSPAR uses dissolved oxygen deficiency as an assessment parameter, with 4 mg l^{-1} as the limit below which there may be fish death or prevention of passage of fish movement. However, concentration alone is insufficient to describe properly the environmental effect as concentration of dissolved oxygen naturally varies with temperature and salinity. Most data available as % saturation, although they are presumably available in terms of mg/l.

Relatively few data are available on oxygen concentrations around the UK. From the first application of the OSPAR Comprehensive procedure, there was no evidence of significant depletion of dissolved oxygen (e.g. Fig. 7). Levels of supersaturation generally reflect significant plant growth during the growing season. Howarth *et al.* (1994) provide a good summary for the southern North Sea which is supported by subsequent monitoring programmes.

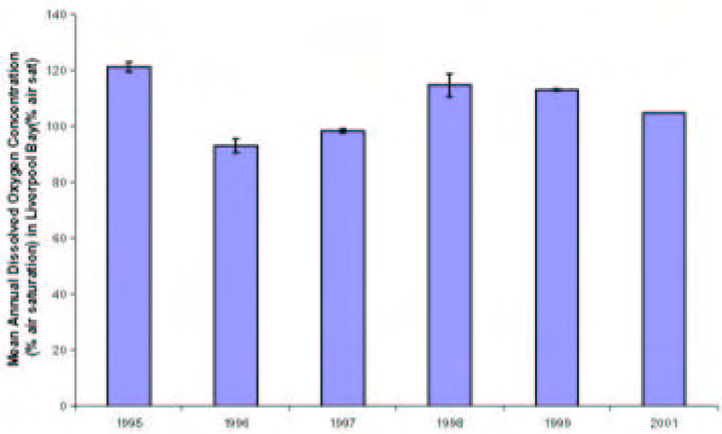

Figure 7. Oxygen concentration (% air saturation) for Mersey Estuarine Area from 1995 - 2001.

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In terms of the ICES criteria for good indicators of ecological quality, the use of oxygen as an EcoQO (Table 10) is easy to understand. It is, however, difficult to demonstrate sensitivity to the management of nutrient inputs, or linkages in space and time to the availability of nutrients. Oxygen concentrations are easy to measure with a low error rate but require considerable effort, and are not routinely measured over a large proportion of the area over which the EcoQO is to be applied. At present, the main limitation to the use of this EcoQO is the availability of data for the realistic setting of objectives, particularly on a regional basis.

Table 10. Evaluation of the EcoQ for oxygen against those features considered to be qualities of good EcoQOs. Y = Yes, M = Moderate, N = No.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
Oxygen	Y	N	N	N	Y	Y	N

5.5. Changes in zoobenthos

Table 11. Ecological Quality Objective for monitoring changes in zoobenthos (from the Bergen Declaration, 2002).

Ecological quality element	Ecological quality objective
(m) Changes/kills in zoobenthos in relation to eutrophication	• There should be no kills in benthic animal species as a result of oxygen deficiency and/or toxic phytoplankton species.

Oxygen deficiency and/or increased abundance of toxic phytoplankton species in the water column or near the seabed have been shown, in numerous studies in Europe and the USA, to result in changes in benthic communities due to increased mortality of those species sensitive to oxygen concentrations or algal toxins. Long term changes in the biomass and species composition of the benthos may indicate sustained organic enrichment, particularly in the vicinity of specific sewage/industrial discharges. An example of the sensitivity of the benthos to subtle changes in sediment quality is provided by a study of the effects of sewage-sludge disposal and its aftermath off the Tyne (NE England, Fig. 8 and Rees *et al.*, 2003). This study employed quantitative criteria for determining the acceptability of observed changes, which were derived from an empirical model describing the effects on the benthos of organic enrichment (Pearson and Rosenberg, 1978). For example, ratios of abundance for the disposal site (DG) and the southern reference site (REFS) relative to an 'Action Point' for acceptable change indicate that the activity was in compliance for the duration of the disposal activity. Ratios significantly higher than 0 indicate marginal enrichment throughout the disposal period. In the period following cessation, values decline to near-equality. This approach has certain similarities with the goal of the EcoQO approach.

