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Report of the Benthos Ecology Working Group (BEWG)

19–22 April 2005

Copenhagen, Denmark

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Conseil International pour l'Exploration de la Mer

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Executive Summary

The Benthos Ecology Working Group (BEWG) met from 19–22 April 2005 at the ICES Headquarters in Copenhagen, Denmark. 21 participants from nine countries attended the meeting, many of which new and young attendees, re-juvenated the group. Heye Rumohr, Germany, acted as Chair, Hans Hillewaert was editing Rapporteur assisted by daily Rapporteurs.

The agenda comprised reports from ICES meetings and other meetings of interest as well as reports of on-going cooperative studies and other studies on benthic ecology questions relevant to ICES. This included a first-hand report from M. Tasker, Chair of WGDEC, on the recent meeting of this newly established Working Group.

In order to contribute to the REGNS process, available metadata about long-term time-series and long-term comparisons of benthic communities in the North Sea were compiled. Metadata about long-term benthos studies, which were previously compiled within the German project SYCON, were used as a starting point. The metadata set was extended and modified during this workshop. The following benthic categories were considered: soft bottom endobenthos, soft bottom epibenthos, and hard bottom epibenthos. Due to the importance of historical data for long-term comparisons, an additional table concerning the oldest available benthos datasets in the North Sea was added.

There was not enough experience of the current framework for environmental risk assessment within the BEWG of the long term effects of oil pollution. However, a preliminary list of recommendations for the assessment of the long-term effects of oil pollution was provided.

BEWG recognized the challenge of matching the aspirational need for a small suite of widely applicable benthic biological indicators with the typical local sources of evidence for determining effectiveness. Thus the utility of an individual indicator may vary with locality (especially habitat type) and the activity under investigation so that, in practice, a larger ‘toolkit’ of measures was required to meet different circumstances. No universally applicable measure was yet available. BEWG recognises the need to further develop this work to actually list those indicators available based on the published case studies as a meta-analysis in a future meeting. Our aim is to recommend that both indicators of state and those that identify cause-effect relationships with human activities (performance indicators) can be recommended. We also emphasize the need to test the applicability of different indicators at local, regional and global levels in order to aid the development of appropriate monitoring programmes.

Despite recent efforts to explore the fauna and habitats on the mid-Atlantic Ridge, rather few areas of the mid-Atlantic Ridge have been mapped in detail. The limited areas that have been explored by Remotely Operated Vehicles (ROVs) show a vulnerable habitat and a diverse sessile fauna, not unlike those found in other waters that have similar habitats and which have been explored more fully. However, the level of knowledge of the MAR or other Atlantic seamounts is not sufficient to determine what areas are most vulnerable or have been most damaged by trawling

Investigations by the wind farm developers on ecological effects involve a high sampling effort and are quite expensive. For economic reasons, these investigations will mostly be at a minimum required effort. To ensure a scientifically sound result, a minimum standard should be established by all national regulating bodies. Especially in areas where proposed wind farms touch national borders, an international harmonization is necessary to make comparison of results possible and to assess cumulative effects, which do not stop at national borders. To allow thorough assessment of effects across various regions and habitats, all data produced in environmental studies should be collected centrally and consequently be available for scientific purposes.

A distinction between natural spatial variation and wind farm effects will require multiple reference areas. This may also be achieved by a combined analysis of data from several projects, combining data from all reference areas to estimate natural variation. This will require a central data collection and a common minimum standard for the data produced to allow comparisons between studies. To allow a differentiation of fishing effects and direct effects of offshore wind farm installations, at least some reference areas without fishing influence will be needed. The group decided to tackle environmental implications from energy generation from wind, waves and tidal currents under one headline.

1 Opening and local organisation

The Chair, Heye Rumohr, opened the meeting and welcomed the participants. Vivian Piil, ICES Science Secretary also gave some practical information about domestic issues. A list of participants is included at Annex 1.

Apologies were received from L. Watling, Alf Norkko, M. Robertson, J. Davies, G. Duineveld, J. Kotta, J. van Dalfsen, P. Archambault (Can), K. Moo. Some e-mails are not known. (K. Essink, Portuguese members).

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. H. Hillewaert was appointed Editorial Rapporteur; daily Rapporteurs were H. Hillewaert, K. Howell, I. Moulaert, H. Kautsky, and A. Schroeder.

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 agreed unanimously and is attached at Annex 3.

3 Report on ICES meetings and other meetings of interest

3.1 ASC, Vigo 10/2004

H. Rumohr reported briefly on the ASC in Vigo last autumn. He highlighted the very high number of participants and the professional management even as the meeting and the business meetings took place in two buildings. S. Birchenough mentioned the habitat mapping Theme Session as being highly relevant to the work of BEWG.

3.2 MHC, Vigo 2004

Again, a low attendance of members and WG chairs and consequently few reports on current work led to some strong conclusions about the viability of the Science Committees under present arrangements, H. Rumohr reported. This point will be taken up again in the ICES Consultative Committee.

3.3 ACE, Vigo 2004

The meeting of ACE (Advisory Committee on Ecosystems), being one of the three advisory committees, was briefly introduced by H. Rumohr. J. Nørrevang explained the role and the workings of the committee.

3.4 ACME, Vigo 2004

H. Rumohr also briefly reported on the ACME (Advisory Committee on the Marine Environment) meeting. It was the last session chaired by S. Carlberg. P. Keiser, Canada, was elected new Chair.

3.5 SGQAE/SGQAB, Copenhagen 2005

K. Howell reported on SGQAE/SGQAB.

There was concern shown about the ICES database, which was at present not perceived to contain enough biological data to be useful for, e.g., OSPAR, leading OSPAR to seek other datasets that have not gone through any QA procedure.

Adoption of ERMS coding instead of ITIS was advised. It was noted that different coding systems could be inter-connected relatively easily using computer programs. However it was also important that systems used up-to-date taxonomic information.

There was concern that certain OSPAR standards as specified in the JAMP procedures (e.g., on benthos and chlorophyll) didn't meet present QA requirements.

3.6 WGMHM

D. Connor, Chair of WGMHM contacted H.Rumohr by mail. The WGMHM suggested a 1–2-day joint meeting with BEWG in Galway next year. WGMHM had concluded that production of a habitat map for the North Sea was beyond their capabilities in view of the significant resource requirements. However, they would offer guidance and advice on frameworks for producing habitat maps to others engaged in this activity. WGMHM was keen to establish 'user' requirements and problems from other ICES WGs, including BEWG. They need the cooperation and data input by BEWG. D. Connor’s mail is at Annex 4.

3.7 WGEXT, San Sebastian 2005

H. Hillewaert gave a brief account on the activities of the WGEXT.

3.8 MARBEF, Porto 2005

H. Rees and H. Rumohr reported on the Annual General Assembly of MARBEF in Porto.

This was the first General Assembly, following the well-attended start-up event in March 2004, with a good attendance of about 100 participants, including high-ranked representatives from the EU (Brussels), EEA and ICES. The meeting was dominated by the reporting of progress and administrative matters. This was inevitable given the complexity and recent origin of the network. The likelihood is that there will be greater scientific emphasis in the coming years.

The EU Commission have indicated that MARBEF could, and indeed should, extend beyond the life expectancy forecast at the conception of the project.

There was unanimous support for a proposal to ‘top-slice’ the Phase 2 MARBEF budget to generate about 500, 000 euros to fund more substantive bids in support of the Responsive Mode Projects.

Overall, this was a very positive event, which provided clear evidence of the developing strategic importance of the MARBEF initiative. A good example is the large number of new institutes seeking affiliated status, though it was emphasised that the limited funds available would not extend beyond the 56 ‘core’ participants.

Several members of BEWG are involved in the various Themes. Part of the project involves QA and ‘outreach’. MARBEF is perceived as being an important strategic initiative. The well kept webpage www.marbef.org provides details of the project.

S. Birchenough mentioned a range of collaborative initiatives that are being set up through MARBEF, in keeping with its objectives.

3.9 WGECO, Copenhagen 2005

WGECO had its session parallel to the BEWG meeting, allowing some informal contacts. L. Robinson (FRS, Aberdeen and a member of WGECO) reported on their work on indicators to a sub-group of the BEWG on 20 April.

Leonie Robinson reported on the recent meeting in Copenhagen (12–19 April 2005). The terms of reference of most relevance to the Benthic Ecology Working Group were:

> c) Review and report on the available data contributions made to the REGNS process by other WGs and describe their value to an integrated assessment, in time for the REGNS workshop in May 2005;
>
> d) Review and report on the analytical work on ecosystem indicators and objectives undertaken during past meetings of WGECO, and evaluate their potential roles in supporting the new ICES advisory capacity being developed in ToRs a) and b), and;
>
>> (i) In the context of fisheries effects on the ecosystem, continue the identification of fish and invertebrate taxa which are appropriate to use as indicators of habitat quality. Criteria should include those used in past WGECO meetings and adopted by ACE.

In relation to ToR (c), WGECO developed an approach for prioritising the requirement for variables within a REGNS Integrated Assessment. This approach recognised the need for two matrices, one which associates individual ecosystem components (e.g., benthos, fish) with specific mechanisms of pressure (e.g., loss of substratum, smothering), and another which links those mechanisms to the activities which are responsible for them (e.g., fisheries, dredging, aggregate extraction). The benefit of this approach is that links between ecosystem components and pressures caused by human activities can be represented by sets of indicators. WGECO recognised the need for focusing parts of a future meeting on the comprehensive evaluation of indicators which fit into the Integrated Assessment matrix. WGECO would benefit from the advice of experts in other WGs, including BEWG, on the development of the matrices, and on the provision of potential indicators for the Integrated Assessment.

In relation to ToR (d), WGECO reviewed the work undertaken by the group in developing frameworks and analyses for evaluating the use of indicators within the ICES advisory role and more generally, in supporting the developing European Marine Strategy. It was identified that indicators are required to provide information on the state of the ecosystem, the extent and intensity of human impacts and the progress of management in relation to objectives. Indicators may include those based on single species, community or ecosystem level metrics. WGECO provided criteria and frameworks for selecting and evaluating indicators and also commented on the need to extend the developing ICES advisory capacity for fish stock management, to include indicators of valued ecosystem components, which would include the benthos.

In relation to the specific request to continue the identification of fish and invertebrate taxa which are appropriate to use as indicators of habitat quality (ToR d (i)), WGECO carried out a review and analysis of potential taxa, with assistance from members of the ICES Study Group on the North Sea Benthos Project 2000. The approach was based on the formulation of a multispecies index of habitat quality, but unfortunately WGECO were unable to find any combinations of species that would meet all criteria to assess habitat quality in offshore sedimentary environments. Following the analysis, WGECO remained unconvinced of their ability to develop a useful, scientifically defined, measure of marine habitat quality, or the utility of this over and above direct measures of impact in ecosystem based management.

In relation to the ongoing development of performance indicators (i.e., those that show a close link between a component and a manageable human activity) in the EcoQO framework, WGECO note that ICES have recommended that OSPAR consider dropping the EcoQ element (p) Density of opportunistic species. This follows the work of a number of WGs (e.g., WGECO, SGSOBS, BEWG) which has demonstrated that these species are ubiquitous and provide no close link to human impacting activities (ACE report – ICES, 2004). A more useful formulation of EcoQ element (o), on the density of sensitive (e.g., fragile) species, would make use of a limited selection of sentinel species rather than extensive lists of such species. This could be made operational, at least for the physical impacts of towed fishing gears on the benthos. This would require, amongst others, a further examination of the behaviour of metrics on a range of different scales, and the development of a set of criteria for the rational selection of sensitive species.

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ICES. 2004. Report of the ICES Advisory Committee on Fishery Management and the ICES Advisory Committee on Ecosystems. ICES Advise, 1(2): 1544 pp.

3.10 WGDEC, Copenhagen 2005

The Chair of the newly-created WGDEC, M. Tasker, reported on the latest meeting of the group and presented a final draft of the WG report. Ecological requests to look at areas of corals (Rockall and Hatton Banks) and to look at seamounts on behalf of OSPAR were discussed. Part of the report was used for the TOR c on Seamounts.

Evaluation and reporting of the sensitivity of deep-water habitats to anthropogenic disturbances was commenced.

3.10.1 Seamounts

Seamounts (defined as being at least 1000 m high from the seabed) in the OSPAR area had been mapped through JNCC on behalf of OSPAR as far as present information allowed, since few studies about them exist. Not all seamounts appear to be important for conservation purposes. A classification (terminology) overhaul may be necessary.

3.10.2 Cold-water corals on Rockall and Hatton Banks

Maps were produced, combining French and UK data on deep-water corals. Information from scientific sources, interviews with fishermen and VMS data from 2002 showing areas with fishing intensity, were combined to get a further idea of distribution of corals and their potential vulnerability to damage by fishing gears. The aim is to find areas appropriate for closure to protect cold-water corals. Several management options combining different sets of the data were produced.

3.11 IOC-UNESCO Workshop on Benthic Indicators, Sardinia 2004

A. Borja, H. Rees and H. Rumohr were invited attendees at an IOC-UNESCO sponsored workshop on benthic indicators. An editorial synthesis and highlights are attached at Annex 5. A book of abstracts was available for consultation by BEWG members.

3.12 Helgoland workshop, 2005

H. Kautsky reported. Methods were compared for the study of hard substrates. Taxonomical issues were also discussed.

3.13 History of BEWG

H. Rumohr presented an updated PPT about the history of the BEWG since its installation in 1981. This presentation was especially for the many new BEWG members and focussed on the many work foci and long lasting efforts to consolidate the important role of this group within ICES. Recurring North Sea Benthos Sampling Programmes and their scientific evaluation used to be the central *raison d'être* of this group. This history of the Working Group is also displayed on the BEWG webpage www.dvz.be/bewg.

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

4.1 Co-operative studies

4.1.1 Catch efficiency of a standardized 2 m beam trawl (EPICATCH)

A Study by H. Reiss, I. Kröncke and S. Ehrich was presented by H. Reiss and is at Annex 6.

It was noted that epibenthic sampling will never be 100% efficient using 2-m trawls (or most other towed devices), and the problems of sampling mixed biotopes must also be recognised. The study could not address all the issues but was very useful in obtaining an estimate of the catch efficiency.

4.1.2 Long-term studies of the Barents Sea

Data have been fed into MARBEF by S. Dahle (Aquaplan/NIVA, Tromsø). The Institute of Marine Research in Bergen, Norway is trying to collate benthic data from the Barents Sea in collaboration with Russian colleagues.

4.1.3 Benthic monitoring in the Basque Country

A. Borja reported on benthic monitoring programmes for the evaluation of anthropogenic disturbances in the Basque Country.

Members noted the difficulty of comparing data from summer and winter sampling, which will separate through (e.g.) MDS analysis.

4.1.4 Wave energy installations and the impact on benthos fauna and flora

A. Borja reported on the environmental framework on wave energy utilization in Spain.

The necessity to follow up this topic in the BEWG was discussed. Research is going on in the UK, but there has been negative evaluation regarding wind farms. The group should take note of new developments and should be prepared to give advice when needed and asked for.

An overview of the presentation is given at Annex 7.

4.2 Benthos and fisheries

4.2.1 RESPONSE project

Presentation by A. Schröder.

Link: www.icm.csic.es/rec/projectes/response

K. Howell wondered how VMS was corrected for ships passing by (i.e., not fishing).

All vessels travelling at speeds greater than 8 knots were excluded, but some boats fish at 8.5 to 9 knots so the correction factor may have to be reconsidered.

Turbidity measurements also indicated likely peaks due to fishing activities.

A summary can be found at Annex 8.

4.2.2 Does the fauna in closed areas around production platforms in the southern North Sea reflect different fishing intensity?

M. Lavaleye reported.

There seems to be only a minor effect on *Corystes sp.* as opposed to significant disturbance-induced effects on *Upogebia* and *Callianassa*.

In situ respiration experiments are not involved in this project, but in other programs with benthic landers these techniques are applied. However, there are problems with fouling on these landers. Use of this equipment is also dependent on the availability of adequate funding.

Sidescan sonar was also used to find trawl tracks but without result.

A summary can be found at Annex 9.

4.3 Benthos of soft sediments

4.3.1 MAFCONS

L. Robinson reported on the ongoing work on the EC Fifth Framework project MAFCONS, which H. Reiss introduced to the group last year. Both sampling cruises in collaboration with the 2003 and 2004 Third Quarter IBTS surveys have now been completed by all partners. Epifaunal, infaunal and demersal fish samples have been collected using standardised methodologies. Both epifaunal and infaunal samples are being analysed to produce data on secondary production, and on species diversity and composition where possible. Currently empirical models developed by Brey (1990, 1999), Edgar (1990 a,b) and Tumbiolo and Downing (1994) are being explored with data from 2003, to examine the variability in estimating secondary production between different models. Size-class based methods to estimate secondary production, as developed by Jennings *et al.* (2002) are also being explored with epifaunal data, where individual biomass data is available. Initial analyses of the distribution of total biomass, total abundance and indices of species diversity for the epifaunal dataset suggest similar patterns to those recorded by Callaway *et al* (2002). Final analyses of epifaunal data will be undertaken this year and it will be possible to present results on the distribution of epifaunal and infaunal secondary production across the North Sea (and species diversity/composition of epifauna), to BEWG in 2006. FRS Marine Laboratory also extended the sampling to the North and west coasts of Scotland and epifaunal results from all west coast surveys will also be available in 2006.

Another major objective of MAFCONS is to develop indices of ecological disturbance based on fisheries effort statistics. Over the past year the international fishing effort database as originally developed by Jennings *et al.* (1999) has been updated to 2002. This gives total effort in hours fished per ICES rectangle for all demersal gears recorded by the UK, Germany, Norway and the Netherlands. Large-scale patterns in distribution have varied little over the past six years and are comparable with those from the 1990s. However, it is recognised that in trying to understand the relationships between fishing disturbance, secondary production, invertebrate and demersal fish diversity and species composition, knowledge of the microscale distribution of fishing effort within each ICES rectangle is very important. Microscale distribution data based on VMS records are becoming more available to research and MAFCONS will make use of all available VMS data to improve the development of indices of fishing disturbance. A spatially and temporally dynamic model of the mortality of benthic invertebrate taxa given a particular distribution and quantity of fishing effort is currently under development. This work will be in collaboration with colleagues from the EC Cost-Impact project, who updated the meta-analysis of studies on mortality of benthos subject to fisheries disturbance.

At the 2006 BEWG meeting it will be possible to report on the results of the analyses of secondary production, fisheries disturbance and species diversity across the North Sea and to the west of Scotland. It will also be possible to describe the modelling approaches currently being developed to explore the relationships between these parameters in the context of the overall management framework being developed in MAFCONS.

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H. Reiss reported on the small scale case study being undertaken by MAFCONS.

It is necessary to get a good understanding of the linkage between fishing disturbance and benthic diversity. The main spatial scale on which the studies of MAFCONS are based on is the ICES statistical rectangle scale in the North Sea. In order to investigate this linkage additionally at a different spatial scale, a case study within the framework of MAFCONS was started in 2004 by the German project partners. Data of the microscale distribution of fishing effort of the Netherlands and Germany are used to study the effect of fishing disturbance on the benthic communities on a spatial scale of 1 nm. Microscale fishing effort data were provided by the Netherlands Institute for Fisheries Research (RIVO) and the Institute for Sea Fisheries (ISH), Germany. The Netherlands effort data originate from the micro distribution project (1993–2000) and the Vessel Monitoring System (VMS: 2000–2002) with a spatial resolution of a 1 nm. Only part of the fleet was monitored. The German effort data originated from the VMS only, for nearly the whole German fleet in the period 2001 until 2003.

A standard area of the German Small-scale Bottom Trawl Survey (GSBTS) in the southern German Bight (Box A) and its vicinity (within ICES rectangle 37F7) was chosen as study area. The extension of study area is 15x15 nm subdivided into grid cells of 1x1 nm according to the microscale fishing effort data. In total 25 sampling stations were selected in regard to differences in fishing effort and sediment characteristics. At each of the 25 stations the infauna (Van Veen grab), the epifauna (2 m beam trawl) and the fish fauna (GOV) was sampled according to the standardized sampling protocol of MAFCONS.

The results of this case study will give an insight into the linkage between fishing disturbance and benthic communities on small scale and, thus, provide a separate fine scale model in combination with the main model based on the ICES statistical rectangle scale within MAFCONS.

4.3.2 HABMAP

L. Robinson reported on HABMAP.

Leonie Robinson reported on a new Scottish Executive funded project HABMAP to develop benthic habitat mapping methodology at FRS. This is a pilot project to run between April 2005 and 2007. The main objectives are:

- To classify seabed habitat in a series of small “intensive survey” boxes (3NM by 3NM) across the North Sea (approximately 20 sites) and west of Scotland (approximately 15 sites) using acoustic mapping techniques. Sediment and infaunal ground-truthing samples will be collected for calibration of the acoustic equipment.
- To determine how representative the habitat type and variability observed in the small intensive survey boxes is of the larger ICES rectangles, in which they are contained. This information could be useful in future large scale sampling designs for fish and benthos (e.g., as used in MAFCONS where one sample site is deemed representative of an entire ICES rectangle).

The methodology used in HABMAP is illustrated in Figure 4.3.2.1.

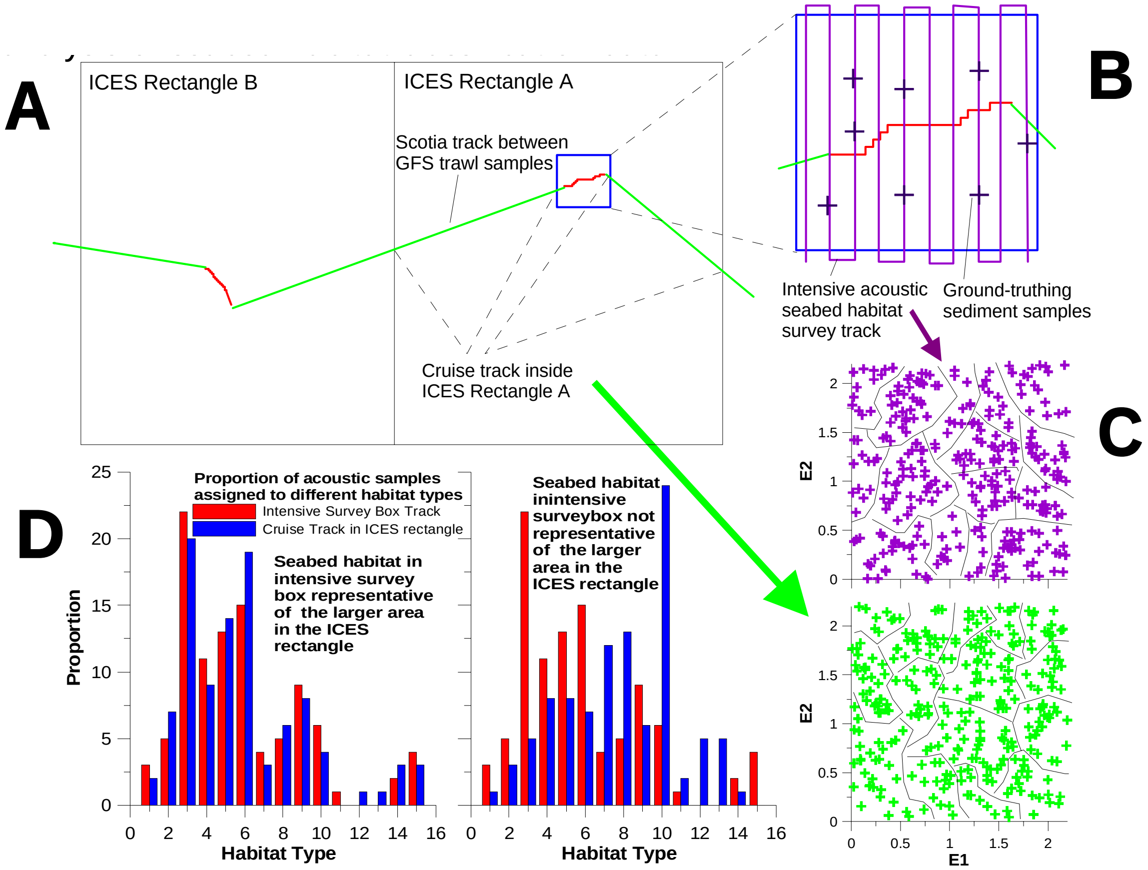

Figure 4.3.2.1: Schematic illustrating collection and analysis of seabed habitat classification data.

4.3.3 BWZee

Report attached (submitted by S. Degraer and edited by S. Derous) at Annex 10.

4.3.4 Benthic Infaunal Monitoring of the St Lucie Estuary and the Southern Indian River Lagoon

B. Tunberg reported on the new long term monitoring project financed by the South Florida Water Management District (SFWMD). This project is part of the Comprehensive Everglades Restoration Plan, and is being performed at the Smithsonian Marine Station, Fort Pierce in cooperation with Florida Department of Environmental Protection (FDEP). See Annex 11 for more information.

Link: www.evergladesplan.org

It was noted that the requirement to use NODC codes, is reasonable in the USA, assuming all species have already been coded. Historically there had been a problem in Europe due to the difficulty of getting new codes assigned for the range of species not encountered in the USA. The code is hierarchical unlike ITIS, its successor.

BEWG endorsed the proposed approach for monitoring, i.e., an overview sampling program with localised more detailed study, as required. The latter may require additional resources. Sampling is supposed to be quarterly but future recommendations based on the evidence from initial work may result in a reduced frequency.

A suggestion was made to take oxygen samples and investigate flushing of the system.

The infauna will be sampled using a 0.04 m² Ponar grab and a dredge will be used to investigate the epibiota. There are no long term data sets available for the area.

