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Executive summary

Highlights

- A subgroup of the BEWG (SGNSBP) finished a comprehensive report (CRR) on the North Sea Benthos Project 2000 in which they deliver a valuable dataset on the benthos of the North Sea together with long-term evaluations and model developments.
- Reports from current benthos work in Europe revealed positive news that the PRESTIGE oil disaster in NW Spain had no lasting negative effects on the benthos, and the Baltic coastal region in east Sweden shows signs of general ecological improvement as seen by a deepened distribution of algae and decreased nitrate concentrations in the water.

The BEWG held its 2007 meeting at the Senckenberg Institute, Wilhelmshaven, Germany. 18 participants from seven countries attended and concentrated on the challenging agenda and also reported on benthos research on-going in Europe.

ToR a and b: The question concerning the effects of changing hydrodynamics and sea temperature on benthic communities cannot be answered without difficulties. Observations on a smaller scale may give contradicting results. On a large scale, changes in hydrodynamics and sea temperature are often interconnected and are a result of climatic variability as indicated by the NAO index.

With regard to changes of hydrodynamics there is only little information available. On the Dogger Bank increased current velocities caused changes in sediment composition and as a consequence also in the benthic community. Off the English east coast hydrographic changes were considered responsible for changes in food availability (derived from phytoplankton) to the benthic community.

Changes in the characteristics of winters and summers play an important role in structuring the benthos.

If the trend of milder winters and warmer summers, also expressed by the NAO index, continues, shifts in species composition and numbers, abundance and biomass can be expected, as it is being recorded now for some of them.

No species can be named as being specifically responsible for changes in hydrodynamic conditions, whereas a temperature increase is indicated by shifts in the distribution of a range of several species, e.g., *Megaluropus agilis* and *Amphiura brachiata* in OSPAR region II, e.g., in OSPAR region IV and species region II.

ToR c: The Chair answered an intersessional OSPAR request concerning listing of *Cymodocea* meadows in southern Europe. They were consequently listed as endangered.

ToR e: Highlights of the reports were the documentation of the improvements of the coastal ecosystem at the eastern Swedish coast as evidenced by deeper algae distribution compared with historical pre-industrial records and decreasing nitrate concentration in the water. The phosphate levels seemed nevertheless to increase. This could be a result of increased bioturbation in the sediment due to the improved environmental conditions.

A national project in Belgium on Marine Biological Valuation revealed exciting new ways to value ecologically important sites in a non-monetary fashion. It will shortly be combined with MarBEF attempts to enlighten the socio-economic sides of biodiversity research.

The final report on the *Prestige* oil disaster in NW Spain showed in the end no lasting effects in the benthic system although the argumentation was hard since there were no pre-event monitoring data except some epifauna records. Tar clumps in the deeper waters are no longer

visible as there are no visible effects in the coastal ecosystem. Also the coastal fishery is back to normal and the lesson learned is that recovery is a normal process in nature.

ToR d and i: New improved methodical investigations were reported as method harmonization and standardisation was always one of the prime aims of the group. This was the sieving of fresh material vs. fixed material and a comparison of the widely used Van Veen grab and the Hamon grab which is mainly used in coarse sediments. The TIMES 27 document was revised and an updated version is almost ready for publication.

ToR f: The group updated the list of metrics and recommended the organisation of a workshop on benthos related environmental metrics.

ToR h: The SGNSBP presented its final reports in the form of and CRR draft just submitted to ICES for publication. Most of the material presented here was also used to answer the OSPAR requests under ToR a and b. The group is planning a new North Sea benthos project in 2010.

1 Opening of the meeting

The Chair, Heye Rumohr, opened the meeting and welcomed the participants. The local host, Ingrid Kröncke from the Senckenberg Institute gave some practical information about domestic issues. A list of participants is included at Annex 1.

An ICES sharepoint site was made available during the meeting and proved to be a valuable tool to speed up the work and make exchange of information more efficient. The Chair emphasized the importance of taking OSPAR request very seriously as they are important for ICES advisory work.