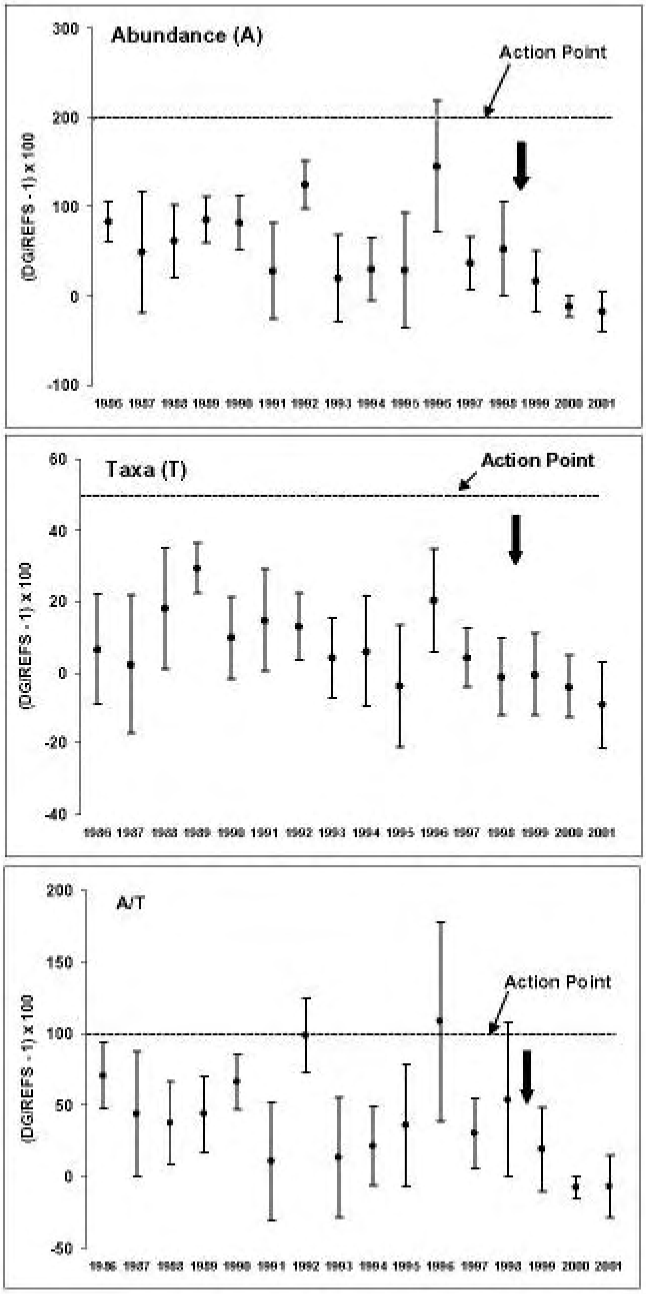

Figure 8. Means with 95% bootstrapped confidence limits for pairwise comparisons of univariate measures at the Tyne sewage-sludge disposal site (DG) and southern reference site (REFS). 'Action Points' denote upper limits for acceptable change. Vertical arrows indicate the time of cessation of sewage-sludge disposal (1998).

There are few recent examples from the OSPAR regions of the UK which indicate death of benthic animals associated with oxygen deficiency or algal toxicity. However, in the former case, there are well-documented examples of changes in the biota associated with historical declines in water quality in certain urbanised/industrialised estuaries, such as the Tyne, Tees and Thames. Investments in sewerage and sewage treatment facilities, along with improvements in industrial effluent quality, have done much to reverse these historical problems. Offshore, long term changes in zoobenthos have been detected (Clark and Frid, 2001, Kroncke and Knust, 1995) but few studies have been able to provide unequivocal evidence of a link with the consequences of nutrient enrichment.

For the stated EcoQO (above), all criteria are easily met since all that is required is the detection of gross effects ('kills'). We advocate a second objective, namely that there should be no unacceptable trends in benthic communities in response to the end products of incipient nutrient enrichment. In the latter case, in terms of the ICES criteria for good indicators of ecological quality, the use of zoobenthos as an EcoQO (Table 12) is easy to understand. It is, however, difficult to demonstrate sensitivity to the management of nutrient inputs, or linkages in space and time to the availability of nutrients. Abundances and species composition of benthic animals are relatively easy to measure with a low error rate, but this requires considerable monitoring effort, and is not routinely done over a large proportion of the area over which the EcoQO is to be applied. Nevertheless, monitoring commitments of a number of North Sea states over the last 10 years or so are beginning to generate consistent, quality-controlled trend data over relatively long time-scales and are therefore increasingly 'fit for purpose' in the present context. Examples include the UK's National Marine Monitoring Programme (NMMP) and the Dutch national monitoring programme (Daan and Mulder, 2003). On a North Sea–wide scale, an ongoing evaluation of the current status of benthic communities, and any changes since an earlier (1986) ICES survey, is also notable (see ICES website). At present, the main limitation to the use of this EcoQO is the availability of site- or habitat- specific cause/effect data for the realistic setting of objectives.