Dr. Rachor suggested consideration of a small (0.05 m²) Van Veen grab. It was noted that it works well in soft muddy sediment, but is not good for sand.

4.3.5 The response of hyperbenthos, infauna, and foraminifera to hypoxia in Fjord-Basins

L. Buhl-Mortensen reported.

Fjords on the Norwegian Skagerrak coast have experienced a decrease in oxygen during the last 30 years due to increased load of organic matter. Long time oxygen measurements exist for several of the fjords. This offers an opportunity to study the fauna in fjords that has different oxygen history to detect effects of hypoxia. The main goal is to document the response of different components of the bottom-fauna in sill-basins to increased carbon flux and the resulting reduced oxygen concentration and to establish an eutrophication index based on the sensitive fauna-components.

The benthos community was studied in 11 fjords representing three categories of hypoxia with minimum levels of O_2: < 2 ml/l; 2–3 ml/l; and > 3 ml/l, and with 3, 3, and 5 basins within the categories.

The infauna is still being analysed.

More than 50,000 hyperbenthic crustaceans representing 150 species were sorted and identified. There was a clear relation between species richness and oxygen minimum ($r = 0.97$). Number of species decreased from 48–56 in the well-oxygenated basins, to 22–32 in intermediate hypoxia, and 0–7 in the most hypoxic environment. Ostracoda, Isopoda and Tanaidacea dominated in numbers (41%, 20%, and 19%, respectively) in basins with oxygen > 3 ml/l, at oxygen levels < 2 ml/l the fauna was very poor and dominated by Cumacea (87%), and at oxygen levels between 2–3ml/l Amphipoda and Cumacea dominated (42% and 23% respectively). To identify fjords that historically have experienced low oxygen concentrations a retrospective study of the environmental conditions based on the foraminiferal fauna was undertaken. Sediments retrieved from vertical core samples from all basins were dated using radioactive tracer. The foraminifer *Stainforthia fusiformis* was a good indicator for the historic onset of and indicated that some of the basins have experienced hypoxia in the early 1900.

4.4 Benthos of hard substrates

4.4.1 BeoFINO

Reported by A. Schröder.

Link: www.fino-offshore.de

In response to a query about the value of *in situ* studies it was asserted that continuous measurements were very important. New findings also justify the approach.

Effect of a complete wind farm cannot be confidently predicted from studies of individual turbines according to E. Rachor. The potential for significant habitat changes may increase non-linearly.

If there is no extra algal production there would be no net effect. Food would be taken from elsewhere, thereby establishing a new equilibrum.

A summary is attached in Annex 12.

4.4.2 Artificial reefs

S. Smith reported on artificial reefs outside Gothenburg Harbour, Sweden.

There was no evidence that *Cancer pagurus* was competing for habitat space with lobsters in the artificial reefs

The rationale behind the creation of an artificial reef was to mitigate for the loss of lobster reproduction areas removed as a result of deepening and re-alignment to accommodate larger vessels. Another benefit is that there is much being learned about lobster biology.

S. Smith also showed an under water video (Tomas Lundälv, ROV) from the artificial reefs outside Gothenburg, Sweden.

A summary can be found at Annex 13: .

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4.4.3 Long-term monitoring of a rocky-bottom macrobenthic community in Arctic Kongsfjorden, Svalbard

F. Beuchel reported.

Results from an ongoing long-term monitoring project on benthic rocky-bottom fauna in Kongsfjorden/ Svalbard are presented. The project started in 1980, when a photographical monitoring station at Kvadehuken (78° 58,6’ N, 11° 30,1’ E) at the southern entrance of Kongsfjorden was established. The monitoring area consists of ten 0.50x 0.50 cm squares that are located about 300 m from the shore in 15 m depth. From halve of the squares, all fauna was removed at the beginning of the project, while five squares remained undisturbed. Since then, pictures have been taken annually in the end of august.

The objective in this study is to reveal inter-annual variations in composition of an arctic macrobenthic community on a rocky bottom habitat and the study of succession in an area where all fauna was removed. Further, co-variations between faunal patterns and environmental factors were tested.

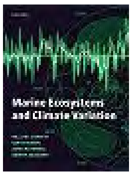
Although the sample design looks relatively simple, the great value of the data is the presence of a now 25-years continuous long time series for benthic fauna that is unique for such high latitudes.

In the succession experiment, after eight years the treated (scraped) areas were for the first time not significant different from the undisturbed areas (control). Stable non-significant values are obtained after 1993. Therefore the succession time for group treatment to reach a climax community is suggested to be 8–13 years for this locality.

The inter-annual differences are not even distributed during the observation period. Minor changes are observed in the middle of the 80`s especially for group control, followed by a very period with low changes from 1990–1993 for both groups. Then, increasing changes occur in both groups, after 1999 these changes decrease again. The periods of large changes are mainly characterized by high concentrations of brown-algae and a rapid decline in the actinian population.

The inter-annual changes in the faunal pattern showed significant positive correlation with the NAO-index (lag one-year) and temperature in the adjacent West-Spitzbergen current.

B. Tunberg recommended on these issues the following publication:



MARINE ECOSYSTEMS AND CLIMATE VARIATION
THE NORTH ATLANTIC: A COMPARATIVE PERSPECTIVE
EDITED BY NILS CHR. STENSETH, GEIR OTTERSEN, JAMES W. HURRELL AND ANDREA BELGRANO

4.4.4 *Gammarus tigrinus* arrived in the Gulf of Riga in July 2003

Communication by J. Kotta.

In 2003 a mesocosm experiment was performed in the shallow area of Kõiguste Bay, northern Gulf of Riga. In the experiment we measured how susceptible are different communities to the addition of species from neighbouring areas. To our surprise *Gammarus tigrinus* was observed in many mesocosms at the end of the experiment. The species was mainly associated with the communities that contained *Cerastoderma glaucum*. Densities ranged between 100 and 800 ind m^{-2}. More information will soon be available about the experiment and the potential effects of the species on native communities.

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

5.1 SGNSBP meeting in Copenhagen

H. Rees reported, assisted by J. Craeymeersch and M. Lavaleye.

The Study Group was formed to co-ordinate the analysis of data on North Sea benthos collected from 1999–2001, following the earlier ICES 1986 North Sea Benthos Survey. The data were gathered opportunistically either from new sampling or the collation of existing data with the emphasis on spatial coverage. There were 15 data contributors from eight countries, and data management was being conducted by VLIZ, Belgium (E. Van Den Berghe). As with previous meetings, the SG combined plenary and sub-group activity, involving the analyses of data on various topics. Following the November 2004 inter-sessional workshop, work was initiated in the production of an ICES Co-operative Research Report, in parallel with scientific papers for peer-reviewed publication.

Examples of outputs to date, e.g., on the distribution of fishing effort in relation to the distribution of benthic communities, and 1986/2000 comparisons of variation in diversity measures, were presented by J. Craeymeersch.

An inter-sessional seminar/writing workshop was planned for November 2005 at Oostende, in order to develop the *Cooperative Research Report*, followed by a final meeting in April 2006 at NIOZ, Texel. Recommendations arising from the NSBP 2000 will be developed, including the benefits of future synoptic surveys of the North Sea (and other areas), further co-ordinated sampling at representative stations, contributions to ecosystem-level evaluations and other matters.

Further details will be available in the 2005 report of the Study Group and on the NSBP 2000 website (www.vliz.be/vmdcdata/nsbp).

In response to queries, it was noted that datasets from the seventies to compare with 1986 and 2000 data were not available at the scale of both North Sea Benthos projects. Due caution would be exercised in assigning causes for changes, that have been observed over the 15-year period.

It is the intention of the project to consider differences in fishing efforts between 1986 and 2000, but collating of fisheries data is still ongoing. VMS data are more reliable in the southern North Sea.

5.2 Identify sources of available data on the North Sea Ecosystem by expert groups contributing to the REGNS process

A sub-group of the BEWG addressed this item, with the emphasis on available time-series studies.

In order to contribute to the REGNS process, available metadata about long-term time-series and long-term comparisons of benthic communities in the North Sea were compiled. Metadata about long-term benthos studies, which were previously compiled within the German project SYCON, were used as a starting point. The metadata set was extended and modified during this workshop. The following benthic categories were considered: soft bottom endobenthos, soft bottom epibenthos and hard bottom epibenthos. Phytobenthos and hyperbenthos could not be considered up to now, but it will be included during the improvement of this inventory in the forthcoming BEWG meetings. Due to the importance of historical data for long-term comparisons, an additional table concerning the oldest available benthos datasets in the North Sea was added.

Data are described by name of project, investigated 'North Sea Task Force' boxes (Tables 5.2.1 and 5.2.2), number of sampled stations, covered time scale, temporal resolution, gears used, sieve size used, contact person, and exemplary references concerning these datasets.

This overview of metadata represents only a preliminary compilation and should be gradually improved and completed.

Table 5.2.1: Overview of metadata, soft-bottom epifauna.

Survey Description	North Sea Task Force boxes													Spatial resolution	Time scale	Density	Biomass	Temporal resoluti	Gear	Sieve	Contact
	1	2a	2b	3a	3b	4	5	6	7a	7b	8	9	10								
Shellfish monitoring North Sea						x								stratified	1995-2004	x	x	yearly	dredge	5mm	Craeymeersch
Shellfish montoring Waddensea													x	stratified	1991-2004	x	x	yearly	dredge	5mm	Craeymeersch
MAFF	x	x	x	x				x	x						1980-1986	x		none			
NSBS			x	x	x	x	x		x	x					1986	x	x	none			
ZISCH	x	x	x	x	x	x	x	x	x	x	x			various	1987-1988	x					
EU (Biodiversity, MAFCONS)	x	x	x	x	x	x	x	x	x	x				ICES rectangles	1986-2004	x	x	yearly	2m beamtrawl		

Table 5.2.2: Overview of metadata, soft-bottom infauna.

Survey description	North Sea Task Force boxes													Spatial Resolution	Time scale	Density	Biomass	Temporal Resulution	Gear	Sieve	Contact person	Reference
	1	2a	2b	3a	3b	4	5	6	7a	7b	8	9	10									
German Bight							x							various, 19 stations	ca1950-1970	x		half yearly (since 1950)	grab	1 mm	Reise	Ziegelmeier
Doggerbank									x	x				175, 50	1985-86, 1996-98	x	x (86-87)	yearly	grab	1 mm	Kroncke	
AWI Bremerhaven							x							4 stations	1965-2004	x	partly	half yearly	grab	1 mm	Schroeder	
Skagerak											x			12-15 stations	1970-1998	x	x	yearly				
Northumberland				x										2 stations	1971-2004	x	x	half yearly				
NOR oil platform monitoring	x		x					x	x					various	1973-2004	x		various				
UK oil platform monitoring	x	x	x						x	x				various	1977-1998	x						
Norderney (Senckenberg)						x									1978-2004	x	x	half yearly	grab	1 mm	Kroncke	
Norderney (Niedersachsen)																						
northern North Sea	x	x	x	x				x	x					various	1981-1986	x	x	various				
Dutch oil platform monitoirng						x				x				various	1985-1993	x		yearly				
NSBS, NSBP		x	x	x	x	x	x	x	x	x		x		various	1986-2000	x	partly	yearly	grab, box-c	0.5-1mm		
German inshore monitoring							x							6 + ? stations	1987-2004	x		yearly	grab	1 mm		
Danish monitoring program							x								1989-1999	x		monthly				
Dutch monitoring North Sea						x				x				25-100 (since 1995) stations	1991-2004	x	x	yearly	box-corer	1 mm	Daan	
Dutch Continental Shelf						x				x					1988-1993	x	x	none	box-corer	1 mm		
Shellfish monitoring North Sea						x								800-1000 stations	1995-2004	x	x	yearly	dredge	5 mm	Craeymeersch	
Shellfish montoring Waddensea													x		1991-2004	x	x	yearly	dredge	5 mm	Craeymeersch	
Dutch monitoring Waddensea													x			x	x					
Molander																						

6 Contribution with MCWG and WGBEC to an assessment of the long-term impact of oil spills on marine and coastal life, based on a list of issues from OSPAR

S. Parra reported on oil spill long term impact on coastal life in NW Spain. It proved difficult to find the best study method as requested from OSPAR. This is a problem that can best be addressed in a theme session during an ICES Annual Science Conference.

An update of the Prestige oil spill is given at Annex 14: .

6.1 Request for advice on development of guidelines for the assessment of long-term effects of oil spills

Following the ICES/OSPAR Workshop on the development of guidelines for integrated chemical and biological effects monitoring, a number of outstanding issues related to the assessment of long term oil spills on marine and coastal life were raised. BEWG considered the requirement to advise on these issues and based on their experience of working on a number of long term oil spill studies (López-Jamar *et al.*, 1996; Parra and López-Jamar, 1997; Sánchez *et al.*, 2003, 2004), the following comments were made. However, the group recognise the limitations of their advice and recommend a future themed session or workshop to draft final guidelines for the assessment of long term oil spills. In particular, a review of the variability of impacts related to habitat type, climatic and hydrographic regimes would be useful. A preliminary list of recommendations are given for drafting guidelines.

6.1.1 Response to outstanding issues

a) the distinction between the effects of the oil and what is caused by natural changes;

The group suggest the ability to distinguish between the effects of oil and what is caused by natural changes depends on the nature and quantity of the oil input. In the case of acute oil contamination, particularly following a large spill there are clear ecological effects on the benthos (Dauvin, 1982, 2000; Elmgren *et al.*, 1983; Jewett *et al.*, 1999; Peterson, 2001; Peterson *et al.*, 2003; Sanders *et al.*, 1990), but in order to effectively monitor the recovery of these sites it is very important to design surveys that follow a seasonal pattern so that natural variability can be differentiated from the actual effects. In chronic situations, however, where there may be ongoing oil contamination, in combination with other discharges and emissions (e.g., around harbours), it is much more difficult to distinguish the cause of changes in benthic communities and to separate oil impacts from natural variability.

b) the impacts of oil on different types of habitats (i.e., the nature of the coastline) and ecosystems (variability in rates of recovery);

The group suggest that the impacts of oil will vary dependent on the nature of the coastline and local environment (e.g., “Prestige” vs. “Exxon Valdez” oil spill: Sánchez *et al.*, 2003, 2004; Jewett *et al.*, 1999). However, because they only had direct experience of a number of studies, they recommend that a review be undertaken comparing similar spills (quantities and nature of oil) in a number of different habitats. For some habitats this will be more difficult because there is only one (or few) example(s) of a spill in that particular type of habitat (e.g., Prestige on the continental shelf platform; Sánchez *et al.*, 2003, 2004).

c) the impacts of oil in different marine regions subject to different climatic influences;

In different marine regions climatic and hydrographical regimes will vary and this in turn will effect the nature of impact and the recovery process. For example, in more exposed areas with dynamic regimes, oil will be dispersed more quickly and over a greater area. Again, however, there was not enough experience within the group to fully evaluate variation of impacts by marine region and it is suggested that a review of evidence of this is undertaken, comparing the results of the monitoring studies from a variety of regions of varying climatic influence.

d) the impacts of different types of oil, both toxic impacts (toxic effects and accumulation) and non-toxic impacts (physical properties creating nuisance and hazardous conditions – physical contamination and smothering);

Based on evidence from the comparison of the *Aegean Sea* spill with the *Prestige* oil spill it is clear that the impacts do vary significantly with the type of oil. In the case of the *Aegean Sea* spill, the oil was type brent oil which has a high toxicity and is very soluble thus causing mortality which spreads very quickly around the immediate area (González *et al*., 1996; López-Jamar *et al.*, 1996; Parra and López-Jamar, 1997; Sánchez *et al.*, 2004). The effect is particularly severe in enclosed areas. However, due to the high solubility, the effects are not noticeable to the public and the societal interpretation of the severity of the spill can be misinformed due to this. In the case of the "Prestige" oil spill the material is very dense with high tar concentration, and so the spill is very obvious, with high perceived severity to the public. Actual impacts are limited to direct contact of the oil with organisms in the surrounding environment. The material is much less soluble than that of the brent oil (or other light oils) and so the toxicity is contained within the area of immediate impact (Albaigés and Termens, 2003; Alzaga *et al.*, 2004).

e) the impacts of remedial activities such as the use of heavy equipment and high pressure hosing to clean up oil spills;

The group advise that there are a number of mechanisms employed to clear up after oil spills, many of which have an impact on the environment. In choosing a method the known impacts of each should be assessed against alternatives. Here we list a few of the known impacts of remedial activities. In general techniques used to clear oil spills from the coast may be classified into: 1) Mechanical pick-up involving physical removal of the oil from the shore using either human effort or mechanical diggers and, 2) Hydraulic cleaning and sand blasting. The passage of heavy machinery as a result of mechanical clean up may drive oil deeper into the soil or mix it with soil at the surface. Excessive removal of beach material can cause unacceptable beach erosion and resulting changes in community structure. Mechanical removal using human effort is not thought to have any adverse environmental impacts. Hydraulic cleaning using high pressure hot water can result in higher mortality with extended effects on intertidal dynamics (Boucher, 1980), it is possible sand blasting will have similar effects. (Foster *et al.*, 1990; Mearns, 1993).

Clean up techniques at sea may be divided into: 1) Mechanical technique involving the use of booms and skimmers, 2) Chemical treatments such as dispersants, detergents, sorbents and burning 3) Bioremedial treatments and 4) No treatment. Mechanical removal involving skimmers is not thought to have any adverse ecological impacts. The use of sorbents can result in sorbent particles sedimenting to the seafloor and contaminating the benthos. Chemical detergents and dispersants often have toxic effects and are harmful to marine life. They may also persist in the environment and have long term effect on marine organisms (Southward and Southward, 1978; Hawkins and Southward, 1992). Burning has shown some promise as a means of remediation however the ecological effects include atmospheric pollution. Bioremediation can result in eutrophication and habitat degradation (Bragg *et al.*, 1994).

f) whether the current framework of environmental risk assessment and toxicology is sufficient to take account of the long term effects of oil pollution.

There was not enough experience of the current framework for environmental risk assessment within the BEWG to assess whether this is sufficient to take account of the long term effects of oil pollution. However, a list of recommendations for the assessment of the long term effects of oil pollution, based on the experience of the studies undertaken by Spanish Oceanographic Institutes (see Section 6.2) is provided below.

6.1.2 Assessment recommendations

- The monitoring programme must be continued since it is important for understanding of long-term fluctuations of the benthic system. For monitoring large oil spills, not less than 3–6 years of studies should be undertaken.
- Investigations on the seasonal variability of species number, abundance and biomass of benthic communities are required for a better understanding of the functions in the benthic system and for a good discrimination of the pollution effects.
- We need more high resolution information on short-term and small-scale variability for a better interpretation of long-term large-scale changes in the system (Kröncke and Bergfeld, 2001). This will help to distinguish oil impacts from natural variability.
- Investigations on the trophic structure of benthic communities are important for the understanding food availability and utilisation of this by the rest of the ecosystem (i.e., bottom-up type effects; Peterson et al., 2003). This will help to determine the wider ecosystem-level effects of oil spills.
- It is important to draw a distinction between cause and effects of the various factors (fisheries, chronic pollution, climate) acting on the benthos for a good discrimination of the oil spill effects. In order to do this it is important to use metrics that distinguish the nature of the mechanism between the oil impacts and a change in the benthic community. For example, impacts related to toxicity will affect organisms differently to those related to physical disturbance such as trawling. Indicators should be developed in the near future from existing methods of monitoring oil spills for this purpose.

6.2 Example of the assessment of the long-term impact of the oil spills on marine and coastal life

Once the magnitude of the “Prestige” oil spill became evident, the research team at the Instituto Español de Oceanografía (IEO) (Spanish Oceanographic Institute) in collaboration with other Spanish institutions (AZTI, CSIC, etc.) and different Spanish universities (Vigo, A Coruña, Santiago de Compostela and País Vasco), began to devise a strategy to study and assess the effects of the fuel oil released from the tanker (www.ieo.es/prestige). All the assessment of the effects of the *Prestige* oil spill was coordinated by the Technical Office of Marine Spills (Oficina Técnica de Vertidos Marinos) (otvm.uvigo.es). The complete report about the Special Acton activities is available in:

otvm.uvigo.es/investigacion/informes/documentos/archivos/InformeEjecutivoCCC.pdf.

The IEO, which is the only national government agency devoted exclusively to marine research, has a solid background in the scientific monitoring of accidental spills of toxic substances into the sea. Prior to the case of the “Prestige”, the IEO took part in studies to assess the impact of the spills caused by the vessels *Polycommander* (1970), *Monte Urquiola* (1976), *Casón* (1987) and *Aegean Sea* (1992; López-Jamar *et al.*, 1996; Parra and López-Jamar, 1997), all off the coast of Galicia.

Starting on 7 December 2002 up to the present time, various teams from the IEO have been conducting a lot of oceanographic surveys to monitor the evolution of the fuel oil and its effect on the water, sediments and living organisms, with special attention on continental shelf benthic communities of the affected area.

A relevant document can be found at
www.ieo.es/prestige/pdfs/Informe_campanas_junio04.pdf.

Referring to shelf benthic communities and sediments, the main IEO assessments in the long-term "Prestige" oil spill and studies are:

Monitoring of hydrocarbon (PAHs) content in the sediment.

Presence and quantification of oil tar aggregates on the bottom of the continental shelf of Galicia and the Cantabrian Sea.

Long-term impact of the spill on the benthic and demersal communities living on the continental shelf of Galicia, with special attention to infaunal, epifauna and demersal communities.

More complete information of these studies and reports is available in www.ieo.es/prestige/resultados.htm and in the 2003 to 2005 BEWG reports (Sánchez *et al.*, 2003, 2004).

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7 Review of 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

A sub-group of BEWG continued with discussions of 'biological criteria for selecting dredging disposal sites'. Participants reviewed the available information considering the nature of the material, quantities, conditions of the receiving environment, and good and bad scenarios for dredged material disposal at sea. It was also recognised that the biological criteria, should also be incorporated in conjunction with non-scientific issues such as operational factors, socio-economic activities, costs, and convenience.

Members of the sub-group agreed an overview structure, which will provide a review of existing case studies with lessons learned, and recommendations for future practice.

7.1 Structure of the overview

Background information from "hypothetical case scenarios", e.g., considering disposing clean dredged material onto a clean sand environment with a highly resilient benthic community, which will assimilate and manage with the new material.

7.2 Important considerations

Benthic community effects as a result of dredged material disposal and recharge schemes.

7.3 Supporting considerations

As discussed by the group, the most important issue affecting benthic communities is the nature of material. This includes not only its characteristics (grain size, organic matter content, etc.), but also the level of contaminants, quantities of material disposed of, frequency of disposal, period of the year in which it is disposed, etc. All these variables can facilitate an important influence on the posterior evaluation of the environmental impact (e.g., the same sediment composition, but different disposal pattern, in terms of quantities or period of the year, can produce different level of impact upon similar benthic communities).

The area conditions (e.g., site-specific characteristics) should be determined accurately. In this way, the selection of disposal sites with sediment (material) characteristics close to those of the sediment (material) to be disposed should be undertaken. This can be done taking into account also the hydrodynamics of the area, in terms of winds, currents (both in surface and bottoms layers), and waves. Some other important issues could be related to the interest in maintaining some materials within the system (e.g., sands dredged near a beach, and disposed in deep waters, can lead to an erosion of the beach). Hence, clean sands could be disposed in shallower waters than muds, which can require deeper waters.

In order to undertake good BACI analyses, the availability of baseline information (benthic communities data, sediment and other environmental variables) is essential. Data on species composition should be undertaken to the lowest taxonomical level possible (this can help with some European legislation, such as the Water Framework Directive and OSPAR recommendations, in which the presence of sensitive and opportunistic species must be determined in the assessment of the ecological status). This can permit the posterior calculation of different structural parameters (e.g., abundance, diversity, taxonomic distinctness, AMBI, etc.), and the use of multivariate tools (e.g., PRIMER, CANOCO, etc.). All these parameters, together with the environmental variables, and comparing data before and after disposal, and affected and reference locations, can lead to a better comprehension of the environmental impact produced by the material disposed of upon the entire benthic community (not only at species level).

Review and update available methodologies/guidelines for best sea disposal practices as they relate to benthic biological effect.

Participants addressed the need for a guidance document on site selection.

7.4 Review of available case studies:

- Belgium: Hans Hillewaert, Ine Moulaert.
- Germany: Eike Rachor, Heye Rumohr.
- Netherlands: Mario de Kluijver.
- Spain: Angel Borja.
- Sweden: Susan Smith.
- UK: Silvana Birchenough.
- United States: Bjorn Turnberg.

It was agreed by the sub-group participants to review each individual case of study by 15 September 2005. The general structure of individual case-studies will be as follows:

Characterization of study sites:

- Map of the study sites

- Name of location and position
- Depth
- Sediment composition
- Organic matter content
- Additional physical parameters (i.e., currents, temperature, oxygen, heavy metals, etc.)

Site history:

- Nature of materials (contaminated, capital, maintenance)
- Frequency and quantities of disposal
- Season of disposal
- Method of disposal (i.e., surface, etc)

Benthic monitoring:

- Limitations of the study (i.e., money, time constraints, lack of baseline information, etc.)
- Baseline community type (if available)
- Frequency of monitoring (quarterly, annually, biannually, etc)
- Number of sampling locations (transect, grid, random, etc.)
- Sampling equipment (type of gear, sieve mesh type)
- Sampling analysis (type of biological data i.e species numbers, abundance, biomass, etc.)
- Analysis of results (i.e., univariate, multivariate)

Main findings of the study (for main overview discussion)

This section will aim to include main recommendation or conclusions obtained from studies to allow general guidelines for best dredged material disposal at sea practices.

7.5 Discussion

This will be based on specific case studies (point 3).