Apologies were received from J. Craeymeersch, Silvana Birchenough, Hubert Rees, Kerstin Mo, Lene Buhl-Mortensen, B. Tunberg, Jan van Dalfsen and A. Schroeder.

1.1 Appointment of Rapporteur

The Chair expressed his wish to have daily Rapporteurs, together with an editing Rapporteur who would bring the daily contributions together into the final report. H. Hillewaert was appointed editorial Rapporteur; daily Rapporteurs were I. de Boois, I. Moulaert, M. Robertson.

1.2 Terms of Reference

The Terms of Reference (ToR) for BEWG 2007 are listed at Annex 3. The respective ToR item is included in the headings of subsequent sections for information.

2 Adoption of the agenda

The agenda was agreed unanimously and is attached at Annex 2.

3 Report on ICES meetings and other meetings of interest

3.1 ASC 2006 (Maastricht) / ICES Annual Report for 2006

H. Rumohr reported briefly on the ASC 2006. Mainly fish and management subjects were on the agenda and only a few environmental topics. To improve this uneven situation we need more activities and input from the environmental side of the ICES community. The report is on the ICES website and can be downloaded from there.

3.2 Marine Habitat Committee, Maastricht 2006

H. Rumohr reported, as outgoing MHC Chair, on the creation of a new study group within the Marine Habitat Committee: namely the SGBIODIV (the Study Group on Biodiversity Science), this group will continue to review all MarBEF-work undertaken within ICES. Dr Hubert Rees will be the first Chair of this group.

The Marine Habitat Committee has a new Chair, Tom Noji (NOAA) from the USA.

3.3 WGEXT

H. Hillewaert, reported on the recent WGEXT meeting in Helsinki, Finland. A summary by Kris Hostens (ILVO, Belgium) is given below.

For each member country, the total extracted amount of sand and gravel in 2006 was reported and the development of EIA's and marine resource and habitat mapping programs were reviewed. Much time was spent on finalizing the Cooperative Research Report, which wasn't finished during the last year due to a variety of circumstances. However most of the chapters are now ready. Only the executive summary and the final editing of the Report need to be completed. The final report will be sent for publication by May/June 2007. The group also started to review the ICES Guidelines on sand extraction monitoring and the complementarities/overlap of the COST-Maggnet action with the work of the ICES WGEXT group were discussed.

An interesting (and to several of the participants astonishing) presentation was given by Ad Stolk (Netherlands) about the '*Extraction of sand for the enlargement of the Rotterdam harbour*'. The EIA describes the effects of large scale marine sand extraction with a maximum of 365 million m^3 (see www.maasvlakte2.com for the Environmental Impact Assessment).

Jan Van Dalfsen gave a short overview of the MESH project (Mapping European Seabed Habitats - http://www.searchmesh.net), where much effort has gone into the development of state-of-the-art digital databases of various bathymetric, sedimentological and biological parameters. These digital databases can be queried and analyzed rapidly, will enable intercomparison to establish relationships, and make it possible to produce tailor-made maps on demand. Another presentation was given by Michel Deprez on '*the trophic role of benthic communities for the main commercial demersal fish species in Dieppe*'. (Actually this is one of the recommendations of this group which still little attention). Results were also presented from the monitoring program of the construction works underway in the new Port of Helsinki in 2005.

(http://www.vuosaarensatama.fi/linked/fi/tiedotteet/vesisto_2006.pdf).

WGEXT is planning to take a clear look at the use of the guidelines for sand and gravel extraction. However, this will be dependent on the area studied, country, etc. For this review, WGEXT requested that BEWG consider how to create a list of standard areas.

The WGEXT will next meet in the UK from the 8–11 April 2008.

3.4 MarBEF

H. Rumohr reported on MarBEF (a network of excellence for biodiversity research in Europe). A special RMP project on recovering historical data, lead by staff from VLIZ (http://www.vliz.be) is currently working. The next General Assembly will be held in Poland during May 2007.