Table 12. Evaluation of the EcoQ for changes in zoobenthos against those features considered to be qualities of good EcoQOs. Y = Yes, M = Moderate, N = No. For an EcoQO based on kills in benthic animal species, all responses are Yes.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
i. Zoobenthos Changes	Y	Y (using predictive models) N	N (in general: risk of confound-ing subtle influences)	Y (with sound sampling design) N	Y	Y (uniform environme nts) N (patchy environ-ments)	Y (for some areas) N (infor-mation is patchy)
ii. Zoobenthos kills	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**

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6. CONCLUSIONS

Evaluations of the five EcoQOs for assessing risks and impacts of eutrophication are summarised in Table 13. In general, the indicators are easy to understand, but it is not always easy to demonstrate the cause and effect relationships in response to manageable human activities. Similarly, monitoring of the nutrients and eutrophication effects is generally feasible and in place (*e.g.* through OSPAR and various directives). Adequate time-series of data are available for the setting of reliable reference points in select areas but, in general, insufficient long-term data are available for the setting of reference points on a regional basis.

Detailed evaluations of the five agreed Ecological Quality elements suggest that the best EcoQO (in terms of the ICES criteria) is the concentration of winter nutrients. This is particularly true for coastal environments, where it is feasible that all of the ICES can be met. For offshore waters, it is less likely that all the criteria will be met, as nutrient concentrations are primarily responsive to other processes (such as hydrography) and not directly to human activity.

Concentrations of phytoplankton chlorophyll *a* also appear to be a good indicator in environments which are susceptible to nutrient enrichment (*e.g.* clear coastal water). In water bodies which are less susceptible to the impacts of nutrient enrichment, this EcoQO may not meet any of the criteria for demonstrating cause and effect relationships. Reduced susceptibility may be due to factors which limit or control phytoplankton growth, for example light, advective losses and grazing pressure.

Detailed evaluation of phytoplankton indicator species as an Ecological Quality element suggested that this EcoQO does not meet sufficient ICES criteria to be considered a good indicator. In specific cases where human activities are clearly evident, it may be easy to demonstrate localised cause and effect relationships between nuisance/toxic species and human activity, but on a broader (*e.g.* regional) scale this is not feasible. Indicator species are easy to monitor, but relatively few data sets are available for regional analyses.

Preliminary analysis of available data on oxygen concentrations suggested that this EcoQO also fails to meet sufficient ICES criteria to be considered a good indicator. In specific areas, it may be easy to demonstrate cause and effect relationships, but on a broader/regional scale this is less feasible. Oxygen concentrations are easy to monitor and measure, but relatively few time-series data are available.

The EcoQO for zoobenthos (or fish) kills meets all the ICES criteria for a good indicator, but an EcoQO based on changes in benthic communities is subject to the same limitations as those described for phytoplankton indicator species and oxygen.

Consideration of specific examples and the limitations of each EcoQO suggests that for assessing eutrophication effects, greater emphasis may need to be placed on:

(a) Defining seasons and seasonal effects of nutrient inputs and seasonal responses of the phytoplankton community. For example, during the entire phytoplankton growth season (summer) the availability of nutrients on an ongoing basis may be as important, if not more important, than the winter nutrient concentrations which fuel the initial spring bloom but not subsequent blooms. Within any given region, *e.g.* the southern North Sea, temporal variability in physical factors plays an important role in limiting or controlling the biological response to nutrient enrichment. This has been incorporated into the current EcoQOs, which propose season-specific reference levels for nutrients and phytoplankton chlorophyll *a*, albeit loosely.

(b) Assessing the natural susceptibility of different water bodies. Numerous factors determine the response of different water bodies to nutrient enrichment, including physical processes (such as water column stratification and light availability), the hydro-dynamic regime (including vertical and horizontal advection), and biological processes (such as rates of phytoplankton growth, zooplankton grazing, and filter-feeding by benthic organisms and fish).

(c) Distinguishing between coastal and offshore environments. Spatial variability plays a critical role in determining susceptibility to nutrient enrichment, both alongshore and in near-shore *vs* offshore waters. Nutrient inputs and biological responses in coastal waters adjacent to river mouths or sewage outlets, for example, are likely to be different from those in coastal waters which are not strongly influenced by river run-off or point sources. Similarly, nutrient inputs and biological responses in coastal waters are likely to be significantly different from those in offshore waters, where the influence of freshwater inputs is weakest and the temporal variability in hydrographic and biological processes is high. Clearly defined local or salinity-specific reference levels may therefore also be essential for sensible application of the EcoQOs. To some extent, these have been incorporated into the current EcoQOs, but insufficient emphasis has been placed on this point. Certainly, the suitability of the EcoQOs based on the ICES criteria (Table 2) is far more difficult to evaluate for offshore waters than for coastal waters.