7.6 Recommendations

The production of guidelines/recommendation will be beneficial for national and international regulatory agencies in the effective management of dredged material disposal.

8 Review the status of indicator metrics, for 2005 including, the development and its applications for phytobenthos and hard-substrata benthos

8.1 Review

The main objective of this group was to state the current view of benthic ecologists with regard to benthic indicators and its application under the determination of the quality of benthic ecosystems.

The most recent legislations tend to integrate the whole ecosystem in the assessment. Hence, the Common Fisheries Policy (CFP) tends to manage the European fisheries under an ecosystem-based approach; and the European Water Framework Directive (WFD) requires the assessment of the ecological status of the water bodies by integrating physico-chemical, morphological and biological (phytoplankton, macroalgae, benthos and fishes) elements. Indicators are recommended by a number of fora (ICES, 2001, 2004a, b; OSPAR, 2005, etc.) to support the implementation of an Ecosystem Approach (EA), as they provide information on the state of the ecosystem, the extent and intensity of human impacts and the progress of management in relation to objectives (ICES, 2001).

Indicators that represent ecosystem health have been defined as ‘Descriptive’ or ‘Surveillance’ indicators (ICES, 2004b). These fulfil the important role of providing information on the state of the ecosystem and its’ components (e.g., benthos, fish, habitat). In order to assist in the management process, there is a further task for science, to develop the indicators that give a good direct measure of the extent to which an activity is impacting the system and so requires a directed management response. Such “Decision Support” indicators that are able to inform the management process directly have been defined as “Performance” indicators (ICES 2004b).

In this way, the determination of indicators based on the density of sensitive and opportunistic species has been proposed by OSPAR, within the EcoQO approach, to act as performance indicators that can be used within a management context (Lanters *et al.*, 1999; OSPAR, 2005). We also need to develop indicators of the ecological status of the benthos, which can be used to assess overall “health” and variation in this. The selection of a unique or a small group of indicator species (both in hard- and soft-bottom substrata), in the assessment of the entire community status could lead to a posterior misinterpretation. Hence, the presence or absence of the selected indicator species in a zone (e.g., *Fucus*) could be done by environmental differences (e.g., changes in wave exposition, differences in substrata characteristics, etc.) and not by man-induced differences. In this case, all that we are being told is that a change has occurred, but we cannot relate this change specifically to a manageable human activity.

BEWG recognized the challenge of matching the aspirational need for a small suite of widely-applicable benthic biological indicators with the typically local sources of evidence for determining effectiveness. Thus the utility of an individual indicator may vary with locality (especially habitat type) and the activity under investigation so that, in practice, a larger ‘toolkit’ of measures was required to meet different circumstances. No universally applicable measure was yet available.

BEWG also emphasized the fundamental importance of sound sampling design for indicator applications to be effective in environmental management. Again, designs will vary from one location to another depending on such factors as the nature and scale of the human activity under investigation, and the presence of confounding influences nearby, whether of human or natural origin.

The members of the group consider that the best approach should be based on a combination of indicators of the ecological status (e.g., structure and function) of the benthos and performance indicators that can be used to link variation to specific manageable human activities. State indicators may include a combination of species indicator indices (such as trophic or other functional groups, AMBI, etc.) and other metrics (e.g., density, diversity, biomass, etc.), and the use of multivariate tools (e.g., PRIMER, CANOCO, etc.). All these parameters, together with the environmental variables, can lead to a better understanding of the entire benthic community. This will require that data on species composition should be undertaken to the lowest taxonomical level possible. We consider that further work will be required to develop performance indicators that meet criteria that have been developed by ICES (2001, 2005) and others (Rice and Rachet, 2005) (e.g., tightly linked to a manageable activity, cost effective to monitor, etc.).

Based on the knowledge of the members of the group we have described the success of available performance indicators to be used within a management context for human activities (Table 8.1.1). These indicators may be based on community indices and/or single species approaches, as recommended previously (ICES, 2004c). This is an initial step and BEWG recognises the need to further develop this work to actually list those indicators available based on the published case studies as a meta-analysis in a future meeting. Our aim is to recommend that both indicators of state and those that identify cause-effect relationships with human activities (performance indicators) can be recommended. We also emphasize the need to test the applicability of different indicators at local, regional and global levels in order to aid the development of appropriate monitoring programmes.

Table 8.1.1. Success of available indicators in identifying cause/effect relationships and applicability of these findings at different spatial scales (in some cases there can be several applicabilities, depending on the different indicators).

ACTIVITY	SUCCESS IN IDENTIFYING ACTIVITY SPECIFIC CAUSE/EFFECT RELATIONSHIPS	APPLICABILITY OF FINDINGS			PUBLICATION OF PAPERS
	1: low, 2: medium, 3: high	Local	Regional	Global	*Low, **Medium, ***High
Sewage pipelines	3	x	x		**
Sewage sludge from ships	2	x	x		***
Sediment dredging	2	x	x		**
Dredging disposal	3	x			***
Aggregate extraction	2	x			*
Oil spills	3	x	x		***
Oil/gas extraction	3	x	x		***
Aquaculture	3	x			*
Trawling disturbance	1–2	x	x		***
Chemical discharges	3	x	x	?	***
Coastal/offshore construc.	1–2	x			*
Mining	2	x	x	?	*
Harbour activities	3	x			**

8.2 References

ICES, 2001. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2001/ACME:09.

ICES, 2004a. Report of the Regional Ecosystem Study Group for the North Sea (REGNS). ICES CM 2004/ ACE:06.

ICES, 2004b. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2004/ACE:03.

ICES, 2004c. Report of the Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species, ICES CM 2004/ACE:01.

ICES, 2005. Ecosystem Effects of Fishing: impacts, metrics and management strategies. *ICES Cooperative Research Report*, No. 272, 179 pp.

Lanters, R.L.P., Skjoldal H.R., and Noji, T.T. (Eds.) 1999. Ecological Quality Objectives for the North Sea. Basic Document for the Workshop on the Ecological Quality Objectives for the North Sea. 1–3 September 1999, Scheveningen, The Netherlands. Fisken og Havet 10-1999. RIKZ Report 99.015. 57 pp.

OSPAR, 2005. Draft Report on the North Sea Pilot Project on Ecological Quality Objectives. Meeting of the Biodiversity Committee. Bonn 21–25 February 2005 .

Rice, J.C., and Rochet, M.J. 2005. A framework for selecting a suite of indicators for fisheries management. *ICES Journal of Marine Science*, 62, in press.

9 Work with Working Group on the Statistical Aspects of Environmental Monitoring (WGSAEM)

J. Nørrevang reported from the meeting of WGSAEM. No representative from the BEWG was present, and the members are more experts on time-series, therefore nothing was presented about multivariate analysis.

BEWG recommends a workshop open for everyone with WGSAEM and biologists to promote a constructive exchange of expertise. The group will work over a period of one year including a one-week workshop. Data from HELCOM will be used. Also datasets from A. Josefson (NERI) are available. M. de Kluijver writes a TOR about minimum sampling size and justification. R. Fryer is proposed as chairman. One wish is to be given a statistical method to pick out indicator species.

10 Review progress of development of guidelines for phytobenthos sampling with a view to publication in the *ICES TIMES* series

On hard substrates there are several methods used to estimate species presence, abundance, coverage and biomass. They range from remote techniques over video on hanger or ROV-platform to direct divers observations and quantitative sampling. The different methods have different resolution, but also acquire more or less time for processing. Several remote methods (i.e., satellite images, aerial photography, side-scan sonar and echo-sounding) also require interpretation of the signals and ground proofing. The direct methods include video-hanger and ROV (both which require ground proofing to some extent) as well as direct observations by scientists and divers. There is not a single best method and usually it is recommendable to combine several methods to obtain geographical resolution as well as detailed descriptions of the communities and the populations present.

The visual direct observations include video-based methods either on video-hanger, usually with a limited depth range, or ROV. Those methods are under constant improvement mostly due to better cameras available on the market and the integration with GIS-applications and large scale, indirect methods (e.g., echo-sounding). Both methods give a good overview of community distribution and are suited for habitat documentation. Also, they can be used to verify that the results represent larger areas which are based on divers line transects and community estimates done on the more exact, on spot estimates in frames.

The divers operated methods include transects either along or perpendicular to the shore line, depending on the question asked. Species distribution and estimates of cover is made either under the line, line intercept or in a corridor along the line. Along the transects, frames for cover estimates may be placed and destructive sampling by scraping an unit area. There is a trade off between the estimates of coverage done along a corridor as applied in Norway, also suggested as ISO-standards as well as in the Swedish national monitoring programme in the Baltic Sea (HELCOM-recommendation) and estimates in frames. The later is time consuming but can give a more exact measure within each frame, the former may be exact as well but emphasizes, e.g., the depth distribution of species. Quantitative sampling is done by the non-destructive, in situ description of species and their abundance and coverage in frames or (stereo-) pictures thereof and later photogrammetric processing. The later is, e.g., done in the Swedish national monitoring on the marine west coast, where frames are sampled at given depths along the whole photic zone down to ca 25 m depth. The description of the communities within frames is widely used especially in the intertidal zone. Also, destructive sampling is done using one or a combination of frames of appropriate size for recovering the populations under observation.

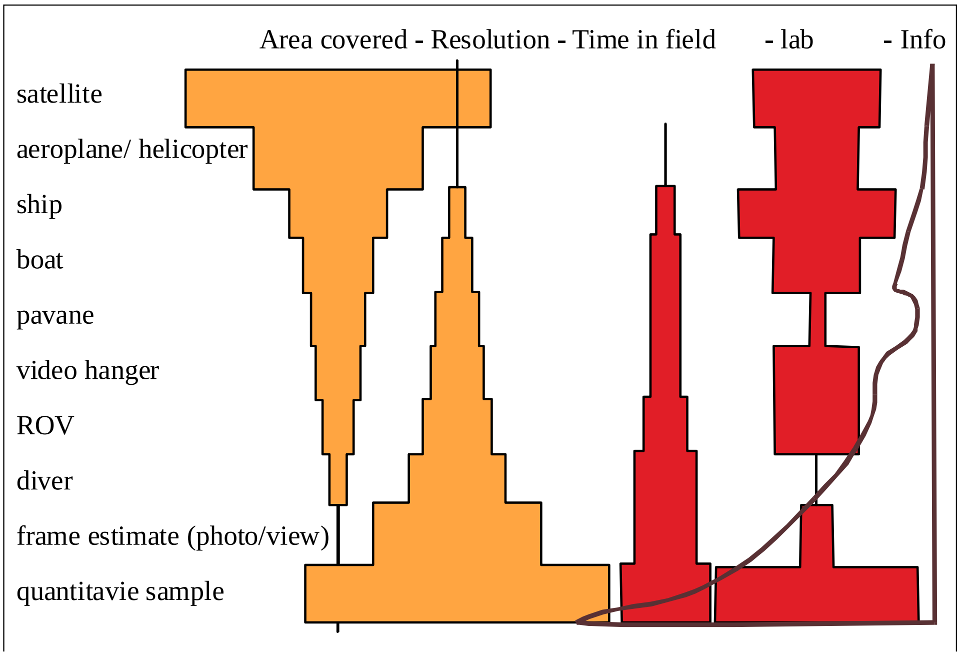

Figure 10.1: A schematic presentation of various techniques areal coverage, resolution (information on species), the time spent for retrieving data and a rough estimate of information recovered (pavane is also referred to as, e.g., dragon or manta taw).

11 Review the state of benthic communities at seamounts as presented by MarEco and other projects and provide input to [WGDEC] in relation to the provision of advice to OSPAR on the evidence for the threats to, and/or decline in, seamount habitats and their populations in the OSPAR regions where seamounts occur [OSPAR 2005/3]

To review the available information and references on threats to, and/or decline in the OSPAR area of, seamounts, and to provide advice on the evidence for threat to, and/or decline in, seamount habitats and populations in all of the OSPAR regions where seamounts occur. The available information and references, and more detailed terms of reference for this review will be provided to ICES by MASH in November 2004.

Benthic data from the MarEco project are in an early stage of analysis and therefore were not available to the group to enable assessment of the state of benthic communities at seamounts on the Mid Atlantic Ridge (Bergstad, pers. com.). The lack of available data also meant the group were unable to assess whether seamount benthic habitats within the OSPAR region are in decline. However with regard to the threats to seamount benthos it was agreed the largest threat is posed by fishing and specifically bottom trawling. Therefore the BEWG has reviewed available information on deep-water fishing activity on seamounts in the OSPAR region in order to advise on threat. The information provided here is in addition to that already provided by WGDEC in their 2005 report under Section 2.5 'Identifying whether and where there are threats from fishing activities within the OSPAR maritime area'. The information provided is taken from a proposal by Norway to NEAFC for closure of areas on the Mid Atlantic Ridge and Hatton Bank to bottom trawling. The threat posed by fishing to seamounts of the MAR was sufficient for NEAFC to introduce closed areas.

Taken from www.ices.dk/advice/Request/NEAFC/2004-28 Norway additional information1.doc

Areas on the mid-Atlantic Ridge and in the ocean basins

Based on scattered reports submitted to ICES over the last decade by, e.g., Russia, Norway, Spain and the Faroe Islands, there is reason to believe that exploratory fishing has been conducted on most fishable hills and seamounts along the mid-Atlantic Ridge (including the Reykjanes Ridge). In many areas there have also been regular or irregular commercial fishing by bottom trawl, but the scale of these fisheries in terms of effort measures are not exactly known. ICES has noted this lack of documentation several times in previous reports from ICES WGDEEP.

Despite recent efforts to explore the fauna and habitats on the mid-Atlantic Ridge (e.g., the MAR- ECO project described on www.mar-eco.no), rather few areas of the mid-Atlantic Ridge have been mapped in detail. The limited areas that have been explored by remotely operated vehicles (ROVs) show a vulnerable habitat and a diverse sessile fauna, not unlike those found in other waters that have similar habitats and which have been explored more fully. However, the level of knowledge of the MAR or other Atlantic seamounts is not sufficient to determine what areas are most vulnerable or have been most damaged by trawling.

12 Review of the environmental studies at wind energy locations at sea and make recommendations on means for a harmonized European approach to benthic ecosystem studies

Basic information on environmental studies related to offshore wind energy farms has been compiled during the last meeting (see ICES BEWG Report 2004). In addition to this, some updates and additions have been collected during the 2005 meeting.

12.1 Belgium

Reported by I. Moulaert.

The construction of the windfarm on the Thorntonbank (c-power) is planned to start in 2006. The permission is for a park with 60 windmills, separated in 2 blocks (24 and 36), each with a capacity of 36 MW. MUMM (Management unit of the north sea mathematical models - department VI of the royal Belgian institute of natural sciences) is handling the monitoring of environmental effects of the construction and the exploitation of the wind farm. A general monitoring plan has been set up. Next to macrobenthos, epibenthos and fish also hydrodynamics, sediment, noise, birds, mammals and electromagnetic fields will be monitored. For the first year of the contract (2005) the objectives are to have a base line of the concession zones for further study.

For macrobenthos a total of 60 van Veen grabs will be taken, for two seasons (spring, autumn). 30 in the concession zone, 15 in the nearby surroundings and 15 in reference areas. For epibenthos and demersal fish 2 tracks will be sampled in the concession zone, 4 next to it and 3 more in a nearby reference area. The report on this first year is planned for the beginning of 2006.

12.2 Denmark

Reported by S. Smith

Interim reports about environmental effects available on the web from two established wind farms by the companies (www.hornsrev.dk; uk.nystedhavmoellepark.dk). Research on environmental effects does not follow a fixed standard protocol, but is adjusted to the specific habitat and asses by the Danish forest and nature agency on a case by case basis. The only restriction is that the studies have to be comparable to the national monitoring programme (www.dmu.dk/Overv%C3%A5gning/Fagdatacentre/Det+Marine+Fagdatacenter/Tekniske+anvisninger+NOVANA+2004-2009/).

Further information can be found in a recent publication by Greenpeace (2004): “SeaWind Europe” and at several web sites: www.windpower-monthly.com, www.euroex.com, www.ecu.nl. More details were given in a presentation given by S. Smith and a summary can be found at Annex 15.

12.3 Germany

Reported by A. Schröder.

Most proposals for wind farms are in the offshore zone. Each windfarm company has to conduct an EIA and a monitoring program two years before, during and 3–5 years after construction of the wind farm. Data are collected centrally (BSH, Federal Maritime and Hydrographic Agency) but are at present not available for scientific purposes. At present, permission has been granted for 7 pilot farms (12–80 mills; updated maps at www.bsh.de). Germany has developed a standars monitoring program (English version available at www.bsh.de, see links below). 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. There are a number of on-going research projects that are considering the impact of wind farms on the marine environment, at present mainly focused around research platforms (e.g., BeoFINO see 4.4.1).

12.4 Norway

Reported by L. Buhl-Mortensen.

Four farms are planned 2006 on the coast of mid Norway (southwest of Trondheim):

HAVSUL I-IV. They will provide the biggest wind-energy source on a global scale. The EIA is not public yet and there was no information available about regulations for standards on environmental studies related to offshore wind energy development in Norway, as this is a very new development.

12.5 Spain

Reported by A. Borja and S. Parra.

The marine wind energy potential in Spain is over 25,000 MW.y−1. Currently, there are not wind farms operating in Spanish coasts. Several areas have been identified as potential use: Gibraltar Strait, cape Creus, Ebro delta and Galician coasts. However, the Spanish coast is not very adequate, due to the high depth of the continental shelf.

The most important project, evaluated in a cost of 1,650 million euros, is being to be developed 18 km off Trafalgar cape, with 276 wind mills (on 25 m water depth, with mills of 104 m height, 50 m of the sails, 2.5–5 MW). The total power of the farm will be 1,000 MW. We don’t know if the Environmental Impact Assessment (EIA) has been done. There are several stakeholders against the project: fishermen claim against the project, due to the high fish productivity in the area (including the tuna migratory route); local authorities have concerns due to the tourism and visual impact; the area is important in terms of bird migratory routes from and to Africa; finally, the area is an important submarine archaeology site.

On the other hand, there are two proposals for wind farms construction in the northwest of Iberian Peninsula (La Coruña, Galicia). The first one, will be situated in “los Bajos de Baldaio” (near to −8º 42' 17" W / 43º 21' 11" N), between 5 and 7.5 km offshore, and will be formed by 20 wind mills (40 MW total power), in an area of 8.32 km2. The area extends over 10 to 20 m water depth, with hard, gravel and mud bottoms. The other offshore wind farm proposal will be situated in “los Bajos de los Meixidos” (near to −9º 12' 40" W / 42º 46' 16"

N), between 5 and 7.5 km offshore, and will be composed by 15 wind mills (30 MW total power), covering an area of 6.36 km^2 (10 to 20 m water depth, on hard bottom). Currently, there is not environmental impact study for both proposals.

As far as we know, there are not specific guidelines for marine wind energy in Spain. All projects are under the general EIA legislation. Hence, projects with more than 10 mills must conduct an environmental impact study.

12.6 Sweden:

Reported by S. Smith.

Recently in Sweden, new means were forwarded for research on offshore windmill parks. Information and projects can be found under www.vindenergi.org. Under the Swedish "Energy Agency" (www.stem.se) reports, policy etc. can be found. Also, Swedish armed forces deal with the problem (www.foi.se) as well as companies engaged in the construction of the windmill parks (www.aricole.se, www.vindkraft.nu). The Swedish EPA has an ongoing project of obtaining background data from offshore, shallow reefs which are of interest to place windmill parks (www.environ.se). All data are collected centrally (EPA) and are available for scientific use.

More details were given in a presentation given by Susan Smith at Annex 16: .

12.7 UK

Reported by K. Howell.

A national project "COWRIE: Collaborative Offshore Wind Research into the Environment" is funded by a levy from wind farm operators, including a central database collecting all data. Main projects up to now:

- Potential effects of electromagnetic fields (EMF) on fish;
- Baseline methodologies for aerial and boat based surveys;
- The displacement of birds (especially Common Scoter) from benthic feeding areas;
- Potential effects of underwater noise and vibration on marine mammals;
- Interim and final reports at www.crownestate.co.uk.

The COWRIE research studies are quite separate from the requirements on developers to undertake site investigations to inform the environmental impact assessments or site monitoring requirements but it is envisaged that the outcome of the research will be guidance and best practice which should be of great benefit to developers.

Developers are required to provide data through the whole life cycle of the project including monitoring data during operational and decommissioning phases. Together with the data from EIAs, these data are to be collected centrally by a new project within COWRIE, and shall be available for scientific use.

Results from a national workshop on offshore wind farms including extensive links to guidance documents etc. can be found at: www.cefas.co.uk/renewables/r2eiaworkshop.

12.8 United States of America

Reported by B. Tunberg

A first proposed project involves the development of 170 Wind Turbine Generators (WTGs) on a grid over approximately 26 square miles of sub-tidal area in Nantucket Sound known as Horseshoe Shoals1. a Draft Environmental Impact Statement has been produced complying with local and regional authorities' requirements, but no information was available about explicit standards for studies on environmental effects of offshore wind farms. Details and more information on planned projects in the US and wind farm related subject can be found at the website www.capecodonline.com/special/windfarm and the links therein.

12.9 A discussion on the means for a harmonized European approach to benthic ecosystem studies resulted in several recommendations from the BEWG

Investigations by the wind farm developers on ecological effects involve a high sampling effort and are quite expensive. For economic reasons, these investigations will mostly be at a minimum required effort. To ensure a scientifically sound result, a minimum standard should be established by all national regulating bodies. Existing procedures (e.g., Danish regulations; UK and German protocols see links below) should serve as starting points. Especially in areas where proposed wind farms touch national borders, an international harmonization is necessary to make comparison of results possible and to assess cumulative effects, which do not stop at national borders. To allow thorough assessment of effects across various regions and habitats, all data produced in environmental studies should be collected centrally and consequently be available for scientific purposes.

A distinction between natural spatial variation and wind farm effects will require multiple reference areas. This may also be achieved by a combined analysis of data from several projects, combining data from all reference areas to estimate natural variation. This will require a central data collection and a common minimum standard for the data produced to allow comparisons between studies. To allow a differentiation of fishing effects and direct effects of offshore wind farm installations, at least some reference areas without fishing influence will be needed.

The BEWG compiled all information that we were aware of and would be willing to comment on scientific methods if requested, definition and implementation of standard procedures has to be worked out by national regulating bodies.

12.10 Resources

OSPAR Commission, 2004:Problems and Benefits Associated with the Development of Offshore Wind-Farms (available at: www.ospar.org/documents/dbase/publications/p00212_Wind%20farms_Problems%20and%20benefits.pdf)

German Monitoring standards: www.bsh.de/en/Marine%20uses/Industry/Wind%20farms/Standard.jsp

UK wide regulations: www.og.dti.gov.uk/offshore-wind-sea.

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

13 Any other business

13.1 Upcoming symposia

Workshop on Benthic Indicators in Wimereux, 6–7 June 2005.

ASLO Santiago de Compostela, 19–24 June 2005.
Link: aslo.org/meeting/santiago2005

EMBS in Vienna, August 2005
Link: www.promare.at/bssc2005

Marine Themes at British Ecological Society Conference in Hatfield, UK, 5–7 September
Link: 2005 www.britishecologicalsociety.org/articles/meetings/current/annualmeeting2005

Baltic Sea Science Congress in Sopot, Poland, 20–24 June 2005
Link: www.iopan.gda.pl/bssc2005

13.2 Election of new Chair

The group nominated Heye Rumohr as the new/ongoing Chair for a period of two years.

14 Recommendations and action list

The **Benthos Ecology Working Group** [BEWG] (Chair: H. Rumohr, Germany) will meet at HCMB, Heraklion, Crete/Greece from 1–5 May 2006 to:

a) Review and consider recent developments in ongoing benthos research in Europe

b) Review the final meeting report of the SGNSBP and consider future joint activities in the North Sea

c) Discuss the environmental implications of off-shore renewable energy generation (wind, wave, tide, etc.)

d) Update the list of available information for the REGNS process and review the outcome of the REGNS workshop in May 2005

e) Based on the outcome of the ICES ASC session on Oil in Marine Systems, review progress on guidelines for the assessment of long-term impacts of oil spill

f) Work intersessionally to produce a draft report on the use of benthic biological criteria for selecting dredging disposal sites

g) Relate a list of indicators to the impacts of human-induced activities and changes in ecological state. Assess the effectiveness of any potential performance indicators in identifying cause-effect relationships.

h) Consider the outcome of a Workshop on statistical analysis with special emphasis on minimum sampling area and trend analysis in ecological studies

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 a prerequisite for the scientific information status of the group b) The SGNSBP is a major research activity of the BEWG and the basis for future joint activities and c) There is a growing need for a harmonized approach to benthic studies in view of the rapid expansion of the interest in off-shore wind energy and other forms of energy generation off-shore. It will provide further advice in response to the OSPAR. d) This will be an important review of the Integrated Assessment Workshop in May e) This will be a basis for future OSPAR requests f) This is in response to a OSPAR request g) 2005This is to continue important work on definition of benthic indicators in response to the ongoing requests from OSPAR. h) This is a continuation of the attempts to cooperate withWGSEAM
Resource Requirements:	The research programmes which provide the main input to this group are already underway, and resources already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants:	The Group is normally attended by some 20–25 members and guests
Secretariat	None

Facilities:	
Financial:	No financial implications
Linkages To Advisory Committees:	There are no obvious direct linkages with the advisory committees
Linkages To other Committees or Groups:	There is a very close working relationship with all the groups of the Fisheries Technology Committee. It also is of close relevance to the Working Group on Ecosystem Effects of Fisheries.
Linkages to other Organisations:	The work of this group is closely aligned with similar work in FAO and in the Census of Marine Life Programme
Secretariat Marginal Cost Share:	ICES:NASCO 80:20

Actions

- Alex, to present the final report on the RESPONSE and BeoFINO project
- Angel, report on ECASA project (environmental impact of aquaculture)
- Bjoern, to report on new developments in Indian River Lagoon monitoring
- Chris, to report on ongoing benthic research projects in greek waters
- Frank, report on his study on long-term image recordings in Spitsbergen
- Hans, to continue updating the BEWG website
- Henning, present final update on small scale MAFCONS
- Henning, to update on EPICATCH
- Ine, Hans report on monitoring studies on the Belgian Shelf
- Ine, report on SPEEK project
- Kerry, report on benthos research on UK seamounts
- Lene, to report on Barents Sea data collection by IMR
- Leonie to report on on HABMAG and MACFONS North Sea
- Santiago, report on ECOMARG project
- Santiago, update on the PRESTGE oil impact studies
- SB AB, HH, IM, ER, HR, SM and BT to produce intersessionally case studies on effects of dredges material disposal
- Silvana, update on UK habitat mapping project
- Steven, update BWZee

15 Closing of the meeting

The Chair thanked the participants for their enthusiastic cooperation and thanked ICES and its staff for hosting the meeting in their headquarters.