3.5 WGECO

I. de Boois briefly reported on benthos issues under WGECO. BEWG will assess benthos information in the recent WGECO report. It is not clear whether WGECO expected BEWG to create input for their meeting. The BEWG Chair will contact the WGECO Chair for clarification.

3.6 Other meetings

3.6.1 WKNEPHTV

H. Rumohr reported on the newly formed WKNEPHTV (Workshop on the use of Under Water TV surveys for determining abundance in *Nephrops* stocks throughout European waters). This group aims to assess *Nephrops* by employing imaging as an addition/complement to traditional fishing surveys. It was a useful meeting where fishing and benthos interests met. The aim was to use non-destructive methods for stock assessments of *Nephrops*. However not only *Nephrops* were counted on the images, other benthic organisms, for example sea pens, was also observed. A CRR (Co-operative Research Report) is a likely outcome out from this meeting.

3.6.2 Workshop on taxonomy of macrophytes

H. Rumohr mentioned a workshop on the taxonomy of Baltic macrophytes. The resulting report contains a useful identification tool.

3.6.3 ASC 2007

ASC 2007 will be held in Helsinki, Finland. There will be a Theme Session (A) chaired by members of the BEWG on benthic dynamics in ICES waters. Presentations in this Theme Session will focus mainly on the NSBP 2000 but other projects are welcome. Abstracts should be submitted before the end of April 2007.

4 Assess and report on changes in the distribution, population abundance and condition of benthic invertebrates in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (ToR a)

K. Essink introduced a document prepared by a subgroup of the Working Group on aspects of changes in benthic communities from within the OSPAR area. The paper described temporal trends over the period between 1986 and 2000 and presented a compilation of long-term studies in the OSPAR region.

A. Borja presented a talk entitled “Benthos and Climate Change in the Bay of Biscay”. An outline of his talk is in Annex 5.

The data presented were extremely useful and will be added to the compilation paper described by K. Essink previously. It was pointed out that there was a strong correlation between changes noted in the fauna and the North Atlantic Oscillation (NAO) and with light and suspended solids levels in the water column. For example, *Gelidium* biomass was closely correlated with light levels. Secchi disc depth data were unfortunately not available.

E. Rachor reported on the ongoing work in Germany revising the Red List of endangered and potentially endangered species of marine benthic invertebrates.

This will be the 3rd revision of these marine species lists (1984, 1998, 2008) and the aim is to revise all German Red Lists every ten. The assignment of species to the Red List is controlled by four main criteria: status of the population, long-term trend, short-term trend, additional (new) risk factors.

From more than 2000 species, 600 were studied in detail and it is expected that up to 200 will be placed in the final list. (Tables in Annex 6).

5 Assess and report on the extent to which the changes reported in (a) can reliably be attributed to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE) (ToR b)

A subgroup regarded Tor a and b together and formulated a combined report on both TORs.

See Annex 7.

6 Assess and report on the evidence on which the nomination of Seagrass *Cymodocea* meadows for the OSPAR List of Threatened and/or Declining Species and Habitats is based (ToR c)

This ToR item was intersessionally covered by the Chair after consultation with an external panel of experts.

The Chair posed the OSPAR request to the members of the BEWG and had only few substantial answers because the subject was beyond the expertise of the group as *Cymodocea* grows only in southern Spain and on the Canary Islands. Nevertheless answers were received from two senior members of the Working Group who argued that *Cymodocea* meadows should be treated in a similar manner to endangered *Zostera* and *Posidonia* stands since they suffer similar threats. The Chair also contacted colleagues who work on *Cymodocea* meadows in Cadiz Bay and on the Canary Islands namely:

- In Andalusia: Ignacio Hernández (ignacio.hernandez@uca.es) and Juan José Vergara (juanjose.vergara@uca), both from the University of Cádiz;
- On the Canary Islands: Inmaculada Santana Ojeda (macu@iccm.rcanaria.es), from the Canary Institute of Marine Sciences;

and received useful answers from Ignacio HERNANDEZ: “We are presently studying the meadows of *Cymodocea* in the Cadiz Bay. In 2007 two theses will be finished about the biomass and growth dynamics of *Cymodocea nodosa*. The next step will address the interaction of these meadows with *Caulerpa prolifera*. This chlorophyte is spreading into *Cymodocea* meadows but at present we cannot assess whether *Cymodocea* is declining or not in Cadiz Bay. It may be possible but we need to address the question of the patch distribution of *Caulerpa* first. This species grows under very different sediment conditions than those of *Caulerpa*, but at the moment we do not know if the sediment is cause or consequence of the covering by *Caulerpa*. In Cadiz Bay, *Cymodocea* meadows are suffering from different impact, including eutrophication, dredging and water turbidity by shell-fishing. In case you need further information about biomass dynamics of *Cymodocea* (although still unpublished) please let me know. We have been looking carefully at the document and consider that the data are reliable. The following comments may improve the sheets about *Cymodocea*.

Comments to OSPAR list::

- **Definition for habitat mapping**. *Cymodocea nodosa* forms large and dense patches with green leaves that can reach up to 100 cm long and 8.0 mm wide.
- **Geographical extent**. Seeds have been recorded in Cadiz Bay but probably many seedlings are not successful. In Cadiz Bay there are intertidal meadows of *Cymodocea* which are exposed for several hours during a tidal cycle
- **Decline**. Probability of significant decline in Cadiz bay YES. The main impact is construction works (harbours, factories, roads...) that cause water pollution within the habitat.”

The Chair’s personal view and answer to ACE was “*Cymodocea* meadows are, at least in Cadiz Bay, candidates for nominations for the OSPAR List of Threatened and Declining Species as set out in the table presented by OSPAR. The data used to support the nominations are sufficiently reliable and adequate to serve as a basis for conclusions that the species and habitats concerned can be identified as threatened and/or declining species and habitats according to the Texel/Faial criteria. There were no indications from experts that the presented evidence was not sufficient or unreliable. But special attention should be paid to the interaction/ competition with *Caulerpa prolifera*. The coming thesis/report by Hernandez and Vergara (University of Cadiz) should be used as baseline information once it is available. The proposed amendments for the OSPAR list should be checked for inclusion”.

But, since there was no information about the present situation on the Canary Islands this could only be adopted under precautionary aspects for the Canary Island region.

This intersessional answer was well received by the ACE Chair and the advice to OSPAR was to include it in the relevant list as endangered what was finally also agreed on.

7 Discuss and report on quality assurance and control guidelines for sampling and analytical practices for benthos (ToR d)

The group discussed new QA matters concerning benthos sampling and sample processing and used the results in the update of the TIMES 27 document under ToR i)

8 Review and consider recent developments in ongoing benthos research in the ICES area (ToR e)

8.1 Cooperative studies

8.1.1 MAFCONS

H. Reiss reported on the EU-project MAFCONS (Managing fisheries to conserve groundfish and benthic invertebrate species diversity). This project started in 2003 and was finalised in autumn 2006. The main objective was to provide scientific advice to fisheries managers with mathematical tools to quantify the consequences of fishing on demersal fish and benthic invertebrate species diversity (for details see BEWG-Report 2005). The Houston's dynamic equilibrium model was used as a starting point to describe the relationships between disturbance due to fishing activities and diversity. This model predicts that both positive and negative responses of diversity to increased disturbance are possible, depending upon local productivity.

The main spatial scale on which the studies of MAFCONS are based, was the ICES statistical rectangle scale in the North Sea. Thus infauna (van Veen grab), epifauna (2 m beam trawl) and fish (GOV) were sampled over the entire North Sea in summer 2003 and 2004. Secondary production and diversity for each component have been determined and compared. The final testing of Houston's model showed that it could not provide a basis for predicting the relationship between diversity and disturbance at least on the spatial scale studied. Therefore, the development of an alternative size-structured species-interactive model was initiated.