(d) Development of longer (>20 y) time-series of data. These are essential for assessing the significance of anthropogenic inputs by quantifying the natural variability in different water bodies, and for setting reliable thresholds.

Other potential elements to be considered for EcoQOs include indices of greenness from the Continuous Plankton Recorder and the "Phytoplankton Trophic Index" currently under development through CEFAS, although it is not clear at this stage how these indicators could be applied.

Table 13. Evaluation of EcoQ metrics against those features considered to be qualities of good EcoQOs. Fully shaded rectangles fully match the criterion, partially shaded rectangles do not fully match the criterion and limitations are discussed in the section indicated. Y = Yes, M = Moderate, N = No.

Ecological quality element	a) Understandable	b) Sensitive	c) Linked	d) Responsive	e) Low error	f) Measurable	g) Time series
(t) Winter nutrient concentrations (DIN and DIP)	Y	Y	Y	Y (coastal areas) N (offshore areas)	Y	Y	Y (critical areas) N (other areas)
(q) Phytoplankton chlorophyll *a*	Y	Y (clear coastal) N (turbid coastal and offshore)	Y (no other limiting factors) N (limiting or cont-rolling factors present)	Y (no other limiting factors) N (limiting or cont-rolling factors present)	Y	Y	Y (critical areas) N (other areas)
(r) Phytoplankton indicator species	Y (obvious impacts) N (in general)	N (in general) Y (in specific cases)	N (in general) Y (in specific cases)	N	Y	Y	N
(u) Oxygen	Y	N	N	N	Y	Y	N
(m) i. Zoobenthos Changes	Y	Y (using predictiv e models) N	N (in general: risk of confound -ing subtle influence s)	Y (with sound sampling design) N	Y	Y (uniform environme nts) N (patchy environ-ments)	Y (for some areas) N (infor-mation is patchy)
(m) ii. Zoobenthos kills	Y	Y	Y	Y	Y	Y	Y

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Directives

Water Framework Directive, WFD (2000/60/EC)

Habitats Directive, HD (92/43/EEC)

Urban Waste Water Treatment Directive, UWWTD (1991)

Annex 10 Windfarm-related Research

A questionnaire for the comparison of national requirements has been filled out by all participating national representatives present at the 2004 BEWG meeting. No information from Norway, Denmark, France or from North America was available. The results are summarised in the included table.

Based on this table, a discussion resulted in several preliminary **recommendations** from the BEWG:

The permission procedures should always include public participation.

An EIA is necessary including an assessment of benthic communities. This should be based on recent data including sediment structure, epifauna (beam trawl/dredge, video and/or diver assisted surveys), infauna, fouling on piles and foundations and macrophytobenthos if present. Details should formulated similar to the existing German and UK guidelines (see links below).

Trophic relations with other ecosystem compartments (e.g., fish/birds) should be taken into account.

The period of investigations should cover the whole time span from a baseline survey, the construction period, 3 to 5 years of the operational period and finally the demolition period. The inclusion of appropriate reference sites is essential.

All collected data should be nationally centrally collected and stored. The availability of the data (possibly after permission of the construction) for scientifc purposes would be very desirable.

Ecologically valuable biotopes (e.g., Natura 2000) should be avoided.

Possible constructual measures to mitigate negative environmental effects should be explored and applied.

The BEWG strongly suggests European harmonisation of the regulations for environmental assessments of offshore wind farms.

Links:

www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/index.jsp (German-EIA-standards)

www.fino-offshore.de (Research on offshore platform Germany)

www.org.dti.gov.uk/offshore-wind-sea/index.htm (UK wide regulations)

www.cefas.co.uk/publications/files/windfarm%2Dguidance.pdf (UK windfarm-guidance)

www.cefas.co.uk/renewables/r2eiaworkshop/default.htm (Windfarm related workshop)