Annex 1: List of participants

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Annex 2: 2004 Terms of reference

2E07 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 seamounts as presented by MarEco and other projects and provide input to [WGDEC] in relation to the provision of advice to OSPAR on the evidence for the threats to, and/or decline in, seamount habitats and their populations in the OSPAR regions where seamounts occur [OSPAR 2005/3];

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) identify sources of available data on the North Sea Ecosystem by Expert Groups contributing to the REGNS process. This information should be submitted to the REGNS website in preparation for the Integrated Assessment Workshop to be held from 9–11 May 2005;

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;

h) with MCWG and WGBEC, contribute to an assessment of the long-term impact of oil spills on marine and coastal life, based on a list of issues from OSPAR [OSPAR 2005/7].

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

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 This is an issue of major conservation interest for ICES, OSPAR and the EU 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 This arises from the review of future activities of WGSAEM There is an ongoing discussion on sampling design and allocation of sampling effort where benthic ecologists need help from environmental statisticians. This will be an important and timely review which will contribute to the Integrated Assessment Workshop in May 2005 This will support efforts to improve the management of dredged material disposal with respect to the well-being of the benthic ecosystem There is a growing need for a 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. This is in response to an OSPAR request.
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	WGDEC, WGECO, WGEXT, WGITMO, WGSAEM, WGMHM, SGQAE, SGQAB
Linkages to other organizations	OSPAR, HELCOM EEA
Secretariat Cost share	ICES 100%

Annex 3: BEWG Agenda, 19–22 April 2005

1. Opening and Local Organisation, 10:00 hrs
   Appointment of Rapporteur
   Terms of Reference
   Housekeeping
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. Contribute with MCWG and WGBEC to an assessment of the long-term impact of oil spills on marine and coastal life, based on a list of issues from OSPAR [OSPAR 2005/7]
7. 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
8. 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
9. Work with WGSAEM on testing the use of different statistical methods on specific data sets (for example, the 1986 North Sea Benthos Survey data)
10. Review progress of development of guidelines for phytobenthos sampling with a view to publication in the ICES TIMES series
11. Review the state of benthic communities at seamounts as presented by MarEco and other projects and provide input to [WGDEC] in relation to the provision of advice to OSPAR on the evidence for the threats to, and/or decline in, seamount habitats and their populations in the OSPAR regions where seamounts occur [OSPAR 2005/3]
12. Update and finalise guidelines for sampling of the epibiota for publication in the ICES TIMES series
13. Review the environmental studies at wind energy locations at sea and make recommendations on means for a harmonized European approach to benthic ecosystem studies
14. Any other business
15. Further theme sessions and upcoming symposia
16. New BEWG Chair (nomination/election)
17. Recommendations and Action List
18. Adoption of the report
19. Closing of the meeting

Annex 4: Working Group on Marine Habitat Mapping (WGMHM)

At the WGMHM meeting last week members expressed an interest in working more closely with other ICES working groups, especially BEWG, to explore ways in which our work could be developed to mutual benefit. We recognised that BEWG and WGMHM deal with a number of closely related issues (benthic habitat/community types, use similar datasets and similar techniques and QA issues), and felt it could be helpful to exchange ideas on areas of common interest. We have overlapping interests with other ICES groups also (e.g., WGEXT, WGECO, WGFAST, SGASC) and are keen to explore closer relationships with them too. Such interactions were felt to be of potential benefit for joint ICES activities such as the forthcoming REGNS workshop on the North Sea, and the SGNSBP.

We discussed how such a proposal might best be achieved, considering a possible session at a future ASC and working through MHC. However it was felt that a more productive forum to exchange ideas would be in the Working Group environment where we could more thoroughly discuss issues of interest. To this end we discussed the possibility of running the two WGs in parallel next year, with a joint session for 1–2 days. The Marine Institute in Galway have offered to host next year's meeting and would be able to host both meetings, if BEWG were interested in pursuing this idea. We have proposed dates 4–7 April 2006, or possibly 25–28 April 2006, as I know your meetings are later. If we took this forward, we could develop a suitable programme for the joint session and potentially open it to members of other associated WGs.

I attach our draft ToR for next year to give you an idea of what will be tackled. We were particularly thinking that item 11 (ecosystem structure and function) could be developed with yourselves and other WGs.

<<ICES WGMHM draft Tor for 2006.doc>>

I would be grateful if you could consider this proposal at your meeting next week and would be happy to discuss further as necessary.