All final reports can be downloaded from the project web-site (http://www.mafcons.org). The infauna, epifauna and demersal fish datasets as well as a compilation of international annual fishing effort and landings will be available after publication of the main parts of the project.

The group highlighted the importance of the availability of the data. Final storage location of the data after the end of the project is still undecided.

8.2 Benthos and fisheries

8.2.1 BWZee

S. Degraer gave an overview of the project BWZee (A Biological Valuation Map for the Belgian Continental Shelf.).

Decision support systems (DSS) for sustainable marine management should take account of social and economic as well as ecological aspects. The project on marine biological valuation aims at establishing a protocol to provide an integrated view on nature's intrinsic value. Biological value is defined here as the value of biodiversity, without any reference to anthropogenic use. As such, the biological value complements the social and economic valuation within a DSS.

Till now, when requested, the biological value of an area was assessed through a basically unguided procedure, primarily based upon a - best available expert judgement. Such subjective and arbitrary procedures largely contribute to the general ignorance of biological value within current DSSs. Our marine biological valuation protocol, in contrast, should ideally be (1) scientifically widely acceptable, to avoid an uncontrolled proliferation of valuation strategies, and (2) widely applicable, to maximise its applicability. Only when both criteria are fulfilled, will the valuation protocol be taken into DSSs to quantify nature's intrinsic value. The successful application of such a protocol was taken from the terrestrial part of Flanders (Belgium).

A review of relevant literature was first completed. From this, lessons were learned, specifically: (1) the high redundancy in valuation criteria used, (2) the high variability in valuation criteria and (3) the frequent confusion between valuation criteria and criteria for MPA selection. A draft paper, drawn from this literature review, was taken as a starting point for an international expert workshop on marine biological valuation. As a result of the workshop a proposition for three first order valuation criteria and two modifying criteria were fixed into a concept for biological valuation, taking into account all levels of biodiversity organization (from genes to ecosystems). This concept for biological valuation strategy has recently been published: Derous *et al*., 2007, Oceanologia.

The developed marine biological valuation protocol was then tested in the Belgian part of the North Sea (BPNS). For all valuation criteria and organizational levels of biodiversity assessment questions were described, leading to a protocol for biological valuation. These were evaluated for the different ecosystem components for which data were sufficiently available for the BPNS (seabirds, macro-, epibenthos and demersal fish). This leads to different maps for every assessment question per ecosystem component. In a last phase of the test all separate maps need to be combined and this will result in a marine biological valuation map for the BPNS.

Within the NoE MarBEF Theme III Responsive Mode Action on DSSs and the CA ENCORA Theme 7 on Biodiversity Change the protocol is now being tested or will be tested at eight other sites, spread throughout European marine waters: Pico-Faïal channel (Portugal); Puscz Bay (Poland), Scilly Islands (U.K.), Flamborough Head (U.K.), Northern French coastal area (France), Adriatic Sea (Italy) and Sylt-Rømø (Denmark). These tests should provide us with "lessons learned", considering the general applicability of the protocol and it's scientific acceptability (i.e. feed back with local experts) and will thus lead to suggestions for further improvement. The next workshop on these test cases is planned for Paris in November 2007.

Unlike the Bird and Habitat Directive, BWZee only takes the biological value into account, not the degree of threat, political concern, vulnerability, socio-economic criteria, etc.

Project website can be found at http://www.vliz.be/projects/bwzee/.The final report on this Belgian project will be available from the Belgian Science Policy website.

(http://www.belspo.be/belspo/home/publ_en.stm).

8.2.2 HABMAP

M. Robertson (FRS, Aberdeen) described progress with the two year HABMAP project. This work builds directly on the fieldwork undertaken and results obtained during the EC funded MAFCONS project. Samples and information gathered during MAFCONS will provide benthic and fish community data from sites surveyed acoustically thus allowing investigations into the link between habitat heterogeneity and species diversity. Identification of structural features that provide essential habitat for a variety of vertebrate and invertebrate species is essential to furthering the ecosystem approach to fisheries management.