Questions addressed during windfarm planning	UK	S	NL	D	NO	BE	ES	DK	F	Preliminary BEWG recommendations
Public participation during permission?	x	x	x	x		x	x			**Yes**
Separate pilot / expansion phases?	x	-	-	x		x	?			**?**
EIA necessary?	x	x	x	x		x	x			**Yes**
- benthos included?	x	x	x	x		x	x			**Yes**
Studied compartments:						only existing data				**Recent data to be retrieved!**
Sediment and habitat structure and their dynamics using side scan sonar and sediment sampling	x	x, - SSS	x, - SSS	x		"	x			**Sediments mostly yes, SSS ?**
Epifauna (using video equipment and beam trawl/dredge or divers)	x, - V	x	x, - V	x		"	x			**Yes**
Infauna (using grab sampling)	x	?	x	x		"	x			**Yes**
Fouling on piles and foundations	x	?	x	x		"	x			**Occasionally**
Macrophytobenthos, if present	x	?	(x)	x		"	x			**Occasionally ?**
Trophic relations with other ecosystem compartments (e.g., fish/birds)?	x	-	?	?+		(x)	x			**???**
Period of investigations [years]?										
Baseline survey	single	x	1-2	2		x	x			**Several years of monitoring**
Construction period	x	x	x	1-2		x	x			
Operational period	3-5	x	x	3-5		x	x			
Demolition period	x			-						**Needed!**
Reference sites included?	x	-	x	x		x ?	x			**Essential**
Central data collection & storage?	?	-	x	x		?	no			**Yes**
Availability of data? (after permission)	(x)	(x)	?	(x)		?	(x)			**(x)**
General recommendations given?										
Avoid sedimentologically unsuited areas, e.g., mud	?			(x)		no	?			**?**
Avoid ecologically valuable biotopes (Natura 2000)	x	x	x	x ?		x	?			**Yes, if identified**
Constructual measures to mitigate negative environmental effects	x	x	x	x		x	x			**Yes**
Recommendations on shape of the farm (liniear vs. cluster)	?	-	?	x		?	?			**?**
European harmonisation		X								**Necessary!**
Avoid wind farms in coastal waters (12nm-zone)		?		(x)						**?**

Annex 11 Abstract of The response of hyperbenthos, infauna, and foraminifera to hypoxia in fjord-basins: Searching for indicator organisms and controlling environmental factors

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A unique long time series of oxygen measurements exists from several Skagerrak fjords as part of an ongoing monitoring program. It reveals a clear decline after 1975 due to eutrophication. This is a large scale experiment that offers a possibility to get detailed observations on how the bottom fauna is affected. Today indicators of eutrophication are based mainly on infauna but, the fauna living at the sediment-water interface, the 'hyperbenthos', is assumed to be particularly sensitive, however, the detailed knowledge of the response of this fauna group is sparse.

This project will compare the 'hyperbenthos', macro infauna, and foraminiferans, together with environmental factors, of 11 sill-basins that are part of the unique monitoring program. Because the historical levels of oxygen in the bottom water at these localities differs a comparison of the bottom fauna will produce detailed information on responses to hypoxia.

In addition, a documentation of this fauna will provide a baseline for the monitoring of coastal biodiversity. Furthermore, it will ad data that can connect the earlier observed correlation of both carbon-flux and fauna-diversity with fjord topography and improve the existing carbon-flux sill-depth model by including a fauna component

Moreover, the fjords which naturally have experienced repeated situations of hypoxia will be identified by using the foraminiferans in sediment cores as an archive of historical bottom conditions.

Deep-water corals in Atlantic Canada: A summary of results from the ESRF-funded research program on deep-water corals conducted at BIO from 2001 to 2003.

Lene Buhl-Mortensen and Pål B. Mortensen, Institute of Marine Research, Bergen, Norway

Deep-water corals have been known from around the world for many years, but still, there are large gaps in the knowledge about their distribution and biology.

There is increased concern that human activities in deep waters seriously affect the coral habitat. This presentation provides a summery of a research on deep-water coral ecosystems off Atlantic Canada carried out during 3 years (2001-2003) research project at the Bedford Institute of Oceanography, Canada. The project covered different aspects such as distribution, growth and associated fauna. Deep-water corals represent a varied habitat for other organisms. More than 80 invertebrate species have been found on gorgonian corals off Nova Scotia. This number is smaller than for reef-building deepwater corals, but it is comparable with tropical gorgonian corals. Several new species were recorded from the area and two crustacean species were new to science. One of these, a parasitic copepod, constitutes the new genus *Gorgonophilus*. In autumn 2003 the first documented *Lophelia* reef in Atlantic Canada was discovered at the Stone Fence in the mouth of the Laurentian Channel. The results from the project have been crucial for declaring two deep-water protection areas (Northeast Channel and The Gully). The process of designing a protected area around the Stone Fence reed is ongoing.