Best wishes

David
Chair WGMHM

~~~~~~~~~~~~**~~~~~~~~~~~

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WGMHM – 2005 Draft Terms of Reference

The following draft Terms of Reference for the 2006 meeting were recommended (Annex 17).

The Working Group on Marine Habitat Mapping [WGMHM] (Chair: D. Connor, UK) will meet in Galway, Ireland from 4–7 April [or possibly 25–28 April] 2006 to:

International programmes

a) Review progress of international mapping programmes (e.g., MESH, EEA, Baltic, ICES).

b) Assess and review existing habitat maps for the North Sea and make recommendations on how these maps may be further developed.

National programmes (National Status Reports)

c) Present and review National Status Reports on habitat mapping activity during the preceding year according to the standard reporting format (presentations limited to 10 minutes per country).

Mapping strategies and survey techniques

d) Refine the table of generic habitat mapping datasets, developed by WGMHM in 2005, particularly to develop a generic specification of the information needed to produce a habitat map.

e) Initiate the compilation of a list of metadata catalogues which provide data suitable to support habitat mapping studies (i.e., linked to the table of generic datasets).

f) Review the report of the SGASC relating to acoustic seabed classification.

Protocols and standards for habitat mapping

g) Finalise the definitions of the terms habitat and marine landscape/seascape for the purposes of marine habitat mapping.

h) Review and critique guidelines for habitat mapping, including the review of protocols and standards for habitat mapping developed under relevant initiatives (e.g., MESH). In addition, identify other areas where the development of guidelines is required.

i) Review progress in the development of 'discovery' and 'survey/method' metadata standards for marine habitat mapping, illustrated with worked examples.

Uses of habitat mapping in a management context (human activities; implementation of Directives and Conventions) and its relevance in understanding ecosystems

j) Review the application of and needs for habitat maps in a management context, including case studies to illustrate particular applications. Develop a link between various scales and types of maps to relevant issues and end user needs.

k) Explore the use of habitat maps in understanding and assessing ecosystem structure and function.

Annex 5: Editorial synthesis of the IOC-UNESCO workshop

IOC Workshop Report No. 195
Paris, February 2005
English only

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Editorial Synthesis and Highlights

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Overall Synthesis and Some Unifying Concepts

The workshop brought together scientists and coastal managers from different areas of the world involved in the development and application of environmental indicators for assessing and predicting the health of coastal ecosystems. Presentations and follow-up discussions focused on three general themes: development of new indicators and their implications for addressing critical coastal-research and management needs; review of relevant measurement, data-analysis, or modelling approaches; and overview of ongoing programmes related to the topic of “Indicators of Stress in the Marine Benthos,” a major emphasis of the workshop. The forum, which included two days of informal and lively round-table discussions, provided an opportunity to discuss ongoing initiatives in related fields from local to international perspectives and to exchange ideas on future directions regarding the use of environmental indicators.

One important theme that emerged was the recognition that a wide suite of tools, methods, and models would be best for such purposes rather than any one single indicator. It was also recognized that there is a wealth of existing biological and environmental observations originating from specific places and research programmes worldwide, and that there would be a tremendous advantage in bringing such information and resources together through collaborative efforts in order to provide consistent and comprehensive sets of indicators and related data for future regional to global comparisons. However, while consistent and globally applicable approaches are important, there also is a call for good regional models that provide a basis for understanding the natural states and unique properties of specific systems. Thus, there is also a need for adopting monitoring approaches that recognize and account for natural variations among various regions and ecosystem types.

The following is a list of these and other important unifying concepts that emerged from the meeting:

- Promote the use of weight-of-evidence approaches that bring together information from multiple indicators (e.g., including multiple biological endpoints as well as additional data on chemical, biogeochemical, toxicological, physical, and hydrographic conditions)
- Need for collaborative programmes to help develop consistent and comprehensive sets of indicators and processes for broad applications and comparisons (but at the same time realizing that there are often major

differences among various regions and ecosystem types, and thus that any single indicator may not work consistently across all scenarios)

- Need for better regional models of ecosystem health to help in evaluating status and trends in ecological conditions within the region and understanding whether observed changes are due to natural or human-induced sources.
- Need for reliable and accurate taxonomy as a starting foundation for many benthic indicators
- Borrowing from models of freshwater ecology may serve as a useful analogue for marine applications
- Although the benthos was a major emphasis of the workshop, it is also important to think about other biological receptors that are easy to measure and may be more directly linked to public perception.

Several presentations also addressed the topic of what an ideal ecological indicator should be, with the term indicator in this case being a measure of some important attribute of the ecosystem (either biological, physical, geological, or chemical). There was general consensus that a good indicator in this context might be one that consisted of as many of the following features as possible (also see Fisher *et al.*, 2001; Cairns *et al.* 1993):

- Conveys information that is meaningful and useful in decision-making with respect to the risk of concern
- Linkage to a conceptual stressor-response framework with corresponding thresholds signally the onset of conditions that may result in significant ecosystem degradation and thus require management action
- Amenable to measurement and preferably easy to measure
- High predictive ability (indicative of stress where stress should be occurring)
- Applicable over broad regions and environmental conditions
- Capable of surviving legal interrogation.

Other types of indicators were discussed and embraced including the use of various data-analysis techniques to assess change (e.g., basic statistical approaches; graphical methods; multivariate methods of classification and ordination; and diagnostic indices); the use of biological and oceanographic models that characterize the natural state and properties of a system, and thus provide a basis for detection of adverse change; and weight-of-evidence approaches (such as BENTIX, AMBI, and the Sediment Quality Triad) that combine suites of complimentary measurements as a basis for assessing current status and potential changes in environmental quality. Further highlights are summarized below.

Specific Highlights

An example of efforts to develop and evaluate indicators from a global (multi-regional) perspective was provided through presentations by the UNESCO-sponsored Ad-hoc Study Group on Benthic Indicators (www.ioc.unesco.org/benthicindicators), formed in December 1999 by the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Following welcoming words by the workshop's co-organizers, P. Magni (IMC representative and member of the IOC Study Group on Benthic Indicators) and O. Vestergaard (IOC/UNESCO representative), the first three presentations were given by members of this international initiative. J. Hyland (NOAA, Charleston, South Carolina, USA) gave an overview on the scope and activities of the committee, and J. Shine (Harvard University, Boston, Massachusetts, USA) presented results of the committee's recent efforts to look at organic-carbon content of sediment as an indicator of stress in the marine benthos. Macroinfaunal and TOC data from seven different regions of the world were examined to look for patterns of association consistent with conceptual-model predictions and to identify TOC critical points indicative of low to high risks of reductions in benthic species richness. R. Warwick (PML, Plymouth, England), member of the same IOC Study Group, also gave a presentation on the use of taxonomic distinctness (Δ^+) as an additional response variable for evaluating potential changes in the integrity of benthic communities in relation to anthropogenic disturbances. Desirable attributes of this and related measures of biodiversity that would be especially useful in the committee's work, as well as other similar programs, include high sample-size independence, low sensitivity to "noise" in the data, robustness to influences of natural controlling factors (e.g., changes in salinity), and high sensitivity to detection of pollution impacts.

There were additional presentations and discussions that pertained to the topic of benthic-TOC relationships. D. Tagliapietra (CNR-ISMAR, Venice, Italy) presented the results of a large survey conducted in the Venice lagoon and showed how, and to what extent, the spatial patterns of benthic assemblages can be a function of organic matter. Tagliapietra stressed the importance of considering the degree of lability of organic matter and added that, particularly for transitional systems, the residence time seems to have a major effect on the "physiological" distribution patterns of species diversity. A proposal was then made by S. Guerzoni (CNR-ISMAR, Venice, Italy) to implement international protocols to foster the use of common methodologies (i.e., TOC and organic-matter determination) and thus to help facilitate the comparison of results among different study areas. There was a general agreement on this matter. Besides the need for a better standardization of methodologies, the value of TOC as a screening-level indicator was recognized, in addition to its importance as a fundamental variable in the definition of the trophic state (and anthropogenic impact) of an ecosystem. Such efforts to standardize monitoring approaches should be applied to other variables and endpoints as well (not just the measurement of TOC).

An action plan resulted from this latter discussion. Specifically, P. Viaroli (Parma University, Italy), Tagliapietra, Guerzoni and Magni — who are all members of "LaguNet" (the Italian Network for Ecological Research in coastal lagoons and transitional waters, www.dsa.unipr.it/lagunet) — proposed to test benthic-TOC relationships in samples from relatively similar systems, using historical datasets from coastal lagoons in Italy. The focus of such an exercise on a particular typology of coastal-marine systems might help to reduce variability in the data due to natural factors (e.g., estuaries *vs.* coastal sites, or oligotrophic *vs.* eutrophic systems), which could otherwise mask any potential effects due to anthropogenic factors. It was thus agreed to make such comparisons, based on several existing studies conducted in lagoons around Italy. As a first step, which was already started in December 2004 (Magni, Tagliapietra and Viaroli, pers. com.), each group of investigators will work autonomously on a volunteer basis, using their respective data sets. Following these initial independent analyses, there would then be an *ad-hoc* meeting among the participants to compare individual results and to discuss ways of merging the various datasets in support of a combined integrative analysis. Proper funds should be searched along the way, at both the ministerial and private level. Similarly, regarding other future efforts to coordinate results of individual research and monitoring programs, it was proposed and agreed to have a data exchange among various participants in order to correct for potential methodological differences (e.g., sample size, sieve size, etc.) and to see whether meaningful patterns can be detected.

Other significant points and recommendations were made as well. With regard to comparing and predicting trends in benthic community structure, M. Scardi ("Tor Vergata" University, Rome, Italy) suggested that marine ecologists should be in touch with the freshwater scientific community and take into consideration the significant experience they have gathered from these systems. H. Rumohr (IfM-GEOMAR, Kiel, Germany) also pointed out the need for developing and using regional biological models (such as the five-step benthic succession model for the Baltic Sea) as a management tool. Such models would provide a basis for understanding the natural state and properties of a system within a particular region and what to expect under disturbed conditions. À. Borja (AZTI Foundation, Spain) further underlined the need for recognizing and accounting for variations among different regions and systems. Borja, for example, pointed out the major differences that exist between northern and southern Europe. This point was also reinforced by Viaroli who described inherent differences between large and well-flushed estuaries vs. sheltered lagoons with high water retention times.

With regard to management applications, H. Rees (CEFAS, UK) gave an overview of criteria for evaluating scientific and management effectiveness of benthic indicators, which he presented as one of the current initiatives being addressed by the International Council for the Exploration of the Sea (ICES). Key criteria used in a preliminary ranking of several existing indicators are included in the list above. Rumohr presented a five-step succession conceptual model applied to the southern Baltic (as mentioned above) and highlighted the benefits of combining routine benthic sampling with sediment-imaging techniques. Rumohr, as a member of ICES and Chair of the Benthos Ecology Working Group (BEWG) of ICES, also introduced briefly the work of ICES and BEWG. ICES is the oldest organization that coordinates and promotes marine research in the north Atlantic. It acts as a focal point for a community of more than 1600 marine scientists from 19 countries around the north Atlantic. ICES plans and coordinates marine research through a system of committees, including more than 100 working groups, that cover most aspects of the marine ecosystem. ICES is planning to hold a symposium on Marine Environmental Indicators in 2007, with IOC as one of the co-sponsors. Hyland, Chair of the UNESCO/IOC *Ad-hoc* Study Group on Benthic Indicators, proposed that the 2007 ICES symposium be a forum for the presentation of any data and collaborations that may result from the present Sardinia workshop. Rees, co-convener of the 2007 ICES symposium, also agreed to include any such developments in the symposium agenda. This idea was unanimously accepted by the workshop participants.

Presentations by À. Borja (AZTI, Spain) on the use of the AMBI Biotic Index, and by A. Zenetos (HCMR, Greece) on the use of the BENTIX index, were discussed in the context of the European Water Framework Directive (WFD 2000/60/EC), with this latter program being described in more detail by C. Silvestri (APAT, Rome). AZTI and BENTIX were further compared in the presentation by G. Forni (Pavia University, Italy) who tested both approaches on benthic communities in the northern Adriatic Sea. Results showed that the two newly developed indices, based on the same principle (ecological identity of benthic species according to their response to pollution) produce somewhat similar results. However, there are discrepancies observed in the scoring of species and further restrictions to their use in certain environments. It was agreed that the differences should be resolved by collaboration of the two groups (AZTI and HCMR) and, if possible, that the two indices be integrated into a common tool in efforts to minimize confusion among scientists working in the Mediterranean area.

A. Marchini (Pavia University, Italy), using data on the distribution of hard-bottom assemblages in the Lagoon of Venice, described a new and innovative approach, the “fuzzy logic” model, as a potentially powerful tool for classifying different ecological sectors in such dynamic systems that are controlled by a complexity of natural factors and human influences. Furthermore, I. Karakassis (University of Crete, Greece) proposed new tools and prospects for environmental impact assessments in areas of fish farming in the eastern Mediterranean. Viaroli also proposed a biogeochemical approach to evaluate ecosystem functions and properties in coastal lagoons. Additional approaches included the use of thermodynamic and network-oriented indicators by P. Vassallo (Genoa University, Italy) and community-structure models by E. Fresi and M. Scardi (“Tor Vergata” University, Rome, Italy). M. Zavatarelli (Bologna University, Italy) gave an overview of the Adriatic Sea ecosystem-modelling initiative, and discussed the application of a coupled physical/biogeochemical ecosystem model as a preliminary step to operational forecasting and climate-change studies of the Mediterranean Sea ecosystem.

Regarding broad-scale indicator testing at the European level, it was expressed that in spite of efforts of the European Environment Agency (EEA), various countries may not be ready yet to deliver large sets of data to EEA for such purposes. Consequently, pertinent results to date are based largely on smaller-scale case studies (e.g., Greek and Norwegian data sets). At the regional level, Zenetos on behalf of UNEP/MAP (United Nations Environment Programme, Mediterranean Action Plan) indicated that a current task of UNEP/MAP is the preparation of fact sheets on biological indicators, so as to issue guidelines on EQS to be used by Mediterranean countries. Initial results of the testing were presented with data from Greece, Turkey, Syria, Italy and Spain. A major future task will focus on additional validation with other data sets, which will require further collaboration among countries throughout the entire Mediterranean region.

There is also a need for a common set of indicators and monitoring approaches for use in shallow transitional waters (e.g., wetlands and coastal lagoons) that account for some of the unique properties of these systems. For example, one of the major goals of the EU Framework Water Directive (2000/60/EC) is to promote an agreed-upon and common approach to studies of biogeochemical processes as support for management and policy applications. Within this context, Viaroli made a brief presentation of the LaguNet network (also see above). LaguNet provides a forum for discussion and cooperation between researchers who are studying biogeochemical processes in lagoons, wetlands, and salt marshes along the Italian coasts. Key goals of LaguNet include conducting assessments of the quality of these systems, interacting with important stakeholders, and developing EU project-proposals either in Italy or in Europe (with Mediterranean EU partners as well as eventually eastern Europe and North Africa). An overarching goal of LaguNet is aimed at promoting common approaches to the study of biogeochemical processes in these ecosystems that can provide support to management or policy applications.

The LaguNet approach was also developed in Greece and Portugal, is in progress now in the Black Sea region, and will be further implemented in Spain. Overall, a product of this bottom-up networking would be a regional network federation, covering the Southern European Arc (SEANet). The LaguNet approach also has been used within the implementation plan of the Coastal module of the Global Terrestrial Observing System (C-GTOS). The goal here has been to characterize the basic stressor delivery system, namely the release of organic matter, phosphorous (P), nitrogen (N) and chemicals from watersheds into the adjacent ocean systems. A significant challenge is that shallow transitional waters and coastal lagoons are under the influence of multiple factors and have a great internal patchiness and heterogeneity, which can often bias the application of the most common indicator and indices of environmental quality and health status. Here, water-quality criteria that are suited for deep lakes and marine ecosystems cannot be used due to the shallow depth. Overall, the water-volume/surface-area ratio is of paramount importance in determining levels of ecosystem metabolism throughout benthic communities. Issues to be analysed cannot be resolved by considering only simple variables and linear relationships. Usually, the conventional trophic-status parameters and thresholds developed for deeper systems do not apply to coastal lagoons, the pelagic components being quantitatively less important than the benthic subsystem, especially when macrophytes become dominant. Under these circumstances, one should identify a set of basic benthic/sedimentary variables indicative of operative ecosystem properties and functions and that could be used for classification and quality-assessment purposes.

The approach of these latter networks at present is based mainly on the assessment of biogeochemical budgets of C, N, and P and does not consider benthic-community features. Viaroli proposed to start a collaboration between LaguNet and IOC in environmental-assessment and data-exchange issues, in order to help fill some of these critical gaps. O. Vestergaard (UNESCO/IOC) indicated that the collaboration between IOC and LaguNet could help to increase methods of assessment. On behalf of UNESCO/IOC, Vestergaard also pointed out that one of the roles of IOC is to give support for data systems to developing countries. The importance of regional models was again stressed. The need for the development of a rapid-assessment programme also was expressed.

The workshop was a testimony of the importance in bringing scientists and coastal managers together in an international forum to promote open information exchange; to develop a better appreciation of the range in coastal environmental issues and corresponding approaches to addressing them in different parts of the world; and to reach consensus on solutions to some common problems, as well as the need to work collaboratively in the future (e.g., toward the development of consistent sets of indicators and protocols) to provide a stronger basis for understanding and predicting regional to global patterns of coastal-ecosystem health.

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Annex 6: Catch efficiency of a standardized 2 m beam trawl (Epicatch)

By 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 2m-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 6 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 results indicate that the proportion of the epibenthos caught by one trawl in terms of total abundance and biomass is less than 50 %. The catch efficiency was calculated for each of the abundant species separately, ranging from ≤13 % for infaunal bivalve *Nucula nitidosa* and 72 % for the shrimp *Processa* spp. 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 18 % and less. Also the number of endobenthic species was higher in the second and third trawl, probably dug up by the first trawl.

Significant differences in the catch efficiency between the two sediment types were found for the goby *Pomatoschistus minutus*, the shrimp species *C. allmanni* and the swimming grab *L. holsatus*. In each case the catch efficiency was lower on coarse sandy sediments than at muddy sediments, probably due to the higher penetration depth of the trawl in muddy sediments.

Annex 7: Wave energy installations and the impact on benthos fauna and flora

Due to the current situation of the energy production (dependent on oil) some countries are facing the possibility in using marine energy. One of the emergent possibilities comes from wave energy. Hence, in some European countries there are several projects to start with the use of this energy (e.g., in Spain at least 3). The EC objective is to increase from 6% in the use of renewable energies, in 1997, to 12 in 2010, and 18% in 2030.

The European potential in wave energy is high: 120–190 TWh/y offshore and 36–46 TWh/y nearshore. However, the methodology for its exploitation is currently under development (near 600 industrial patents), but there are problems with irregularities in wave size, phase and direction. More than 20 companies are developing equipments, which can be classified as outlined below (underlined equipments are the most developed).

i) On shore: <u>Oscillating Water Column</u> (OWC), Tapchan, Pendulor.

ii) Near shore: OWC.

iii) Off shore: (a) Solid bodies moved by waves: <u>Pelamis Wave Energy Converter</u>, Salter Duck, Archimedes Wave Swing (AWS) and <u>buoy systems (OPT);</u> (b) Systems over sea surface: Wave Dragon, Waveplane; (c) OWC.

In general, the environmental impact of marine energy technologies tends to be minimised. The US Wave Energy Project Environmental Assessment (with the next partners: EPRI; Global Energy Partners LLC; state energy agencies from Maine, Massachusetts, California, Oregon, Washington, Hawaii; Department of Energy; NREL; and Virginia Tech University) has evaluated the impact of 6 Wave Energy Conversion buoys, over 2 years, at Marine Corps Base Hawaii (www.wave-energy.net).

Table A7.1. The activities producing environmental impact.

ACTIVITIES	ENVIRONMENTAL CHANGE	POTENTIAL IMPACTS
Subsea cables (installation and operation)	Mobilisation of silt	Siltation and deposits on benthic communities
Installation of mooring system	Temporary and permanent anchoring	-Damage to benthic communities -Changes on available habitats
Functioning of hydraulic motors	Leaking fluids	Water pollution with effects on biota
Maintenance	Use of anti-foulings	-Removal of marine growth can increase scavengers in nearby bottoms -Damage to communities
Accidents	Several risks (oil release, sinking, etc.)	Damages to communities

Although, the most important impacts come from the presence of the wave farm itself. The impact level will depend on the size of the farm. Taking into account the low efficiency of the devices, this problem is compensated by increasing the size and occupied sea surface (this is a problem of scale). The farm produces changes in hydrophysical regime, due to abstraction of energy. The wave height reduction represents 10–15% behind the farm, extending up to 3–4 km. This can produce different potential impacts:

- Changes in coastal habitats due to changes in hydrodynamic processes and sediment regime (erosion, etc.);
- Changes in the abundance of some benthic resources, such as algae (*Gelidium sesquipedale*), goose barnacle (*Pollicipes pollicipes*), shellfishing, etc., in which their abundance is closely related to wave energy.
- Alteration of benthic community structure, favouring certain species over others (e.g., fleshy red algae over Corallinacea): competence.
- Destruction of kelp-forest (Laminariaceae)

From these impacts, some recommendations can be deduced:

- The use of offshore devices is preferable to nearshore and onshore devices
- The use of cliffs should be avoided (only methods included in breakwaters and seawalls could be considered).
- Offshore systems should be used >40 m water depth and at >5–15 km from the coastline, depending upon the farm size.
- Areas near benthic resources, protected habitats or phanerogams presence should be avoided

Annex 8: The RESPONSE project

By Alexander Schröder, Alfred-Wegener-Institute for Polar and Marine Science, Bremerhaven.

(„*Response of benthic communities and sediment to different regimens of fishing disturbance in European coastal waters*")

This project 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 & MSM, Spain; CIBM, Italy; UWB, Wales; AWI, Germany) and runs from 10/2002 to 09/2005. Details can be found on the project's web site 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:

- morphology, texture and composition of sediments;
- the structure and recovery of benthic invertebrate and demersal fish communities;
- 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 and 60m

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:

- a comparison of fished and unfished areas; and
- a comparison of the situation in areas of high and low fishing effort or even periods of varying fishing intensity.