HABMAP started in April 2006 and all data gathering was completed by March 2007. Over this time, three cruises were completed (one in the North Sea in August 2006 and two off the Scottish west coast in November 2006 and March 2007 respectively). During each cruise, acoustic data were logged from a series of intensively surveyed 3NM by 3NM boxes which were drawn up around the immediate area surrounding and including the track of a trawl haul undertaken for the International Bottom Trawl Survey (IBTS). Further to this, data were also gathered from the survey vessel's cruise track when approaching and leaving each trawl position. These data will determine how representative the habitat type and variability observed in the small boxes and the vessel track are of the larger ICES rectangles in which they are contained and will also allow assessment of the extent to which the single trawl samples in particular ICES rectangles provide representative samples of the fish assemblage occupying each rectangle.

Although no formal habitat maps have yet been produced, acoustic data, ground truthing and infaunal grab samples have been collected from 20 ICES rectangles in the North Sea and from 12 ICES rectangles on the west coast of Scotland.

During the second, final year of HABMAP, it is planned to complete all cleaning and database preparation for the data collected from the intensive survey boxes and from the IBTS tracks during the three cruises completed in 2006 and 2007. Also to report the results of all analyses undertaken and to interpret habitat types and habitat distributions in relation to the biological data collected in MAFCONS

Some other acoustic systems, such as side scan sonar at 410-450 kHz, have the resolving potential for biota imaging. Patches of individual Lanice reefs can be discriminated with this technique.

Synthetic Aperture Radar (SAR) has been looking promising for some years, but no members of the group so far use this method.

Fast still image systems (2 fps) are being pioneered by US colleagues.

(http://habcam.whoi.edu/)

A special issue of the publication *Remote Sensing of Environment* on remote sensing of the marine environment is due to be published later this year.

(http://www.elsevier.com/wps/find/journaldescription.cws_home/505733/description#description).

8.3 Benthos of soft sediments

8.3.1 Long-term benthos studies in German waters

I. Kröncke gave an overview on long-term benthos studies in German waters.

- Infauna from Norderney has been collected since 1978. From 1978–1992 stations were sampled monthly however, from 1992 onwards, they were only sampled three times a year. Sampling up to 1995 has been reported; at this moment analysis is done on the data from 1995 onwards. Especially interesting is the development of the benthos after the very cold winter in 1995.
- Infauna has been sampled along a transect running from the inner German Bight → Dogger Bank since 1990. The biological effects of contamination have been sampled each May since 1995. All samples collected from 1995 until 2003 have been analysed. A paper by Reiss about a comparison of the inshore-offshore has also been published

- Infauna Doggerbank. Decadal scale: 1950s, 1980s, 1990s, 2006/2007. Shows an increase of southern species and a decrease in northern species.
- Epifauna communities from the Greater German Bight have been investigated every July/August from 1998 onwards. Sampling followed the IBTS format where one haul was collected in each rectangle with a 2 meter beamtrawl.
- Epifauna communities in 6 boxes running from the German Bight towards the Norwegian Sea have been investigated since 1998. This sampling attempts to get an overview about differences brought about by climate change in different areas. Sampling is carried out once a year.
- Epifauna from the Jade area has been collected since 1972. The dataset is hardly analysed, but this might be done in a new project.

The Netherlands and Germany agreed on combining 2 meter beamtrawl data since 1998 (Germany) and 1999 (Netherlands) for analysis. German sampling is in the German Bight; the Dutch sampling is mainly in the Southern and Central North Sea.

8.3.2 Long-term benthos study in the Netherlands

I. de Boois presented a long-term benthos study in the Netherlands (by J. Craeymeersch - IMARES). In the Dutch coastal area dredge sampling has been carried out since 1995. It was originally known as the *Spisula*-survey but since 2006 it has been renamed the *Ensis*-survey. *Spisula subtruncata* stock has decreased very much in the survey period while *Ensis sp.* has increased. The complete document is attached in Annex 8.