The German study is centred round 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 500m 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 continued with five consecutive samplings up to 15 month, 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 150m. Fishing intensity is estimated by sidescan sonar surveys and VMS data; benthos is studied by van Veen grabs, beam trawls, photography and video; sediment samples are taken for grain size and organic content analysis. Continuous measurements of hydrographical factors are taken on the platform.

All data have been compiled and analysis is underway. Preliminary results indicate some changes in the fauna of the protected area, but the seasonal differences are very large. From three month after the construction onwards, the epifaunal community differences between protected and fished areas as measured by ANOSIM R-values increased continuously, while the differences between reference areas remained at the same level. Densities of scavenger species like swimming crabs (*Liocarcinus holsatus*) were higher in the fished areas, while other species (e.g., *Ophiura* spp.) were more abundant in the protected area. Although significant differences were found after 15 month of closure in in- and epifauna, differences were larger in the epifauna than in the infauna. Further analyses are needed and final results will be reported at the next BEWG-meeting.

Annex 9: Does the fauna in closed areas around Production Platforms in the Southern North Sea reflect different fishing intensity?

Gerard Duineveld, Marc Lavaleye and Magda Bergman.

(Royal NIOZ, study commissioned by Ministry LNV in cooperation with Alterra)

Introduction

Chronic beam trawling in the Southern North Sea is considered to have destroyed the habitat, led to reduced benthic biodiversity and to shifts in the food web. Many studies (e.g., IMPACT- Lindeboom and de Groot 1998) showed beam trawls to inflict direct mortality and lethal damage to the benthos, or exposure to predators. Mortality varied between species (0–65 %) and was particularly high among bivalves. Longer term effects remain a matter of debate and speculation partly due to scarcity (non-existence) of undisturbed areas. However, there are small areas around Production Platforms (500 m radius) that are forbidden for beam-fishery. In this research we focused on such an area and tried to address the following questions. Do closed areas around production platforms represent such undisturbed areas? Do differences with nearby fished areas - if any - point to fishing effects?

Methods

The Platform must long standing, be clean (no OBM used during drilling), and with a sufficient level of fishing in vicinity! On the basis of these criteria Platform L07A located in the Frisian Front was chosen. This Platform is in operation for 20 years and has no OBM history. Beam-trawl fishing is quiet heavy with up to 300 activities in 2003. In April 2004 samples were taken in the closed area around this Platform and in 4 Reference areas (North, South, East & West). The Triple-D dredge for less abundant larger infauna and epifauna and a box-corer for common infauna organisms.

Results

The Triple-D samples yielded **distinct** differences between Platform and reference areas. PRIMER™ ANOSIM showed Ref-S to be different from other reference areas. Ref-S was therefore excluded. Platform hauls were distinctly different from Ref-N, -W and -E. Species responsible for the differences between Platform and Ref hauls were mud-shrimps, ophiuroids and large bivalves. The species diversity in the hauls (ES=200) was significantly higher near the platform.

Boxcore samples did **not** yield distinct differences between Platform and Reference areas. Ref-S also differed in terms of boxcore fauna from other Reference areas as shown by ANOSIM. Platform samples were not different from Ref-N, -W and -E.

Despite overall higher similarity between boxcores from Platform and Reference areas, there was a tendency for diversity to be higher near the Platform. In accordance with Triple-D hauls mud-shrimp density was also higher near Platform.

Concusions

- Triple-D clearly demonstrated higher abundance of vulnerable species (e.g., large bivalves) near the platform.
- Diversity was highest near the platform in both Triple D hauls and boxcore samples.

- Markedly reduced abundance of deep-living mud-shrimps in the reference areas is probably due to destruction of physical habitat rather than mortality.
- This pilot study shows that closed areas around production platforms can be used to study effects of a reduction in beam trawling on different time-scales.

Recommendations

- Any difference between boxcores from Platform and Reference areas tends to be masked by few abundant opportunists (here *Phoronids*) plus large number of species with one or two individuals.
- Only large numbers of boxcores can reveal difference in abundance of large bivalves which naturally occur in low density. 3
- Multiple reference areas are required to correct for exisiting (natural) gradients as in this case Ref-S.

Annex 10: Progress made in the BWZee project (marine biological valuation) during the first year

In order to implement sustainable management in the marine environment, reliable and meaningful ecological information for a study area is needed. Biological valuation maps that compile and summarize all relevant and available biological and ecological information for an area, and that allocate an overall biological value to subareas can provide a very useful warning system for future management decisions. The BWZee project tries to develop a marine valuation strategy that is able to assess the intrinsic value of marine biodiversity in terms of nature conservation, regardless of its socio-economic value.

From 2-4 December 2004 an international workshop on marine biological valuation was held in Ghent (Belgium). The focus of the workshop was on the selection and use of valuation criteria in the marine environment. This selection of criteria constitutes the first work package of the BWZee project and is therefore a crucial step towards the further development of a scientifically underpinned biological valuation map.

The input of a team of international experts on biological valuation of the marine environment in this criteria selection helped us to develop a solid and scientifically acceptable methodology which is applicable in every marine environment. So, while the scope of the project is to develop a national BVM, the workshop enabled us to produce a valuation strategy that could be applied worldwide.

It was emphasized during the workshop that:

- a marine biological valuation strategy should suit the dynamic and complex character of the marine environment
- the criteria must be simple and univocal, so they can be applied to all marine life forms and ecosystems
- a marine BVM should also be easy to interpret and be useful for marine policy
- the map(s) must represent a realistic view of the intrinsic value of the marine area

Several methods for biological valuation in the marine environment or site selection criteria for the installation of nature protection areas (Bird/Habitat Directive areas, MPAs, Ramsar areas,...) already exist. Before the international expert workshop a review of all available methods/criteria, described in the literature was carried out and this evaluation was used as a starting point for the discussions within the workshop.

Since several projects to develop similar valuation tools are being initiated in different regions, the consultation of this overview could significantly decrease the effort of finding the relevant literature.

Also, a BVM for the terrestrial part of Belgium already exists and the methodology used to develop this map was presented during the workshop (see presentation of Desiré Paelinckx below). This greatly enhanced the comprehension of the objectives of the marine BVM.

So the main objectives of the international expert workshop were:

i) To discuss the working document on existing biological valuation criteria/methods.

ii) To develop a practical valuation strategy that can be applied in the marine environment, with consideration of the most appropriate valuation criteria, methods to apply them and development of a scoring system.

Important conclusions of the workshop were:

- the working document (review), reviewing all existing ecological valuation criteria/methods, should be adapted regarding the discussions held during the workshop. Clear definitions of 'value' need to be included and the objective of the valuation should be mentioned. All redundant criteria should be removed and a final list of valuation criteria should be constructed, accompanied with definitions.
- A valuation strategy needs to be developed around these criteria. Biodiversity should be treated differently than the other criteria and could be assessed by selecting questions related to the 'marine ecological framework' table made by Zacharias and Roff (2000, 2001). When these questions are carefully chosen, a link between biodiversity and the other criteria could be formed and an objective assessment of the criteria is guaranteed. Using the table enables us to include as many biodiversity components as possible.
- A scoring system should be outlined, based on the results of a case study, comparing all different kinds of scoring schemes.
- The purpose of the BVM should be communicated clearly to all users and quality labels and extensive databases should accompany the maps.
- The valuation strategy developed should be made public by submitting a scientific paper on the topic and by displaying the workshop results through a project website. This website should also aggregate all literature that was used for the development of the valuation strategy, in order to reduce the efforts of future colleagues.

Currently a scientific paper on marine biological valuation, outlining the valuation strategy that was developed during the workshop, is being prepared. The marine biological valuation strategy that will be presented in this scientific paper will combine all ecological criteria that are available in the literature into a single widely applicable and practical biological valuation framework. We have also attempted to clarify the numerous criteria and definitions of value that are current in the literature. We also realize that many marine areas are not thoroughly surveyed, and that major data gaps exist. Our valuation strategy anticipates problems with the applicability of certain criteria in data-poor areas by presenting alternative assessment questions. Although suggestions for the possible application of the various criteria are given, the ideal scoring system still needs to be defined. An objective scoring system can only be achieved when the different possibilities are tested in defined case study areas, where good data on all levels of biodiversity exist and where expert judgement is available for the assessment of the valuation outcome. These tests are included in the MARBEF Theme III Responsive Mode Action.

Annex 11: Benthic Infaunal Monitoring of the St. Lucie Estuary and the Southern Indian River Lagoon, Eastern Florida

Total Project Cost: USD 450,000 (the first 3 years)
Principal Agency: Smithsonian Institution
Principal Investigator: Bjorn G Tunberg
Mailing Address: Smithsonian Marine Station, 701 Seaway Drive, Fort Pierce, FL 34949, USA
E-mail: tunberg@si.edu

Introduction/background

The Water Resources Development Act (WRDA) of 2000 authorized the Comprehensive Everglades Restoration Plan (CERP) as a framework for modifications and operational changes to the Central and Southern Florida Project needed to restore the south ecosystem. Provisions within WRDA 2000 provide for specific authorization for an adaptive assessment and monitoring program. A Monitoring and Assessment Plan (MAP) has been developed as the primary tool to assess the system-wide performance of the CERP by the REstoration, COordination and VERification (RECOVER) program. The MAP presents the monitoring and supporting research needed to measure the responses of the South Florida ecosystem.

The MAP also presents the system-wide performance measures representative of the natural and human systems found in South Florida that will be evaluated to help determine the success of CERP. These system-wide performance measures address the responses of the South Florida ecosystem that the CERP is explicitly designed to improve, correct, or otherwise directly affect. A separate Performance Measure Documentation Report being prepared by RECOVER provides the scientific, technical, and legal basis for the performance measures.

Generally, the statement of work described below is intended to support four broad objectives of this monitoring program:

- Establish pre-CERP reference state including variability for each of the performance measures;
- Determine the status and trends in the performance measures;
- Detect unexpected responses of the ecosystem to changes in stressors resulting from CERP activities;
- Support scientific investigations designed to increase ecosystem understanding, cause-and-effect, and interpret unanticipated results.

Objectives

The main objectives of this project are: 1) to evaluate the present health status of the St Lucie Estuary and the Indian River Lagoon (IRL) south as baseline data, 2) to record and follow long term changes in these ecosystems, 3) to attribute causative factors to observed changes (i.e., freshwater runoff/release, natural successions and oscillations, climate change, other anthropogenic impacts), 4) to pinpoint and evaluate anthropogenic disturbances, 5) to provide reference data for possible intensive short term local monitoring programs.

Work breakdown structure

Monitoring area

The study area includes the St. Lucie Estuary and the southern part of the Indian River Lagoon in eastern Florida. Thirteen preliminary sites have been selected for the program (Figure 1).

Field approaches

Quantitative macroinvertebrate sampling is performed at the thirteen sites quarterly (three to four replicates per site, 156-208 discrete samples per year). The samples are collected utilizing a 0.04 m^2 Ponar grab apparatus. These samples are preserved in the field (in a solution of 4% buffered formalin, diluted in sea water) after being extracted through a 0.5 mm mesh size sieve.

Bottom substrate samples for sediment analyses are also collected by means of an Ogeechee corer. Two cores are sampled independently. The sediment from the cylinders is further divided into sub samples from two substrate depths (0–2 cm and 2–5 cm).

The color of the sediment at ca 5 cm substrate depth is defined by means of a rock color chart. The sediment types as well as the absence/presence of H_2S are also determined. Separate sediment core sampling for granulometric analysis will be conducted at each site once per year.

Surface and bottom water temperature, dissolved oxygen, pH, turbidity, Secchi depth, and salinity are measured at each site on each sampling occasion. The time of day and weather conditions (wind direction and strength as well as wave height) are also recorded at each sampling site on each occasion.

Laboratory procedures

All the animals are identified to the lowest possible taxon, and the number of each separate species is determined. Biomass will not be calculated during the initial studies. This for practical reasons. The animals collected are almost exclusively very small. Estimation of biomass as wet weight is therefore not of any significant value.

Data management, analysis and presentation

All data will initially be entered and stored in a spreadsheet for preliminary data treatment, and will then be transferred to the Florida Department of Environmental Protection (FDEP) BioDatabase, which is a secure repository specifically designed and managed for macrobenthic data and can output the data in a variety of formats amenable to statistical treatment. Data analysis will be performed using a combination of several different software packages including Sigmastat 3, Sigmaplot 8, Statecol, Statistica 5.1, and Corel Draw 10. PRIMER 5 will provide multivariate techniques to compare several aspects of community composition within and between sites over time, and will be used within this project as one of the major data treatment components.

Changes in time and space are further defined and interpreted from information in the literature concerning the sensitivity of the separate species to certain environmental disturbances. The species are also divided into different functional groups, e.g., concerning feeding habits, reproduction, etc.

Quality assurance

To assure data validity and control errors through data validation, automatic error checking code is built into the database repository. For example, upon data entry, the program will check for a reasonable range for many variables such as salinity, temperature, dissolved oxygen, and GIS location. This will prompt the entry clerk to recheck numbers if the data are out of expected bounds, and prevent the possibility of introducing error from either database entry or from field recording. If, after rechecking, the numbers are still found to be out of expected bounds, then the principal investigators will examine the field data sheets and determine if the outliers are, in fact, errors. At this point, the data points will be flagged for removal from the final databases. A two-person team will do all proofing/validation. All field and lab datasheets will be maintained for a minimum of five years after the completion of the project. The following guidelines will be used for the field and laboratory procedures: DEP-SOP-001/01 (Department of Environmental Protection Standard Operating Procedures for Field Activities), DEP-SOP-002/01 (Laboratory Activities) and DEP-QA-001/01 (New and Alternative Analytical Laboratory Methods). CERP QASR (Quality Assurance Systems Requirements Plan) will be incorporated when that guidance is made available.

Reports

Quarterly and annual reports (including raw data files) will be submitted both in printed versions and on electronic media. Summary reports on a yearly basis will be developed in coordination with the RECOVER Northern Estuary Module group. These yearly reports will then be used as the basis of reports that will go to the National Academy of Sciences every two years and will provide the basis of the CERP reports to Congress which will occur every five years. The reports will include an assessment and/or analysis of the data or activity as it relates to CERP hypotheses from the MAP.

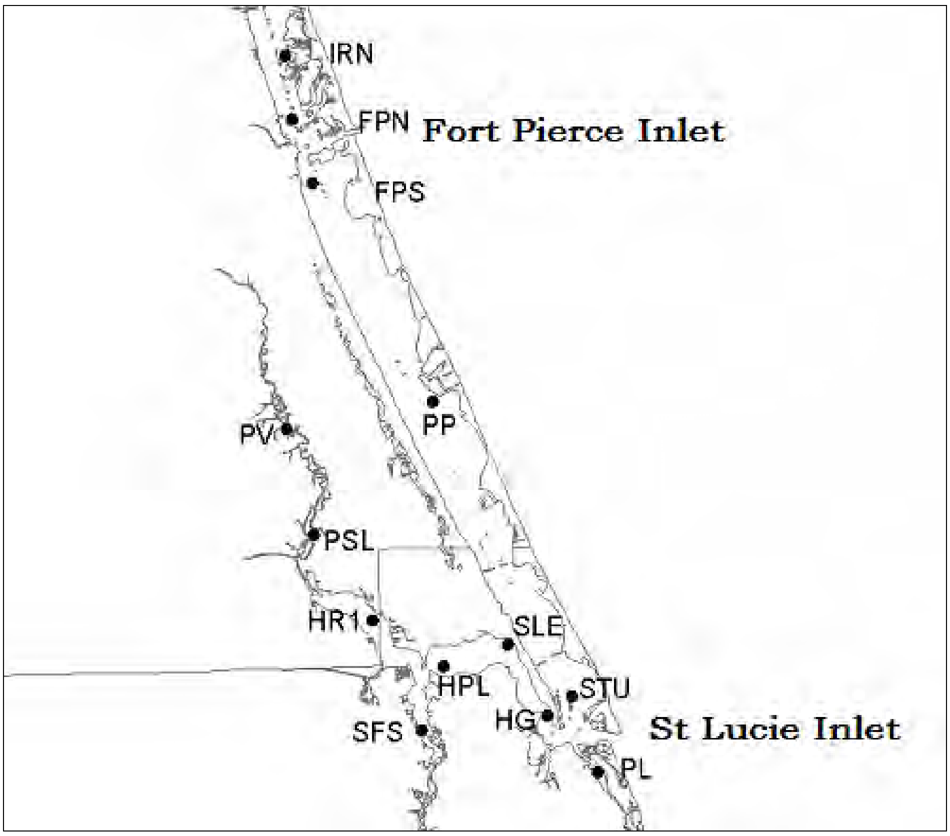


Figure A11.1. St Lucie Estuary and IRL south invertebrate sample collection sites.

Annex 12: The BeoFINO project

By Alexander Schröder

Alfred-Wegener-Institute for Polar and Marine Science, Bremerhaven.

"*Ecological Research on the impact of Offshore Windfarms based on research platforms in the North and Baltic Sea*" (www.fino-offshore.de)

This is a national research project funded by the German Federal Environmental Agency (Umweltbundesamt), the first part was finished in Dec. 2004 and the final report will be ready by July 2005. A follow up project BeoFINO II has been granted recently running until Dec. 2007 continuing the ongoing research with some changes in focus.

A final goal of this study is to contribute to the development of methods and criteria for an evaluation of the effects of offshore wind farms 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) app. 30 nm north off 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 wind farms. 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 substrate 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 potential pool for settling larvae is included in the project.

In- and epifauna in the close vicinity of the pile is studied by grab samples (also used for sediment analyses) and video taken regularly from the platform. Additional sampling from ships in the surrounding three times per year includes also beam trawl hauls. The growth on the underwater construction of the platform is monitored regularly 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. Meteorological 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.

Analyses of data from the first year are underway, only some preliminary result can yet be presented. Experiments on effects of electromagnetic field could not prove any influence on mortality of the tested species and behavioural influences were only seen for Brown Shrimp (*Crangon crangon*). Epifauna of the FINO1 underwater structure showed a very quick complete colonisation by hydroids within few weeks, followed by a succession with a quickly increasing number of taxa. Over time a considerable amount of biomass has been build up, differentiated in different depth zones. Species composition and dominance is constantly changing, with a high dominance of Amphipods (*Jassa falcata*) over prolonged periods. Lately the shallower areas are completely covered by Mussels (*Mytilus edulis*). Interpretation of meroplankton data is at present very difficult due to the large temporal variability and further analyses are needed. Large amounts of shells have accumulated in the scouring pit, which has reached a depth of app. 1.5 m. Infauna in the direct vicinity of the pile changed significantly with a clear gradient in density of predatory species decreasing with distance, while typical infauna species increase.

The follow-on project BeoFINO II “Ecological Effects of Offshore Wind Energy Farms on Benthos in the North and Baltic Sea“ focuses on benthos, with the main topics being the comparison of North and Baltic Sea, interannual variability and assessment of cumulative effects by means of a model.

Final results from the first period and progress will be reported at the next BEWG-meeting.

Annex 13: Artificial reefs in the archipelago of Gothenburg, Sweden: Progress report nr 2 (5)

By S. Smith

In the European Artificial Reef Research Network (EARRN) 36 laboratories (2000) were involved and now there are about 10 countries active in artificial reef research. Reef structures and the ongoing research have much to offer in terms of habitat management, nature conservation, fisheries management/enhancement and coastal defence

Further reading in ICES NO. 41 (2004), Ships, oil rigs and tyres: making reefs in European waters?

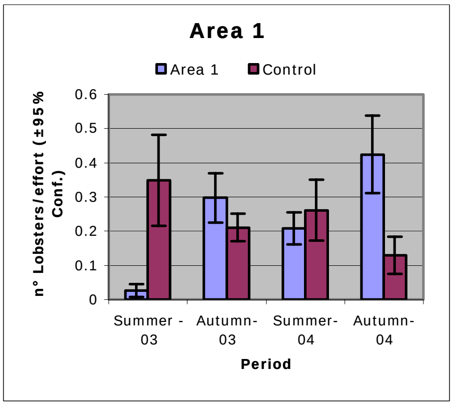
The Swedish contribution was presented last year in San Sebastian and this is a follow up on the 5 year project. The objectives of the project is to monitor the rate of epibiotic and fish and shellfish colonisation and to evaluate its overall effect in regard to productivity and spillover to the surroundings. Some of the preliminary results from three of the four of the different parts of the programme are presented.

1 ROV documentation

A DVD film.

2 Investigation on lobsters

Twice yearly 20 lobster pots were used to catch lobsters and crabs at the reefs and at natural sites within the no-take zone during 2003 and 2004. All the individuals were measured and tagged and released back again. The population density was estimated by number per pot/effort per day. The first period in summer the density was significantly lower at the reefs compared to the natural sites but higher during early autumn. This means that colonisation mainly took place in the late summer months. After two years of investigation the conclusion is that the artificial reefs attract lobsters from the surroundings (see Figure). This in turn means that access to suitable dwellings at the reefs were higher at the introduced reefs.



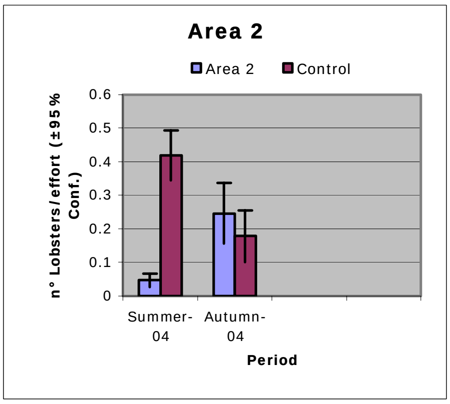


Figure A13.1: Numbers of lobster /effort on areas 1 and 2.

3 Epibenthos: the development between 2003 and 2004

Table A13.1: Number of species 2003 and 2004

ALGAE	AREA 1		AREA 2	
	Reefs	Natural hard bottom	Reefs	Natural hard bottom
	3–0		0–15	
Total	**10**	**15**	**15**	**22**
Invertebrates				
	17–24		15–30	
Total	**25**	**43**	**34**	**68**

In Area 1 *Ciona intestinalis* was the dominating organism since August 2003, an fenomenon only recorded at one site in the control area. *Balanus crenatus* dominated in Area 2 during spring 2004 while *Ciona intestinalis* and young *Laminaria saccharina* were more prominent later during the year.

Annex 14: The impact of the Prestige oil spill on the infaunal and hyperbenthic communities of the Continental Shelf off Atlantic NW Iberian waters (Galicia)

S. Parra, I. Frutos, A. Serrano, F. Sánchez, I. Preciado, and F. Velasco.

Abstract

For two years researchers at the Spanish Institute of Oceanography have been studying the impact of the *Prestige* oil spill (POS) on the benthic communities inhabiting the soft bottoms of the Galician continental shelf. A total of five multidisciplinary oceanographic surveys were conducted to carry out a joint examination of the macroinfaunal (box corer), hyperbenthic (hyperbenthic sledge), epibenthic (beam trawl) and megabenthic or demersal (Otter trawl) communities along eight transects perpendicular to the coastline in the zone most seriously affected by the spill. Moreover the samplings carried out using the beam trawl were used to determine the amount of tar aggregates on the continental shelf. However, no major changes were observed in the temporal evolution of the sediment characteristics (granulometry and organic content) in the stations surveyed over the entire study period (2002–2004).

As regards the temporal evolution of the infaunal communities of sector 1, in stratum A, it is interesting to highlight the increase in the abundance of polychaetes and molluscs and the decrease in the group "others" in spring. In stratum B, on the other hand, we observed a slight drop in spring in the abundance of the polychaetes and a significant rise in molluscs and crustaceans, and, to a lesser extent, in the group, "others". In the stations located in the shallowest (stratum A) of sector 2, the abundance of the polychaete group was seen to diminish in spring, while the echinoderms, and, to a lesser extent, the groups, molluscs, crustaceans and "others" underwent a substantial increase. Stratum B showed a slight increase in spring in the abundance of the group molluscs and crustaceans and a decrease in the group "others". Overall, slight variations were observed in the population parameters between winter and spring in Sector 1. The most significant changes in spring consisted of a slight decrease in total abundance, in the abundance of some of the minor groups and a moderate increase in crustaceans, particularly in the deepest stratum. Species richness, diversity and evenness diminished slightly in spring. In Sector 2, specific richness dropped considerably, as did diversity, but to a lesser degree, while evenness rose slightly. The most striking decrease was in total abundance and in the group "others", while increases were recorded in spring for the groups, molluscs, echinoderms and crustaceans.

In the suprabenthic communities surveyed in stratum A of sector 3 in spring, there was an increase in the abundance of the group euphausiids, along with a substantial decrease in the groups, amphipods and mysids. In stratum B, the amphipods underwent a considerable increase, while the cumaceans and euphausiids decreased very slightly in spring. In the deepest stratum (C), however, where the community was dominated by the decapods in winter, these animals diminished substantially, and this gave rise to a predominance of the euphausiids.

We did not find any significant correlations between the tar aggregates and the species richness, biomass, diversity of the benthic communities. This result was corroborated when the role of depth, season, latitude and sediment characteristics was examined by canonical ordination, in which POS-related variables had little influence on spatial distribution patterns. Depth and sediment grain diameter greatly influenced epibenthic and demersal communities. Sediment organic content is the third key variable for the infaunal, hyperbenthic and lower-sized epibenthic communities, but not for the larger megaepibenthic and demersal communities. Nevertheless, a decrease in the densities of several megafaunal indicators was detected the first year after spill, followed by a noteworthy recovery in 2004.

The impact of the *Prestige* oil spill on the infaunal and hyperbenthic communities of the Continental Shelf off Atlantic NW Iberian waters (Galicia)

Working document. Not to be cited without reference to author(s).

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Introduction

The Prestige oil spill (POS) resulted in the release of over 50 000 tons of heavy oil (type M-100) 250 miles from the Galician coastline in oceanic waters (Northwest Iberian Peninsula) in November 2002. Following the POS, the oil was dispersed and sank, mainly due to the bad winter weather conditions and wave action (Sánchez, 2003). These heavier fractions of oil reached the bottom by dropping from the water column as tar aggregates with low bioavailability or in the form of small toxic particles in sea snow. Tar aggregates (with the Prestige chromatographic fingerprint according to the analysis carried out by the IIQAB-CSIC of Barcelona) were found on the shelf one month after the spill, and there is evidence of a microparticled sinking process in planktonic surveys taking place in the POS area in winter 2002, in which oil was found in the exoskeleton and the gut of several zooplankton species (Bode *et al.*, 2003). Oil drops and stains were also found in suprabenthic amphipods following the POS (Frutos and Parra, 2004). Therefore, the shelf taxa initially affected by these sedimented oil components are assumed to be secondary producers, suspension feeders and detritivorous organisms, followed by planktophagous and benthophagous organisms in the trophic web. These possible shifts in the abundances of lower trophic levels would unleash cascading bottom-up type ecosystem effects (Peterson *et al.*, 2003). Other bottom-up effects include enhancement of hydrocarbon-degrading bacteria, oligochaete and deposit-feeding polychaetes by petroleum hydrocarbon enrichment (Peterson, 2001). This fact may produce enhanced production of demersal fishes or crustaceans of higher trophic levels.

On the other hand, top-down effects may also be relevant due to spatio-temporal prohibitions on trawling following the POS, which reduced fishing mortality (Punzón *et al.*, in press) and led to an enhancement in the biomass of top predators, affecting lower trophic levels.

These cascading changes may affect benthic taxa in different ways. Several sensitive or opportunistic taxa can be used as indicators. Megabenthic species having slow growth and slow recovery capabilities, mainly crustaceans and echinoderms, show a high sensitivity to oil exposure. Several studies have shown a fall in populations of sensitive species, such as benthic Ampeliscidae, megafaunal crabs, gastropoda and echinoderms (Dauvin, 1982; Elmgren *et al.*, 1983; Feder and Blanchard, 1998; Gómez Gesteira and Dauvin, 2000; Peterson, 2001). Furthermore, initial mortalities may be followed by extreme fluctuations in stress-tolerant or opportunistic species, such as capitellid or spionid polychaetes (Dauvin, 1982; Pearson and Rosenberg, 1978; Suchanek, 1993).

The demersal fauna of the Galician continental shelf is well documented by the surveys carried out every autumn since 1983 (Olaso, 1990; Sánchez *et al.*, 2002; Sánchez and Serrano, 2003). These studies, which indicate a diverse benthic community, constitute a good starting point for making pre-spill and post-spill comparisons as well as for analysing changes between minimum-impacted versus maximum-impacted areas after the POS. Few studies have been carried out on the effects of hydrocarbons on shelf communities. Most describe effects that are less pronounced than on intertidal ecosystems (e.g., Feder and Blanchard, 1998; Peterson, 2001) since the shipwrecks usually take place near the shoreline and the distribution of oil appears scattered in the subtidal zone. The location of the Prestige wreck and the oil trajectory over the shelf suggest greater effects on Galician shelf communities than have occurred in other spills. The present work approaches the study of these possible effects through a multi-gear sampling system, analysing variation in the spatio-temporal distribution of the main benthic compartments.

This paper presents new data on the temporal evolution of the sediment characteristics in all the sectors and depth strata during the 2002–2004 period and temporal changes in the infaunal communities (zones 1 and 2, depth strata A and B) and hyperbenthic communities (zone 3, depth strata A, B and C) during the first year of study (2002–2003).

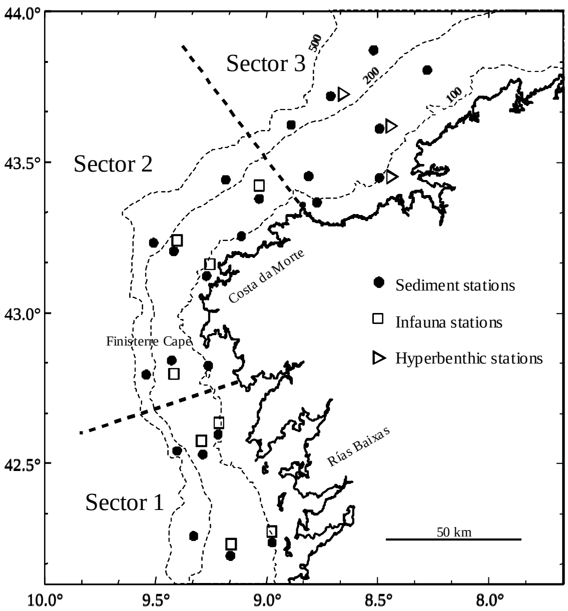


Figure A14.1: General view of sampling and bottom stations.

Material and methods

Field sampling and sediment composition

To study the sediment characteristics, sediment samples were collected from 23 stations (Figure A14.1) distributed over three zones or sectors, having been affected to a greater or lesser extent as a result of the oil spill (Sector 1: minimum impact; Sector 2: maximum impact; Sector 3: moderate impact) and three depth strata (Stratum A: from 70 to 120 m; Stratum B: 121–200 m; Stratum C: 201–300 m) on the Atlantic continental shelf off Galicia (NW Iberian Peninsula). The sampling procedure was repeated in the same stations during four different periods: winter 2003, spring 2003, autumn 2003 and spring 2004, with the exception of depth stratum C which was only sampled in the spring of 2004.

A sample was taken at each station to estimate the organic content and mean diameter of the sediment particle. These samples were frozen on board for later processing. An additional sample was taken to measure the Redox potential, which was performed using a combined Redox electrode and a portable pH meter in recently extracted box corers. Measurements were recorded at three sediment levels: 0–1, 3–4 and 6–7 cm depth.

In the laboratory, the granulometric analysis of the sediment was carried out by dry sorting the coarse fraction (> 62 µm) and the sedimentation of the fine fraction (< 62 µm) (Buchanan, 1984). The content of organic matter in the sediment was computed by the calcination of the sample at 500 ºC for 24 hours, after drying at 100 ºC for the same amount of time. Four calculations were made for each sample, taking the average value as the one representative of the station.

Infaunal communities

Samples were taken using a *Bouma* type *box corer* with a sampling surface area of 0.0175 m^2. This sampler has been used successfully in the study on the impact of the *Aegean Sea* oil spill on the sublittoral infaunal communities of the rías of La Coruña, Ferrol and the near continental shelf (López-Jamar *et al.*, 1996).

Samples from 8 stations were collected for the study of the infaunal communities (Figure A14.1). It was only possible to sample the bathymetric strata A and B in zones 1 and 2. The infaunal communities of stations 1, 2, 4 and 5 of zone 1 and stations 8, 10, 11 and 14 of zone 2 were studied. To examine the temporal evolution of the infaunal communities, the samplings were repeated in the same stations during two different time periods: winter 2002–2003 and spring 2003. This paper presents preliminary information on the autumn 2003 period, but only for stations 8 and 10, in zone 2, where studies are underway on both infaunal biomass and trophic groups.

To study the infaunal communities 3–5 samples were taken (sampling area = 0.0525–0.0875 m^2). These samples were sorted on board the vessel using an 0.5 mm mesh. The material collected in the mesh was fixed in 8% formaldehyde neutralized with borax (previously anaesthetized with magnesium chloride), to which Bengal Rose had been added to facilitate the separation of the organisms in the laboratory. Next the organisms were identified to the species level where possible and the biomass was calculated as ash free dry weight (AFDW), applying the previously computed conversion factors to the fresh weight value.

To assess the amount of variation in species abundance per sample related to tar amount and a set of environmental variables assumed to be important in community structure (i.e., season, latitude, depth, percentage of organic matter, mean particle diameter, sorting coefficient and percentage of coarse sands, fine sands and mud), a Redundancy Analysis (RDA) was used for box-corer analyses. Oil was recorded as the weight of tar aggregates per beam trawl sample. In addition, other sediment characteristics were recorded for each sample: organic matter content, mean particle diameter, sorting coefficient and weight percentage of coarse, fine and mud elements. RDA calculations were based on the log-transformed abundance of all species collected. Species appearing in less than 5 % of hauls were removed. The statistical significance of the first and all canonical axes together was tested by the Monte-Carlo tests using 999 permutations under the reduced model. RDA results were presented graphically in a bi-dimensional ordination diagram generated by biplot scaling focusing on inter-species distances, in which samples are represented by points and environmental variables by vectors.

Hyperbenthic communities

The hyperbenthic sledge trawl consists of a stainless steel frame fitted with two plankton nets 3m in length and 0.5 mm mesh. A plastic collector is attached to the end of each net. A flowmeter is placed at the mouth of the upper net. The sampling area covered by the nets was 0.450 m^2 for the lower net and 0.225 m^2 for the upper net. The sledge is dragged across the ocean floor by means of a steel cable measuring in length approximately three times the depth of the station to ensure a uniform trawl over the sea bottom. During this survey, a depth sensor (SCANMAR) was attached to the sledge frame to guarantee the correct trawling operation on the sea bottom. The sledge is equipped with a front curtain with an automatic opening and closing system to prevent the contamination of the sample by the plankton from the water column when the device is being hauled in or let out.

To study the hyperbenthic communities, sampling was conducted during the day at three stations (Figure A14.1) on the continental shelf near La Coruña (Sector 3) at three depth strata.

The trawl lasted approximately 2 minutes in all the stations and was made to coincide with the trawls of the demersal fishery using trawl gear.

Preliminary results

Distribution of tar aggregates

As a result of the Prestige Oil Spill, the oil degradation and sedimentation through the water column caused the presence of tar aggregates on the bottom. This heavy oil appeared in aggregates of between 1 and 20 cm in diameter. The existence of particles of less than 10 mm could not be determined owing to the beam trawl mesh size, which means, with respect to the results obtained, that at least the quantities indicated were present. The concentrations in each of the three zones considered, expressed in kg of oil · km^{-2}, are shown in Figure A14.2. The highest mean concentrations of oil were found in winter in Sector 2 (off the *Costa da Morte*), diminishing progressively over time until they reached very low levels (0.5 kg · km^{-2}) in autumn 2004, which is close to our detection limit. In Sector 1, the mean density of tar aggregates was always very low (<0.1 kg · km^{-2}), and so this study considers it to be the zone suffering the least impact.

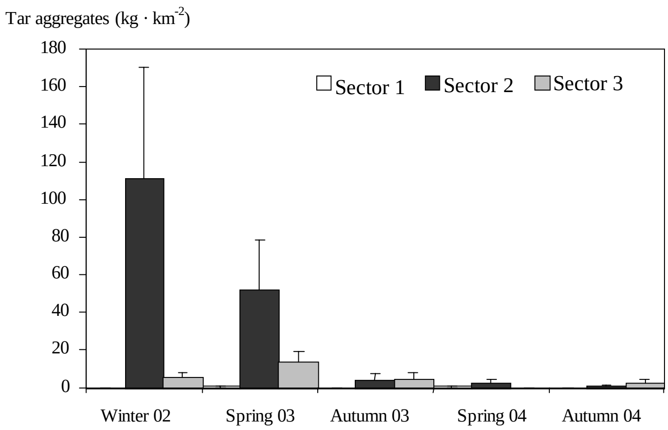


Figure A14.2: Heavy oil (tar aggregates) average concentrations (kg · km^{-2} ± SE) on the Galician continental shelf from five beam-trawl surveys.

Figure A14.3 shows the spatial distribution of the tar aggregates in four successive surveys, using geostatistical analysis (kriging) to define contours of amounts. The greatest amounts were 300 kg · km^{-2} in winter 2002 at depths of 120-200 m off Cape Finisterre. According to the analysis carried out by the IIQAB-CSIC of Barcelona, this oil has a fingerprint that points to its spending a short or null period of time on the surface of the sea. This would allow us to assume that its distribution mainly follows that of a type of oil having a greater density, which sedimented in the first few days following the accident rather than degrading in the successive black tides that reached the coast. It is for this reason that the oil distribution was found to coincide with the tanker's drift during towing maneuvers over the continental shelf before sinking and also that tar aggregates were absent on the shelf of Sector 1, while the coast itself received considerable black tides.

The presence of tar aggregates in winter 2002 and spring 2003 shows a stable distribution pattern (Figure A14.3), which indicates little displacement by currents once they had sedimented. Lastly, the progressive fall in the concentrations of tar aggregates on the continental shelf of Galicia is probably due to their being covered by natural processes of sediment accumulation and because no new processes carrying oil to the bottom have taken place. For this reason, concentrations are considerably reduced from spring, when great primary production takes place in the area due to upwelling.

Sediment characteristics

Table A14.1 presents the sediment variables in the stations surveyed. The sediment of the shallowest stratum (stratum A) in Sector 1, the area suffering the least impact from the oil spill, is characterized by the presence of sediment types dominated by mud (station 1) or fine sands (station 4), with the mean diameter having temporal fluctuations within relatively close boundaries (from 41 ± 1 to 66 ± 10 µm, at stations 1 and 4 respectively). Organic matter content was moderate, ranging from 4.02 ± 0.43 % at station 1 to 2.98 ± 10.36 at station 4. The selection varied from poor (station 1) to moderate (station 4). In terms of the temporal variation of the sediment between the different periods under study, no major changes were found. (Figure A14.4; Table A14.1).

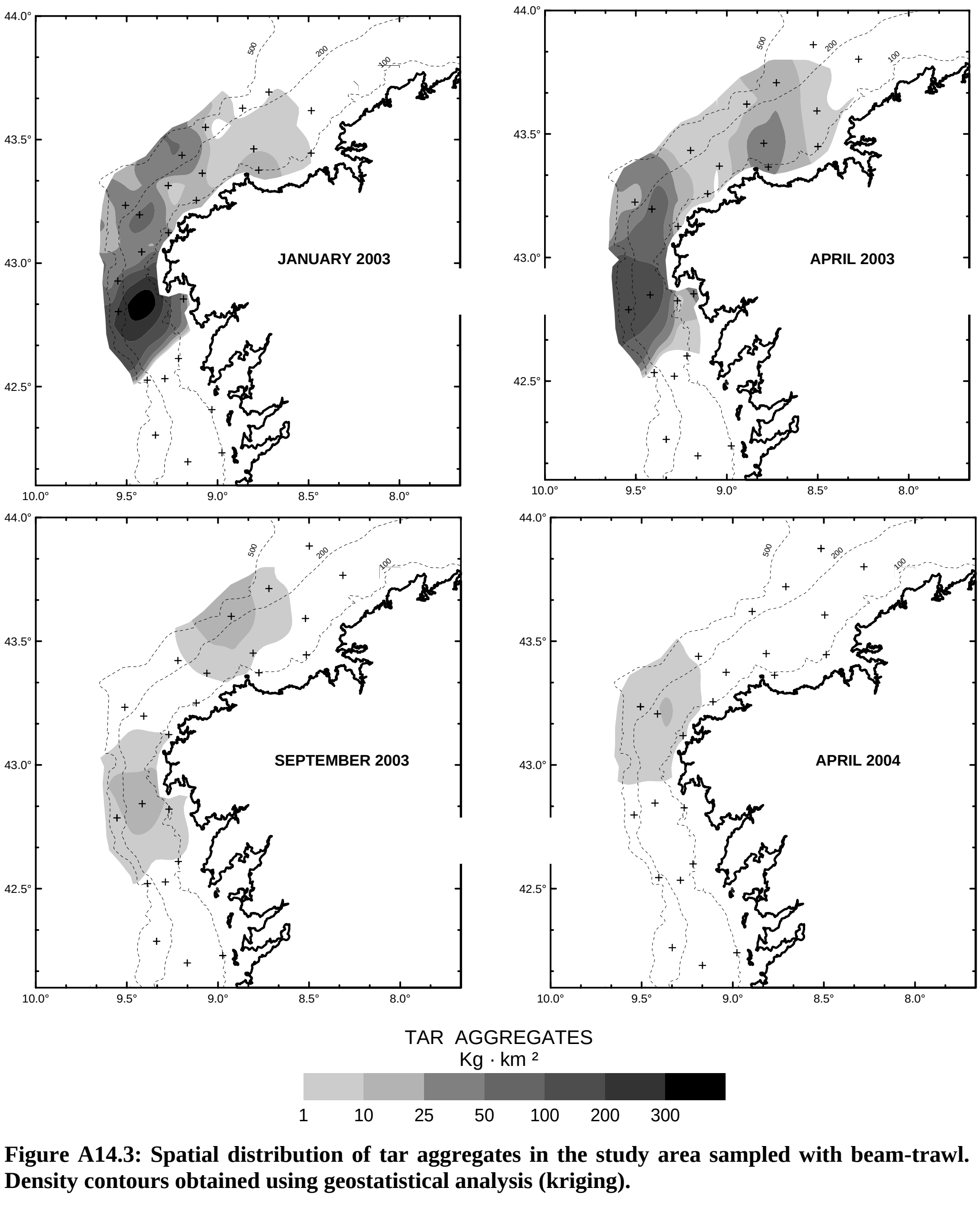


Figure A14.3: Spatial distribution of tar aggregates in the study area sampled with beam-trawl. Density contours obtained using geostatistical analysis (kriging).

The middle stratum (stratum B) of Sector 1, the zone suffering the least impact, is characterized by the presence of sediments made up of fine sands (between 167 ± 4 and 165 ± 9 µm, stations 2 and 5 respectively), with a moderate organic content (between 3.60 ± 0.21 and 2.40 ± 0.56 %, stations 2 and 5 respectively; Figure A14.4). The selection of the two stations is fairly good, without exceeding the sorting coefficient of 1.31 ± 0.02 points at station 5 (Figure A14.4; Table A14.1). The temporal variation did exhibit any major changes, either.

The sediments of the stations located in the deepest stratum (stratum C) in Sector 1, which were only sampled during the spring, 2004 survey, were composed of sediment types that fluctuated between the very fine sands of station 3 and the fine sands of station 6, with diameters ranging from 85 and 158 µm respectively. Station 6 presents a very low organic content (1.92 %) which varies up to moderate in station 3 (3.00 %). Sediment selection went from moderately good and moderate (S_0 between 1.30 and 1.33, stations 6 and 3 respectively; Figure A14.4, Table A14.1).

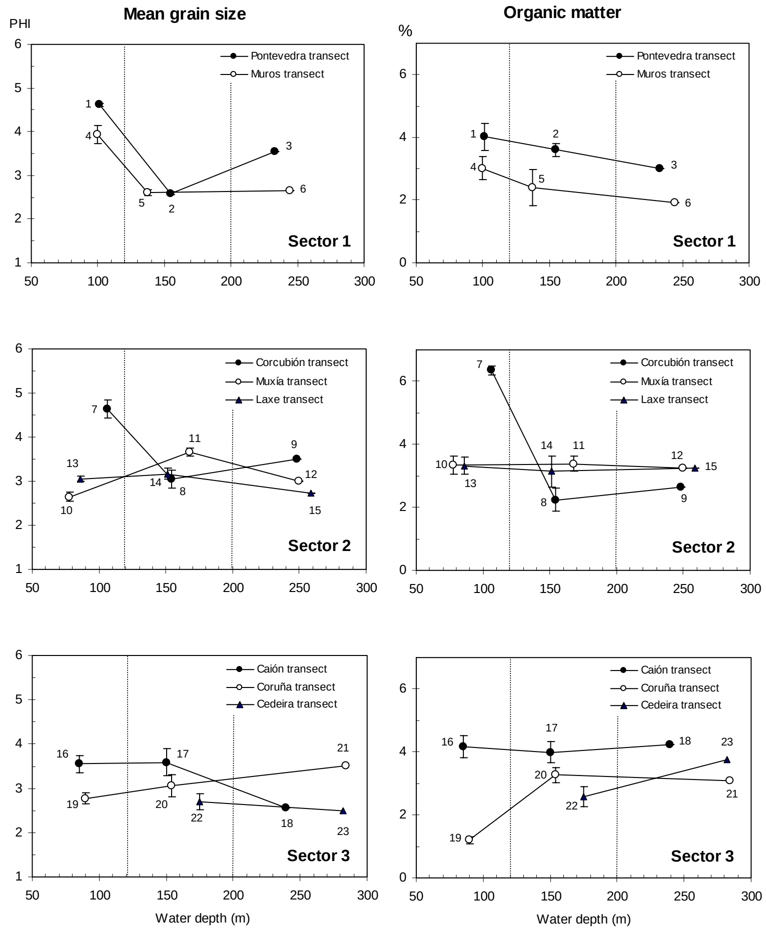


Figure A14.4: Effect of water depth at stations on mean diameter of particle size (Φ Units) and percentage of organic matter in sediments on the continental shelf off Galicia by sectors.

Nine stations from the maximum-impacted area (Sector 2) were sampled –three in the shallowest stratum (Stratum A; stations 7, 10 and 13), three in the middle (Stratum B; stations 8, 11 and 14) and three from the deep stratum (Stratum C; stations 9, 12 and 15), the latter having only been sampled in the spring, 2004 survey. The bottoms of the shallowest stratum (stratum A) in this zone present all of the sediment types, ranging from mud sediment at station 7 (Q_{50} = 41 ± 6 µm) to fine sands with low organic matter content at station 10 (Q_{50} = 161 ± 11 µm). Station 13 exhibited moderate organic content (3.32 ± 0.26 %) which varied up to the highest value found in the study at station 7 (6.35 ± 0.14 %). Sediment selection ranged between poor (station 7) and moderate (stations 11 and 13; Figure A14.4, Table A14.1). The temporal variation of the sediment in the stations belonging to this stratum, for Sector 2, was minor.

The middle stratum of Sector 2, was also characterized by the presence of sandy sediments, made up of very fine sands, with a mean particle diameter ranging from 79 ± 4 µm at station 11 and 120 ± 17 µm at station 8. In terms of organic content, the values fluctuated between 2.24 ± 0.37 % at station 8 and the moderate value found at station 14 (3.15 ± 0.49 %). The sediment selection was moderate, with values between 1.50 ± 0.02 and 165 ± 0.17 corresponding to stations 6 and 11 respectively. No substantial temporal variations were observed in the sediment characteristics by stratum and sector (Figure A14.4; Table A14.1).

The sediments in the stations located in the deepest stratum (stratum C) of Sector 2, which was only sampled in the spring, 2004 survey, were composed of sediment types ranging from very fine sands at station 9 and fine sands at stations 12 and 15, with diameters from 88 to 151 µm, for stations 9 and 15, respectively. Station 9 presented a relatively moderate organic content (2.63 %) ranging on the scale up to moderate at stations 12 and 15 (3.24 and 3.26 %, respectively). The sediment selection was between moderately good and poor (S_0 between 1.29 and 1.99, stations 9and 12 respectively; Figure A14.4, Table A14.1).

In the moderate-impacted zone (Sector 3) eight stations were sampled –two in the shallowest stratum (stations 16 and 19), three in the middle (stations 17, 20 and 22) and three from the deepest stratum (stations 18, 21 and 23), the latter having been sampled only in the spring, 2004 survey. The sediments of the shallowest stratum (stratum A) in this sector had very fine sands at station 16 (Q_{50} = 86 ± 12 µm) with fine sands and low organic matter content at station 19 (Q_{50} = 147 ± 13 µm). Station 19 was low in organic content (1.20 ± 0.11 %) which fluctuated until reaching a high value for organic content at station 16 (4.18 ± 0.36 %). Sediment selection was moderate with the sorting coefficient ranging from 1.68 ± 0.13 at station 16 to 1.36 ± 0.06 at station 19. The temporal variation of the sediment in the stations from this stratum in Sector 3 was minor (Figure A14.4; Table A14.1).

The middle stratum in Sector 3 was also characterized by the presence of sandy sediments, that range from very fine sands with a mean particle diameter of between 85 ± 17 µm (station 17) and 122 ± 21 µm (station 20) to fine sands with a mean diameter of 155 ± 18 µm (station 22). In terms of organic content, the values ranged from 2.58 ± 0.32 % at station 22 and the moderate value at station 17 (3.99 ± 0.34 %). Sediment selection varied between moderate and poor, with values fluctuating between 1.37 ± 0.05 and 2.46 ± 0.25, at stations 22 and 17 respectively. On a temporal level, there were no important fluctuations in the sediment characteristics by stratum and sector (Figure A14.4; Table A14.1).

The sediments of the stations located in the deepest stratum (stratum C) in sector 3, which were only sampled in the spring 2004 survey, were made up of sediment types that ranged from very fine sands at station 21 to fine sands at stations 18 and 23, with diameters of between 88 and 177 µm, at stations 21 and 23, respectively. Station 18 presented a relatively high organic content (4.23 %) which was moderate at stations 21 and 23 (3.09 and 3.76 %, respectively). Sediment selection ranged from moderate to poor (S_0 between 1.42 and 2.19, stations 23 and 21 respectively; Figure A14.4, Table A14.1).

General characteristics of infaunal communities

This section offers a brief description of the general faunal characteristics of the macroinfaunal communities studied, by sector and depth stratum. All stations were sampled on a seasonal basis, with data being provided from the surveys conducted in winter 2002 and spring 2003, as well as autumn 2003. In this section, however, only the dominant species and information on some of the variables in the community will be discussed, namely abundance, diversity, and evenness in each of the stations surveyed. The next section will focus on the temporal variation of the community in relation to the possible effects of the oil spill. Samples taken of the fauna are still being processed, so at this time we can only offer infaunal information from eight station in sectors 1 and 2 in depth strata A and B, from the samples collected in winter

2002 and spring 2003 (Figures A14.5–6; Tables A14.2–4), and information from 2 stations in the same sectors and strata, but from the surveys conducted in winter 2002, spring 2003 and autumn 2003 (Figure A14.7).

In the 71–120 m depth stratum (stratum A) in Sector 1, the minimum-impacted area, we analyzed a total of two stations (1 and 4) characterized by a mud sediment (station 1) or having very fine sands (station 4) with a moderate organic content. The two stations were sampled in the surveys carried out in winter 2002 and spring 2003 (Figures A14.5–6; Tables A14.2–4). Polychaetes were the dominant zoological group in abundance in this stratum (as high as 92.31 % in spring at station 4) while the all the other groups accounted for only 16.87 % (Figure A14.5; Table A14.4). The communities were dominated by the spionid polychaete *Prionospio fallax*, which reached a mean abundance of 2362 ind m^{-2} for this stratum in spring 2003 (station 4; Table A14.2). The species composition of the two stations in this stratum is given in Table A14.2 and the community variables in Table A14.3.

In the 121–200 m depth stratum (stratum B) in Sector 1, the two stations studied (2 and 5) in both winter 2002 and spring 2003 (Figures A14.5–6; Tables A14.2–4), presented sediments made up of fine sands with a moderate organic content, Polychaetes were the dominant zoological group in this stratum (91.57 % in winter, in station 2). The infaunal communities were characterized by the predominance of the polychaetes *Prionospio fallax*, *Monticellina dorsobranchialis* and *Aricidea* sp. The species composition of this stratum is given in Table A14.2 and the community variables in Table A14.3.

To date, we have only analyzed one station (10) in stratum A (121–200 m) from the sector with the greatest impact (Sector 2; Figure A14.1). This station was sampled in winter 2002, in spring 2003 and in autumn 2003 (Figures A14.5–7; Tables A14.2–4). The sediment was composed of fine sands with a moderate organic content. Polychaetes were the dominant zoological group in this stratum (as high as 66.6 % in winter), followed by the echinoderms, reaching up to 19.27 % in spring. The characteristic species of this stratum were the polychaetes *Prionospio fallax* and *Tharyx* sp., the ophiuroid echinoderm and the bivalve mollusc *Mysella bidentata*. The species composition in this stratum is given in Table A14.2 and the community variables in Table A14.3.

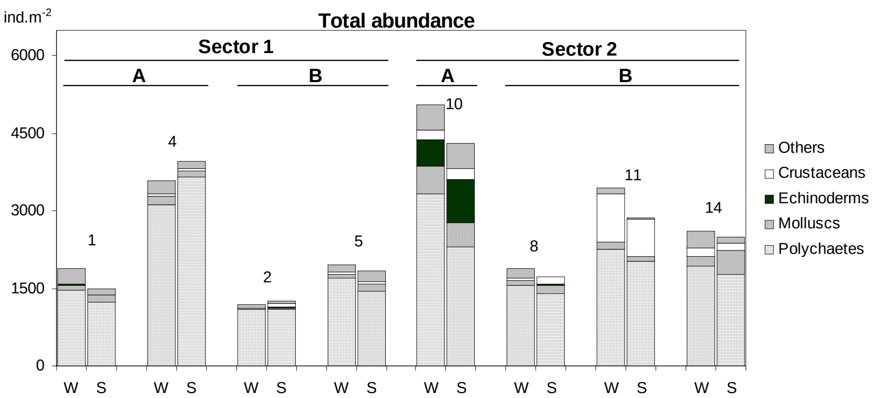
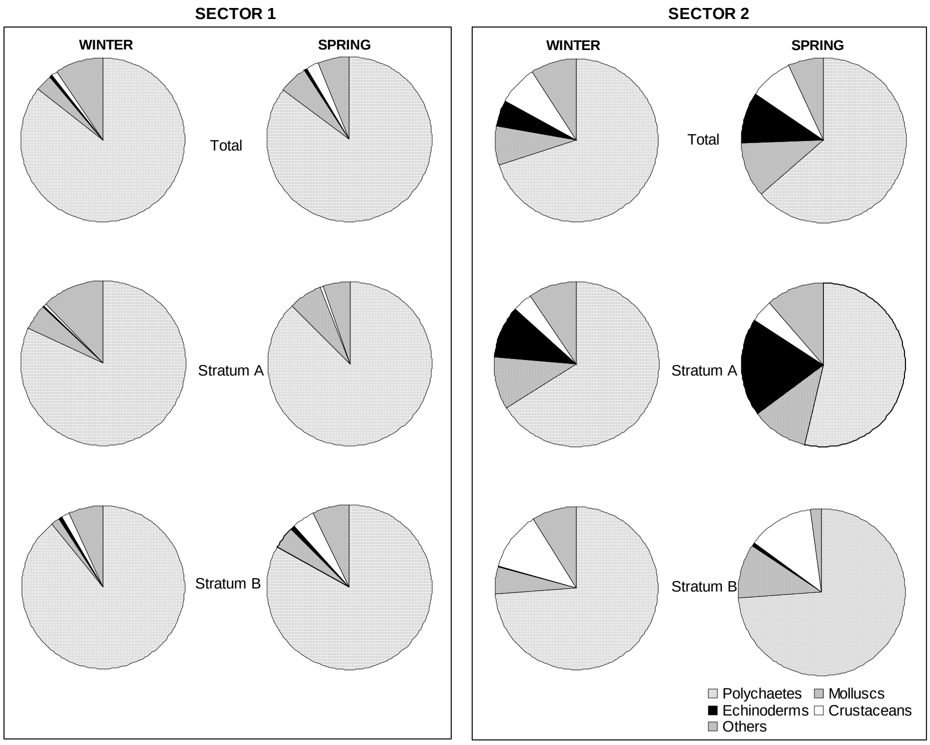


Figure A14.5: Temporal total abundance (ind·m^{-2}) by taxonomic group in the stations analyzed. Distribution is shown by sectors and depth strata.

In the 21–200 m depth stratum (stratum B) in Sector 2 three stations were studied (8, 11, and 14). Stations 11 and 14 were sampled in winter 2002 and spring 2003, while station 8 was also sampled in the autumn of 2003 (Figures A14.5–7; Tables A14.2–4). These stations have a characteristic sediment made up of very fine sands with a moderate organic content. The polychaetes were the dominant zoological group in this stratum (as high as 70 % in spring), followed by the crustaceans which accounted for up to 27 % in winter. The characteristic species of this stratum were the peracarid crustacean *Ampelisca* sp., particularly at station 11, and the polychaetes *Prionospio fallax*, *P. steentrupii* and *Monticellona dorsobranchialis*. The species composition in this stratum is given in Table A14.2 and the community variables in Table A14.3.



FigureA14.6: Temporal percentage of total abundance shown by taxonomic group in the two sectors, by depth strata.

Temporal evolution of the infaunal communities

Overall the sector having the least impact (Sector 1), showed slight variations between winter and spring. The most significant changes in spring were a slight decrease in the percentage of the abundance of the most important group, the polychaetes (particularly in the shallowest stratum), and in some of the less important groups such as "others"(nemertines, sipunculids, etc) and the echinoderms. In contrast, molluscs and crustaceans exhibited a moderate increase, particularly in the deepest stratum (Figure A14.6). Species richness, diversity and evenness declined to some degree in spring, except at station 5 in the deepest stratum where they underwent an increase (Table A14.3).

In a more detailed examination, in the shallowest (stratum A: 70–120 m), at station 1 we observed a decrease in total abundance in spring, especially in the main species of spionid polychaetes and oligochaetes (Figure A14.5; Tables A14.2 and 4). Species richness, diversity and evenness also decreased moderately in spring (Table A14.3). At station 4, on the other hand, which had a relatively high infaunal abundance (up to 3962 ind.m^{-2} in spring) total abundance rose slightly in spring, thanks to the increase in the presence of polychaetes, particularly, *Prionospio fallax* (Figure A14.5; Tables A14.2 and 4). Similar to the previous station, species richness, diversity and evenness decreased slightly in spring (Table A14.3).

Upon an examination of the stations located in the deepest stratum (stratum B: 121–200 m), we observed that at station 2, there was a modest increase in total abundance in spring, owing to the growing number of polychaetes of the genus *Aricidea* and to *Prionospio fallax* (Figure A14.5; Tables A14.2 and 4). This is the station that exhibited the lowest abundance values, and never exceeded 1257 ind.m^{-2} in spring (Table A14.4). Species richness, diversity (with a considerably high value –over 4 points) and evenness also underwent a slight decrease in spring (Table A14.3). In contrast, station 5, which had a relatively high infaunal abundance (ma maximum of 1955 ind.m^{-2} in winter) exhibited a decrease in total abundance in spring, especially in the two main species of spionid polychaetes (*Prionospio fallax* and *P. steenstrupii*), and *Monticellina dorsobranchialis* (Figure A14.5; Tables A14.2 and 4). Unlike the other station in Sector 1, the population parameters for species richness, diversity (with a considerably high value, above 4.6 points in spring) and evenness increased in spring 2003 (Table A14.4).

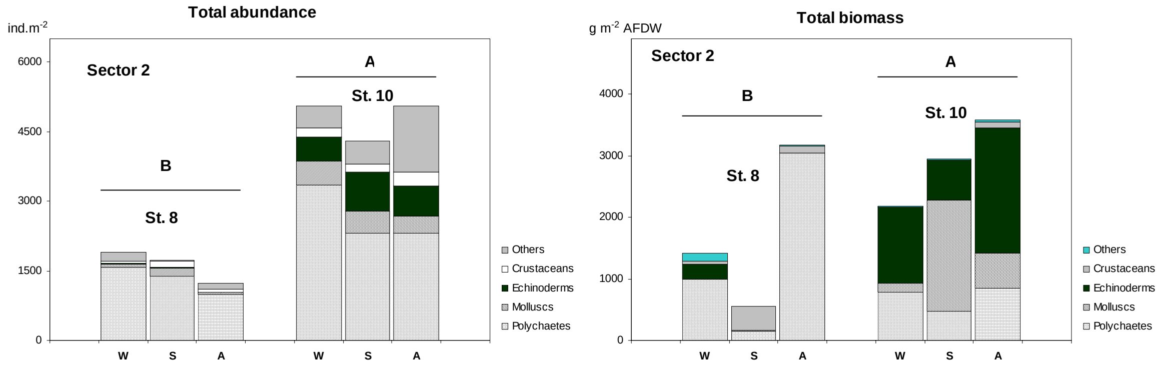


Figure A14.7: Temporal total abundance (ind·m^{-2}) and total biomass (g m^{-2} AFDW) by taxonomic group at stations 8 and 10 in Sector 2. Distribution is shown by depth strata.

Overall, in the zone that suffered the greatest impact from the oil spill (Sector 2), there were slight variations between the different time periods studied. At the stations sampled in winter 2002 and spring 2003 (stations 11 and 14), the most significant changes in spring were a rise in the percentage of molluscs in terms of abundance (station 14) and a decrease in the groups "crustaceans" and "others (nemertines, sipunculids, etc). Species richness decreased slightly in spring, and diversity and evenness increased in spring, showing fairly high values (Table A14.3). In contrast, at the stations sampled in winter 2002, spring 2003 and autumn 2003 (stations 8 and 10), the most significant changes in the time series were a moderate decline in the percentage of abundance of the most important group, the polychaetes (particularly in the shallowest stratum), and an increase in some of the less important groups, such as "others" and the echinoderms at station 10 (Figure A14.6). The number of species diminished in the deep station and rose in the shallow station at the end of the study, while the diversity decreased slightly in spring, rising again in the autumn season. Evenness gradually increased in both stations (Table A14.3).

In a more detailed examination of the shallowest station (stratum A: 70–120 m) of Sector 2, we only have data available for station 10, which was sampled during three different seasons (winter 2002, spring 2003 and autumn del 2003). In terms o total abundance, which was seen to be the highest of all the stations in this study, we observed a decrease in the total abundance of the infauna in spring 2003 (from 4052 to 4305 ind.m^{-2}), which in the following sampling reached initial values once again (5048 ind.m^{-2} in autumn; Table A14.4). Worthy of note was the progressive decrease in the dominant polychaetes, *Prionospio fallax*, which went from 1429 ind.m^{-2} in winter to 381 ind.m^{-2} in autumn, and *Tharyx* sp. from 686 ind.m^{-2} to 191 ind.m^{-2} during the same time periods. The bivalve *Mysella bidentata* underwent a moderate decrease in abundance (from 309 to 286 ind.m^{-2}), while the annelids *Oligochaeta* ind. increased their abundance substantially in autumn 2003, reaching 1219 ind.m^{-2} (Table A14.2). The temporal evolution of the echinoderm *Amphiura filiformis* increased considerably in spring (as high as 800 ind.m^{-2}), later dropping in abundance to 610 ind.m^{-2} in autumn del 2003. The infaunal biomass underwent a gradual but very substantial increase until autumn 2003, reaching 3577.8 g.m^{-2} AFDW, dominated by the echinoderm group in winter and autumn (56.37 % and 57.04 %, respectively of total infaunal biomass), and by the mollusc group in spring (61.44 %; Figure A14.7). The number of species diminished in spring, going from 46 to 31 species, and recovering, once again, in autumn (K = 47). Diversity reached its highest value in autumn (H’ = 4.25) and evenness gradually increased until it attained a maximum of 2003 (J’ = 0.76; Table A14.3).

Upon an examination of the stations located in the deepest stratum (stratum B: 121-200 m) we observed that at station 8, which was sampled during three different seasons, there was a gradual decrease in total abundance, from 1897 ind.m^{-2} in winter 2002 to 1238 ind.m^{-2} in autumn 2003. Also of interest is the gradual decrease in the dominant polychaete, *Prionospio fallax*, which went from 457 ind.m^{-2} in winter to 54 ind.m^{-2} in autumn, and to a lesser extent, a reduction in the number of individuals of *Monticellina dorsobranchialis* (from 126 to 57 ind.m^{-2}). In contrast, *P. stenstrupii* increased in number in spring, reaching 324 ind.m^{-2} only to decrease again in autumn (286 ind.m^{-2}; Figures A14.5 and 7; Tables A14.2 and 4). Infaunal biomass experienced a very important increase in autumn 2003, reaching 3049 g.m^{-2} AFDW, and was dominated by the polychaete group (96 % of total infaunal biomass; Figure A14.7). The number of species was found to diminish, from 44 species in winter to 27 species in autumn. Diversity, which was high, decreased until the values had stabilized at around 4.16 points in autumn 2003, while evenness increased at the end of the study (J’ = 0.87 in autumn 2003; Table A14.3).

Other stations studied in this deep stratum of Sector 2 were numbers 11 and 14, which were only sampled in winter 2002 and spring 2003. At station 11 we noted a decrease in total abundance in spring (from 3555 to 2877 ind.m^{-2}) owing mainly to the diminishing numbers of the amphipod crustacean *Ampelisca* sp. (from 869 to 610 ind.m^{-2}), which was the dominant species in the community, and a decrease in the polychaetes *Prionospio fallax* and *Monticellina dorsobranchialis*. The spionid polychaete, P. stenstrupii, on the other hand, increased in abundance in spring reaching up to 629 ind.m^{-2} (Figure A14.3; Tables A14.2 and 4). Species richness decreased, going from 37 species in winter to 34 species in spring, whereas diversity and evenness values rose in spring 2003 (H’ = 4.01 and J’ = 0.79; Table A14.3). Additionally, at station 14 we observed a decrease in the total abundance in spring (from 2617 to 2496 ind.m^{-2}), primarily attributed to the dwindling number of specimens from the two main species of spionid polychaetes (*Prionospio fallax* and *P. steenstrupii*), and *Monticellina dorsobranchialis* (Figure A14.5; Tables A14.2 and 4). We also observed a moderate reduction in spring of the *Nemertina* indet. and the sipiniculid *Onchnesoma steentrupii* (Figure A14.5; tables A14.2 and 4). Similar to what occurred in the previous station, the number of species diminished, going from 45 species in winter to 41 species in spring, while diversity and evenness increased in spring 2003 (H’ = 4.71 and J’ = 0.88; Table A14.3), with the diversity in this station showing the highest value reached in the entire study.

General characteristics of hyperbenthic communities

From the group of three stations, located in a bathymetric stratum other than Sector 3 (Figure A14.1), a total of 6,530 specimens were collected. These specimens were distributed among 9 zoological groups in varying proportions (Figure A14.8): amphipods (Amp, 27.6%), mysids (Mys, 31.4%), cumaceans (Cum, 11.3%), isopods (Iso, 2.8%), tanaids (Tan, <0.1%), euphausiids (Eup, 10.9%), decapods (Dec, 15.6%), pycnogonids (Pyc, <0.1%) and fishes (Pis, 0.4%).

In the bathymetric stratum 70–120, the dominant groups in terms of abundance were the amphipods (267 ind 100 m^{-2}), mysids (257 ind 100 m^{-2}) and euphausiids (83 ind 100 m^{-2}; Table A14.6). The dominant species in this bathymetric stratum included the amphipod *Amphilochoides boecki*, the mysids *Leptomysis gracilis* and *Anchialina agilis* and the euphausiid *Nyctiphanes couchi* (Table A14.5).

In the intermediate bathymetric stratum (121–200 m) the mysids crustaceans (182 ind 100 m^{-2}), the amphipods (81 ind 100m^{-2}) and the cumaceans (78 ind 100 m^{-2}) were the most abundant (Table A14.6). The prevailing species in this stratum were the mysids *Anchialina agilis*, *Erythrops neapolitana* and *Leptomysis gracilis* and the euphausiid *Nyctiphanes couchi* (Table A14.5). This is the bathymetric stratum having the highest values for total abundance (422 ind 100 m^{-2}) and species richness (K = 71; Table A14.7).

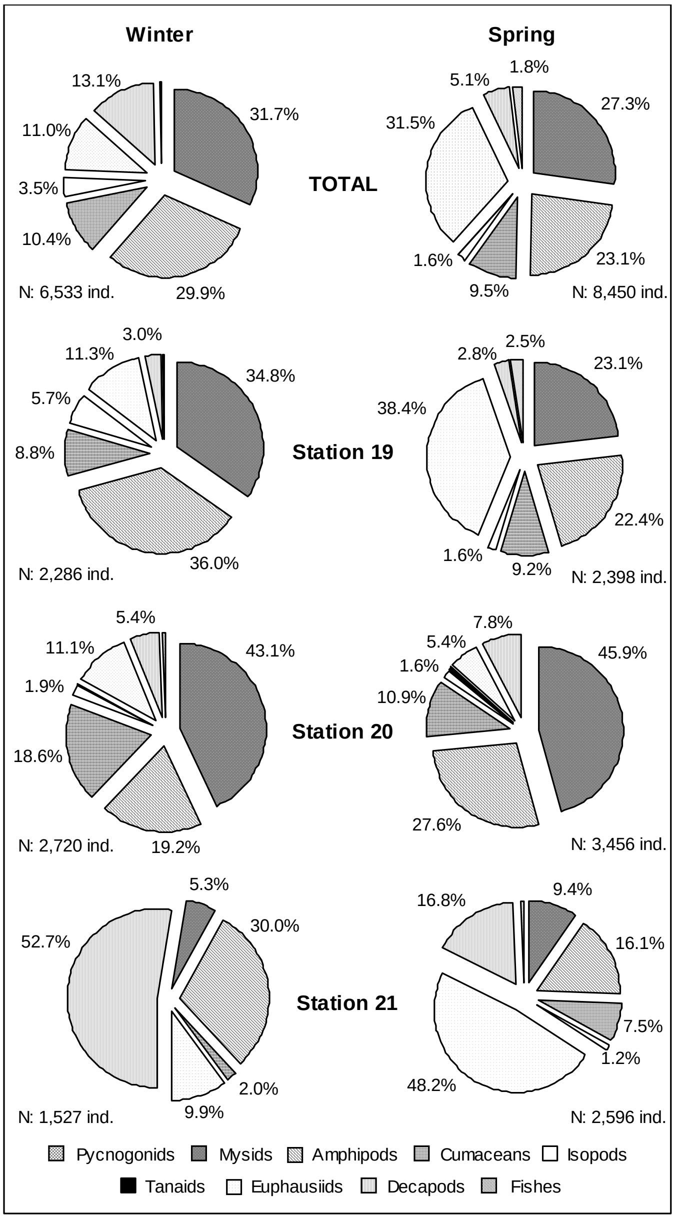


Figure A14.8: Abundance (%) of the main taxonomic groups in the suprabenthic communities off the Ría de La Coruña in winter and spring surveys.

After examining the 1,527 individuals collected in the deepest stratum (201–500 m depth) the groups exhibiting the highest abundance values were: decapods (142.3 ind 100 m^{-2}), amphipods (80 ind 100 m^{-2}) and euphausiids (26 ind 100m^{-2}; Table A14.6). The dominant species in this stratum included the decapod *Pasiphaea sivado*, the amphipods *Scopelocheirus hopei* and *Orchomenella nana* and the euphausiid *Meganyctiphanes norvegica* (Table A14.5).

In terms of the vertical distribution of the hyperbenthic fauna, the highest species richness values corresponded to the lower net, the one closest to the sediment, reaching a maximum of 70 species in the middle stratum (121–200). In contrast, the values obtained for the upper net fluctuated between the minimum richness in the shallow and deep strata (K = 7) and the maximum of 12 species in the middle stratum (Table A14.7).

As far as community types are concerned, it is possible to say that their structure is similar to that found in other zones of the NE Atlántico continental shelf (Cunha *et al.*, 1997; Sorbe, 1989).

Temporal evolution of the hyperbenthic communities

This section offers the preliminary results of the temporal evolution of the hyperbenthic communities from the samplings carried out in winter and spring. Although the data from the spring period are still in the process of analysis, we have included the changes recorded in total abundance of the main hyperbenthic groups of Sector 3.

In the shallowest stratum, there was a marked increase in abundance of the euphausiid group, which went from 11 % to 34 % of the total abundance in spring. Also observed was a substantial decrease in the groups, amphipods and mysids with both groups diminishing from over 30 % to 23 % of the total abundance in spring (Figure A14.11).

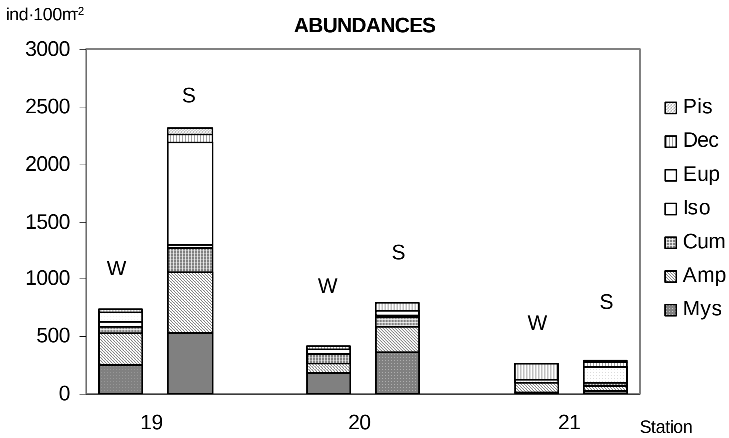


Figure A14.9: Temporal changes in the abundance of the suprabenthic communities off the Ría de La Coruña. W: winter; S: spring.

In the middle stratum, ranging from 121 to 200 m depth, where the community was dominated by the mysids, there was a considerable increase in the amphipods in spring (from 19 to 28 %) and a less important decrease in the cumaceans and euphausiids (Figure A14.9).

In contrast, the deepest stratum, where the community was dominated by decapods in winter, underwent a major reduction of these animals (from 53 to 20 %), together with a great increase in the euphausiids, which was up from a total abundance in winter of 10 % to 41 % in spring, thus being the dominant group in the community in spring. Similar to what occurred in the shallowest stratum, the amphipods dropped in number in spring (down from 30 to 17 %; Figure A14.9).

Effects of the Prestige oil spill and other environmental variables on community structure

A Redundancy Analysis (RDA) provided a bi-dimensional ordination of environmental variables, samples and species. The RDA ordination of the infaunal matrix showed, once again, a dominance of depth over other variables (Figure A14.10). Paradoxically, sedimentary variables seemed to be less important in constructing axis 2. This fact is attributable to the lower N (16 box-corer samples). The latitude and zone 2, dominant variables in axis 2, may suggest a *Prestige* oil spill effect in infaunal communities. Although this hypothesis cannot be rejected, it is obvious that these variables also reflect a sedimentary gradient, splitting the southern muddier samples of zone 1. Problems with the box-corers at great depths prevented the sampling of the 201–300 stratum, the muddiest stratum in zone 2, in contrast to beam and otter trawls in which muddy sediments are represented in all zones. Box-corer samples were located following depth-zone criteria (Figure A14.6).

In conclusion, the RDA's did not provide evidence of any patterns of similarity among samples attributable to contamination by tar aggregates. The minor importance of tar aggregate abundance and the maximum impact zone would also imply that no indicator species or groups of species have shown notable impact effects.

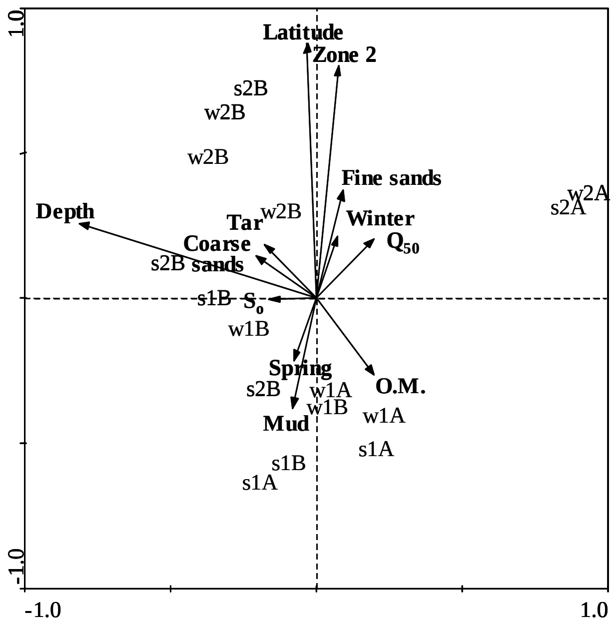


Figure A14.10. RDA ordination biplot of environmental variables and samples in infaunal box-corer analysis. Sample labels represent season (winter: w, spring: s, autumn: a), sector (1, 2) and depth strata (70–120 m: A; 121–200 m: B).

Changes in ecological indices and indicator taxa densities after the *Prestige* oil spill

To investigate the relationships among the environmental variables (i.e., amount of tar aggregates, depth, latitude, organic matter, mean particle diameter, sorting coefficient, coarse sand, fine sand and mud) and species richness, biomass and species diversity, the level of association of the three indices was examined using a Spearman rank order correlation.

The taxa or groups of taxa selected as indicators (Table A14.8) were based on previous works on the oil sensitivity of demersal, infaunal and hyperbenthic fauna (Cabioch *et al.*, 1980; Dauvin, 1982; Hyland *et al.*, 1985; Spies, 1987; Jewet and Dean, 1997; Olsgard and Gray, 1995; Feder and Blanchard, 1998). Relationships among environmental variables (including amount of tar) and indicator densities were determined using a Spearman rank order correlation on log-transformed data.

No significant correlations between tar aggregate amount and species richness, biomass, density and species diversity (Table A14.9) were found for infaunal and hyperbenthic communities. Significant correlations between other environmental variables and ecological indices were detected, although most of them exhibited extremely weak values. Depth showed a positive correlation with species diversity for infauna. Latitude also displayed a positive correlation with species richness and density for infauna. Among the sediment characteristics, significant correlations were found for beam trawls, infauna and hyperbenthos which may explain the relevance of the type of sediment to benthic communities.

Tar aggregate abundance did not show any significant correlation with indicator densities. Latitude and sediment characteristics proved to be important factors in explaining densities of infaunal indicators (Table A14.10).

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Tables

Table A14.1. Sediment variables. Symbols: % O.M.: organic content; Q_{50}: mean diameter (Φ Units and μm); S_0: sorting coefficient ($\sqrt{Q_{25}/Q_{75}}$).

Station	Depth (m)	Q_{50} (phi)	Q_{50} (μm)	% O.M.	S_0
1	101	4.62 ± 0.03	41 ± 1	4.02 ± 0.43	1.90 ± 0.12
2	155	2.58 ± 0.04	167 ± 4	3.60 ± 0.21	1.27 ± 0.02
3	233	3.55	85	3.00	1.33
4	100	3.93 ± 0.22	66 ± 10	2.98 ± 0.36	1.68 ± 0.09
5	137	2.60 ± 0.08	165 ± 9	2.40 ± 0.56	1.31 ± 0.02
6	244	2.66	158	1.92	1.30
7	106	4.63 ± 0.21	41 ± 6	6.35 ± 0.14	2.18 ± 0.47
8	154	3.07 ± 0.20	120 ± 17	2.24 ± 0.37	1.50 ± 0.02
9	248	3.51	88	2.63	1.29
10	78	2.64 ± 0.10	161 ± 11	3.34 ± 0.30	1.37 ± 0.05
11	168	3.66 ± 0.08	79 ± 4	3.38 ± 0.23	1.65 ± 0.17
12	250	3.00	125	3.24	1.99
13	86	3.06 ± 0.05	120 ± 4	3.32 ± 0.26	1.71 ± 0.05
14	151	3.17 ± 0.12	112 ± 10	3.15 ± 0.49	1.62 ± 0.07
15	259	2.73	151	3.26	1.68
16	85	3.55 ± 0.20	86 ± 12	4.18 ± 0.36	1.68 ± 0.13
17	150	3.59 ± 0.30	85 ± 17	3.99 ± 0.34	2.46 ± 0.25
18	239	2.57	168	4.23	1.91
19	90	2.77 ± 0.13	147 ± 13	1.20 ± 0.11	1.36 ± 0.06
20	154	3.05 ± 0.24	122 ± 21	3.27 ± 0.23	1.90 ± 0.10
21	284	3.51	88	3.09	2.19
22	175	2.70 ± 0.17	155 ± 18	2.58 ± 0.32	1.37 ± 0.05
23	282	2.50	177	3.76	1.42

Table A14.2. The most important macroinfaunal taxa at the 8 stations in winter and spring (ind.m^{-2}). Abbreviations: W: winter; S: spring.

	Station															
	1		2		4		5		8		10		11		14	
Season	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Polychaetes																
Ampharete finmarchica	-	-	-	-	-	-	-	-	-	57	-	-	-	152	-	-
Ampharetidae undet.	11	-	14	19	11	-	114	210	103	19	-	-	23	95	11	76
Aricidea sp.	-	-	14	229	194	152	251	248	126	76	217	133	-	95	137	152
Cirratulidae undet.	-	-	57	38	11	38	-	57	-	-	-	-	-	-	11	-
Galatowenia oculata	-	-	129	57	11	19	-	38	57	-	11	-	160	76	160	76
Glycera rouxii	23	-	-	-	11	19	23	-	46	38	-	-	34	38	34	19
Gyptis capensis	11	39	14	57	-	-	-	-	11	-	57	19	-	-	-	19
Hyalinoecia brementi	-	-	-	57	-	-	34	76	-	-	-	-	-	38	11	57
Lumbrineris gracilis	34	39	-	-	-	19	-	57	-	57	11	-	-	19	-	-
Magelona wilsoni	23	20	29	38	137	229	46	95	69	57	537	14	160	38	69	171
Mediomastus fragilis	11	39	86	38	69	38	69	38	46	38	46	19	34	38	91	114
Monticellina dorsobranchialis	-	-	71	19	149	171	297	171	126	76	-	-	343	152	286	57
Nephtys hombergi	-	-	29	38	-	-	23	-	23	-	-	57	-	-	23	19
Paradoneis lyra	11	20	-	-	-	-	-	-	11	-	80	95	-	-	-	19
Paraonidae undet.	-	20	-	38	229	267	103	19	23	76	-	-	137	38	34	-
Prionospio fallax	937	858	214	286	1795	2362	423	76	457	419	1429	1181	549	229	446	438
Prionospio steenstrupii	194	98	43	-	229	114	103	19	114	324	-	19	411	629	251	114
Tharyx sp.	-	-	-	-	-	-	-	-	-	-	686	438	-	-	-	-
Molluscs																
Abra alba	-	-	-	-	23	-	-	57	23	57	-	-	23	-	34	57
Bivalvia undet.	-	-	-	-	-	38	-	-	-	19	-	-	46	19	69	57
Mysella bidentata	-	-	-	-	-	-	-	-	-	-	309	305	-	-	-	-
Thyasira sp.	57	20	-	-	69	19	34	38	34	19	-	-	57	57	57	191
Echinoderms																
Amphiura filiformis	-	-	-	-	-	-	-	-	-	-	423	800	-	-	-	-
Crustaceans																
Ampelisca sp.	-	-	-	-	23	-	11	19	-	-	-	-	869	610	91	57
Urothoe sp.	-	-	-	-	-	-	-	-	-	-	114	114	-	-	-	-
Others																
Nemertines undet.	126	39	43	38	114	133	57	57	34	19	194	133	80	19	171	76
Oligochaeta undet.	194	39	-	-	126	-	23	-	46	-	286	362	-	-	46	-
Onchnesoma steenstrupii	-	-	-	-	11	-	69	133	-	-	-	-	34	19	126	38

Table A14.3. Macroinfaunal total abundance (ind.m^{-2}) and percentage made up of each group of total abundance at each station by season.

Station	K		H'		J'	
	W	S	W	S	W	S
1	22	18	2.84	2.54	0.64	0.61
2	28	27	4.12	4.05	0.86	0.85
4	36	30	3.15	2.62	0.61	0.53
5	30	35	3.89	4.57	0.79	0.89
8	44	29	4.48	4.00	0.82	0.82
10	46	31	3.79	3.60	0.69	0.73
11	37	34	3.80	4.01	0.73	0.79
14	45	41	4.50	4.71	0.82	0.88

Table A14.4. Macrofauna richness (K), diversity (H') and evenness (J') at all 8 stations by season.

Station	% P		% M		% E		% C		% O		Total Abundance ind.m^{-2}	
	W	S	W	S	W	S	W	S	W	S	W	S
1	77.11	82.89	5.42	10.53	0.60	0.00	0.00	0.00	16.87	6.58	1897	1482
2	91.57	87.88	0.00	1.52	1.20	1.52	1.20	6.06	6.02	3.03	1186	1257
4	86.67	92.31	4.76	2.88	0.00	0.00	0.95	0.96	7.62	3.85	3601	3962
5	86.55	78.35	3.51	7.22	0.58	0.00	1.75	3.09	7.60	11.34	1955	1848
8	82.53	80.22	4.22	9.89	0.60	1.10	2.41	7.69	10.24	1.10	1897	1734
10	66.06	53.54	10.41	11.06	10.18	19.47	3.85	4.42	9.50	11.50	5052	4305
11	65.23	70.20	4.30	3.31	0.00	0.00	27.15	25.17	3.31	1.32	3552	2877
14	73.80	70.99	7.42	18.32	0.00	0.76	5.68	5.34	13.10	4.58	2617	2496

Table A14.5. Abundance (%) of the five hyperbenthic dominant species at each site in winter and spring surveys. AMP: amphipods; CUM: cumacans; DEC: decapods; EUP: euphausiids; ISO: isopods; MYS: mysids.

Station	Winter			Spring		
	AMP	*Amphilochoides boecki*	25.3	EUP	*Nyctiphanes couchi*	38.4
	MYS	*Leptomysis gracilis*	12.1	MYS	*Leptomysis gracilis*	9.2
19	EUP	*Nyctiphanes couchi*	11.3	AMP	*Paramphilochoides odontonyx*	5.8
	MYS	*Anchialina agilis*	9.8	MYS	*Leptomysis* spp. (juv.)	5.0
	ISO	*Paramunna typica*	5.4	MYS	*Anchialina agilis*	4.5
		Total	63.9		Total	63.0
	MYS	*Anchialina agilis*	15.7	MYS	*Erythrops neapolitana*	17.5
	MYS	*Erythrops neapolitana*	11.5	MYS	*Anchialina agilis*	10.9
20	EUP	*Nyctiphanes couchi*	11.0	AMP	*Perioculodes longimanus*	7.2
	MYS	*Leptomysis gracilis*	8.0	DEC	*Philocheras bispinosus*	5.4
	CUM	*Diastyloides biplicata*	7.6	CUM	*Diastyloides biplicata*	5.0
		Total	53.7		Total	45.9
	DEC	*Pasiphaea sivado*	51.1	EUP	Euphausiidae indet. (juv.)	20.0
	AMP	*Scopelocheirus hopei*	10.9	EUP	*Meganyctiphanes norvegica*	14.5
21	AMP	*Orchomenella nana*	9.8	EUP	*Nyctiphanes couchi*	13.3
	EUP	*Meganyctiphanes norvegica*	7.9	DEC	*Pasiphaea sivado*	12.7
	MYS	*Boreomysis megalops*	2.8	AMP	*Orchomenella nana*	5.6
		Total	82.5		Total	66.1

Table A14.6. Abundances (individuals·100m-2) of the main taxonomic groups in the hyperbenthic communities off the Ría de La Coruña. w: winter; s: spring.

	Abundances*							
Station	19		20		21		Total	
Season	w	s	w	s	w	s	w	s
Pycnogonids	-	-	0.2	0.2	-	-	0.2	0.2
Mysids	257.7	535.3	182.6	365.7	14.3	27.2	454.6	928.1
Amphipods	267.1	518.8	81.2	220.0	80.9	46.4	429.3	785.3
Cumaceans	65.5	213.5	78.6	86.4	5.5	21.5	149.6	321.5
Isopods	42.1	36.7	8.2	12.9	-	3.6	50.4	53.2
Tanaids	0.3	-	0.3	5.3	-	0.1	0.6	5.4
Euphausiids	83.6	890.8	46.8	42.9	26.7	138.8	157.2	1072.4
Decapods	22.4	63.8	22.9	62.0	142.3	48.3	187.5	174.0
Fishes	2.3	58.0	2.5	0.9	0.2	2.3	4.9	61.2
Total	741.0	2316.9	423.3	796.3	269.9	288.2	1434.2	3401.4

* ind·100m^{-2}

Table A14.7. Structural parameters of hyperbenthic communities off the Ría de La Coruña. H': Shannon-Weaver species diversity index; J' evenness; w: winter; s: spring.

Station		19		20		21	
Season		w	s	w	s	w	s
Depth* (m)		97	96	150	149	290	300
Sampling area (m^2)		308.5	103.5	642.5	434.0	565.8	900.9
Species richness		51	52	74	67	45	64
Abundances ($ind \cdot 100m^{-2}$)		741.0	2316.9	423.3	796.3	269.9	288.2
Diversity	H' (log_2)	3.80	3.56	4.38	4.41	2.72	4.00
	J'	0.67	0.62	0.71	0.73	0.49	0.67

* Depth at the beginning of the haul

Table A14.8. Selected indicator or key species groups. Gear indicated to the benthic compartments sampled box-corer (BC) and hyperbenthic sledge (HS)

Indicator group	Scientific name(s)	Gear
Ophiuroid	**Amphiuridae**	**BC**
Infaunal bivalvia	***Abra* spp, *Thyasira* spp**	**BC**
Polychaete	**Ampharetidae, Capitellidae, Spionidae**	**BC**
Sipunculida	***Golfingia, vulgaris, Golfingia* sp, *Onchnesoma steenstrupii***	**BC**
***Ampelisca* sp**	***Ampelisca* sp**	**BC, HS**
Amphipoda	**Amphipoda**	**BC, HS**
Cumacea	**Cumacea**	**BC, HS**
Peracarida	**Peracarida**	**BC, HS**

Table A14.9. Spearman rank order correlation (r) between environmental variables and species richness (S), biomass (W) or density (N) and species diversity (H') for infauna and hyperbenthos. * = significant correlations at p < 0.05; ** = significant correlations at p < 0.001.

	Infauna (n = 16)			Hyperbenthos (n = 6)		
	S	N	H'	S	N	H'
Tar aggregates amount	0.358	0.107	0.118	0.034	0.068	- 0.135
Depth	0.130	-0.366	0.583 *	0.143	- 0.771	0.028
Latitude	0.730 **	0.630 *	0.265	0.143	- 0.771	0.028
Organic matter (%)	- 0.525 *	-0.184	- 0.294	0.677	- 0.294	0.736
Mean particle diameter (Q_{50})	0.099	-0.230	0.617 *	0.029	0.883 *	0.029
Sorting coefficient (S_0)	- 0.026	0.288	- 0.540 *	0.029	0.883 *	0.029
Coarse sand (%)	0.342	0.376	0.041	- 0.736	- 0.647	- 0.677
Fine sand (%)	0.076	-0.141	0.438	0.029	0.883 *	- 0.029
Mud (%)	- 0.104	0.113	- 0.465	0.029	- 0.883 *	0.029

Table A14.10. Spearman rank order correlation between environmental variables and indicator densities for macroinfauna. r = correlation coefficient; * = significant correlations at p < 0.05; ** = significant correlations at p < 0.001. (Only correlations with r > 0.60 and a significant p value are shown).

Infauna	r
Depth-Ampharetidae	0.760 **
Depth-Cumacea	0.607 *
Latitude-Peracarida	0.790 **
Latitude- Amphipoda	0.770 **
Latitude- *Ampelisca* sp.	0.603 *
Latitude-Cumacea	0.740 **
Coarse sand-Peracarida	0.620 *
Coarse sand-Amphipoda	0.659 **
Fine sand-*Thyasira* sp.	-0.668 **
Mud- *Thyasira* sp.	0.646 **

Annex 15: Investigations at offshore wind farms in Denmark

By S. Smith.

Last September there was a conference on Offshore Wind Farms and Environment In Billund, Denmark, where the first results from a Danish monitoring programme during 1999–2006 at Horns Rev(2002) and Nysted (2003, formerly named Rødsand) were presented. Referring to Simon Leonhard, Bio/consult A/S, Denmark excerpts from this conference and another in Berlin (March 2005) were being forwarded by Susan Smith. The paper recorded the ecological impact of the introduction of hard substrate from 1999–2003 by using surveys on both epifouling communities as well as infaunal communities. The objectives were addressed to the assessment of impacts from "aliens", the assessment of possible hydraulic impacts. Furthermore, the aims of the programmes were to monitor the development and succession in epifouling communities.

Hard substrates

(turbine towers, concrete foundations and scour protections)

The initial vegetation of macroalgae at the introduced hard substrates was generally low in diversity. At Nysted, mainly red algae were recorded, but green algae species of *Ulva* (*Enteromorpha*) that dominated at Horns Rev were less frequent. Typical seasonal changes in vegetation species composition and coverage were recorded at both sites and especially variations in depth distribution were found along turbines at Horns Rev.

Different epifaunal assemblages were recorded at Horns Rev and at Nysted A high proportion of a few main primary colonisers contributed to more than 99% of the total abundance and to more than 91% of the total biomass. At Horns Rev the cosmopolitan amphipod *Jassa marmorata*, not previously recorded in Denmark, was the most frequent species found on turbine towers in abundances as high as 640,000 ind./m^2; whereas at Nysted the barnacle *Balanus improvisus* and the common mussel *Mytilus edulis* were the most abundant species at the concrete foundations - 40,000 ind./m^2 and 361,000 ind./m^2, respectively.

Distinct vertical zonations in the faunal assemblages on the turbine towers and concrete foundations were observed. The common mussel *Mytilus edulis* dominated the biomass and was found in dense aggregations of spat or larger individuals in the sublittoral. At Horns Rev, the vertical distribution of *Mytilus edulis* was typically controlled by the keystone predator; the starfish *Asterias rubens*. Not so at Nysted; due to lower salinity, this predator was missing and no other controlling predator was registered. In the splash/wash zone at Horns Rev, monocultures of the "giant" midge *Telmatogeton japonicus*, not previously recorded in Denmark, were typically found feeding on the green epilithic algae. At Nysted, almost monocultures of *Balanus crenatus* were found in this zone; whereas at Horns Rev, the barnacles were less abundant and due to higher salinity dominated by *Balanus crenatus* and *Balanus balanus.*

Spatial and temporal differences between sites, sample locations and substrate types were found in the immature epifouling communities on the hard substrates. Greater similarities between some of the turbine sites were shown in at the latest sampling occasion in September 2003 than earlier, which might be a result of succession approaching stability in the fouling communities. Attraction behaviour and utilisation of the hard substrates at Horns Rev as nursery grounds was shown for mores species like the edible crab *Cancer pagurus*.

The new habitats have introduced new species, a increased species diversity, hatchery and nursery grounds for mobile benthic species and have increased benthic biomass and prey availability.Records of the European oyster *Ostrea edulis*, considered as threatened in the

Wadden Sea area, might show that wind farms can be regarded as sanctuary for endangered and protected species. Immature epifouling communities in succession at both farm sites were recorded.

Infauna

Distinct differences in benthic communities were found between the two different wind farm sites. The native infauna community at Horns Rev can be characterised as an *Ophelia borealis* or *Goniadella-Spisula* community typical for sandbanks in the North Sea area. This community displayed great spatial and temporal variability in species composition, abundance and biomass. At Nysted, the native infauna community was characterised as the *Macoma* community with patches of stones and an epifauna community of the common mussel *Mytilus edulis*, both typical for shallow coastal areas. Character species that can be used as indicators for environmental changes are identified for the Horns Rev area.

No impacts on the infaunal benthic communities were found when comparing wind park area and a reference area, but some new species were introduced. Neither was any hydraulic impact on the infaunal benthic community found.

Annex 16: Offshore wind farms in Sweden

By S. Smith

The national goal that windpower should generate 10 TW/yr by 2015 would require the creation of offshore wind farms. So far one pilot wind farm (Lillgrund) is commissioned, situated in the Oresund south of the link between Sweden and Denmark. There will be 48 wind turbines rending a total production of 300 GWh/yr. These will be operational in 2007. The next wind farm might be localized in the southern Baltic on Kriegers Flak (328 wind turbines, in the Swedish EEZ), where a German pilot plant of 80 wind turbines has recently been approved.

Last year, as was reported by H. Kautsky, an assessment of the biological values on a number of possible offshore areas of interest to future wind farms started. This year the Swedish government (i.e., the Energy Agency, through the EPA), has granted as a start 2.5 out of 35 millions SEK allocated for impact studies to 5 base-line studies at wind farms in the southern Baltic and Oresund. One of these studies will focus on sessile organisms, the title of which is “Benthic processes on and around artificial structures”. In the meantime another 2 yr project is finalized regarding research on biodiversity and reef effects at constructions for windpower in the Baltic. The project is a cooperation between the Botanical Institution, University of Stockholm (project coordinator T. Malm) and the Danish EPA and their report will appear during 2005.

A report by Greenpeace called Sea Wind Europe was highlighted. Also more information at homepages www.windpower-monthly.com, www.eurorex.com and www.ecn.nl/main.html.

Annex 17: Action Plan Progress Review

Year	Committee Acronym	Committee name	Expert Group	Reference to other committees	Expert Group report (ICES Code)	Resolution No.		
2004/2005	MHC	Marine Habitat	BEWG		2004:\E:07	2.00E-07		
Action Plan	Action Required	ToR's	ToR	Satisfactory Progress	No Progress	Unsatisfactory Progress	Output (link to relevant report)	Comments (e.g., delays, problems, other types of progress, needs, etc.
No.	Text	Text	Ref. (a, b, c)	S	0	U	Report code and section	Text
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	Review the state of benthic communities at seamounts as presented by MarEco and other projects and provide input to [WGDEC] in relation to the provision of advice to OSPAR on the evidence for the threats to, and/or decline in, seamount habitats and their populations in the OSPAR regions where seamounts occur [OSPAR 2005/3];	a)			U	E:07, 11	Not enough expertise + data
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	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;	b)	S			E:07, 8	
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	Work with WGSAEM on testing the use of different statistical methods on specific data sets (for example, the 1986 North Sea Benthos Survey data);	c)		0		E:07, 9	No joint meeting
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	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.	d)		0		E:07, 9	
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	Identify sources of available data on the North Sea Ecosystem by Expert Groups contributing to the REGNS process. This information should be submitted to the REGNS website in preparation for the Integrated Assessment Workshop to be held from 9–11 May 2005;	e)	S			E:07, 5.2	
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	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;	f)	S			E:07, 7	
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	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;	g)	S			E:07, 12	
1.2.1, 2.2.1, 2.13, 4.12, 2.11	Please see Action Items below	With MCWG and WGBEC, contribute to an assessment of the long-term impact of oil spills on marine and coastal life, based on a list of issues from OSPAR [OSPAR 2005/7].	h)	S			E:07, 6	More action and info after ASC05 theme session on oil spills

Action Plan nos.	
1.2.1	Understand and quantify the biology and life history, stock structure, dynamics, and trophic relationships of commercially and ecologically important species.
2.2.1	Contribute to the scientific advice for the development of EcoQOs that will ensure the environmental health of marine ecosystems.
2.11	Evaluate and increase knowledge of the effects of built structures, such as windmill farms, artificial reefs, and other structures, on marine ecosystem structure and functions.
2.13	Evaluate and increase knowledge of the effects of activities that alter physical habitat structure, such as dredging and extractions, on marine ecosystem structure and functions. [MHC/OCC/ACME/ACE/DFC
4.12	Review and advise on procedures for quality assurance of biological, chemical and physical measurements.