8.4 Benthos of rocky substrates

8.4.1 Phytobenthos in the Baltic

H. Kautsky reported on phytobenthos research in the Baltic.

Fucus vesiculosus sampling was first carried out in 1942 ('pre-industrial data') and then in 1984, 1992 and 2006. Between 1942 and 1984 the depth at which *Fucus vesiculosus* was recorded decreased. In 1992 *Fucus vesiculosus* showed a slight increase in coverage while in 2006 the species reappeared at the same depths as first recorded in 1942. The trend is even more visible when looking at one station at a time. Disappearance of species might be caused by different processes such as competition, pollution, climate change, etc. However, the main reason that *Fucus vesiculosus* plants disappear is because they reach the end of their lives. The *F. vesiculosus* life cycle is quite complicated and unpredictable, so the species might disappear for some time and then suddenly reappear. This not only is the case with *Fucus vesiculosus*, but also happens in other species, e.g. *Zostera* communities.

Some factors that determine the depth distribution of phytobenthos are: substrate, light, population dynamics, salinity.

If the increase in depth distribution of *Fucus vesiculosus* is due to increased water quality, then this has to be measurable in e.g. Secchi depth data. However, this is not the case at all sampling sites where nutrients often exhibit a slow decrease. For example, in the sampling sites in the Baltic Sea, all nutrient fractions except phosphorus did decrease. Spring bloom levels of chlorophyll-a are also decreased. This leads to the conclusion that the Baltic Sea coastal ecosystem is recovering.

H. Kautsky also talked on survey methods and results used when surveying and describing phytobenthos in Swedish waters as part of SCOPE (EU_WFD work).

8.5 Other studies

8.5.1 Biological criteria review for the selection of dredged material disposal sites: European examples of best practices at sea.

The draft version of this paper was reviewed during the meeting. The group agreed that the main adjustments to be made to the document are: to include more references, to improve the structure and to focus more on the made on the biological criteria. The group will send these comments back to the main author of the paper (who could not attend the meeting) and attempt to work by correspondence to finalise the paper for publication as soon as possible.

8.5.2 SPEEK

I. Moulaert informed the group on the status of the SPEEK (Study of post-extraction ecological effects in the Kwintebank sand dredging area) report.

(http://www.belspo.be/belspo/home/publ/pub_ostc/EV/rappEV38_en.pdf).

8.5.3 MACROBEL

The Macrobenthos Atlas of the Belgian part of the North Sea was published in 2006. A free copy can be ordered from:

http://www.belspo.be/belspo/fedra/proj.asp?l=en&COD=MN/DD2/013#docum

8.5.4 *Prestige* Oil Spill

S. Parra reported on the *Prestige* oil spill study.

After the grounding of the tanker *Prestige* on November 2002 near the Galician Bank, NW Spain, about 50000 tons of heavy oil (type M-100) was released to the sea, affecting a huge part of the Galician coastline and surroundings areas. Documents presented in 2003, 2004 and 2005 to this working group dealt with the general information about this oil spill, as well as with its initial effects on the benthic and demersal continental shelf communities. This final report presents the main results on macro-infaunal communities obtained after three years of sampling (2002-2004) in the Galician continental shelf. The sediment of this area is dominated by fine sands which have a low organic content. No temporal changes that may be attributed to the impact of the oil spill were observed in the sedimentary variables. The temporal evolution of the structural parameters of Zone 1 (minimum-impacted area) would not suggest that they suffered any effect from the oil spill. In Zone 2 (maximum-impacted area) by contrast, we found an increase in the abundance of one crustacean group (amphipods) in some stations (10 and 14), a general increase in the total biomass in the 2004 samplings and a gradual decline in the total abundance and specific richness during the first three samplings of the stations located in stratum B (8, 11 and 14). Zone 3 (moderate-impacted zone) underwent a progressive decrease in total abundance during the first four samplings and of richness during the first three samplings in the stations belonging to stratum A (16 and 19). In contrast, a gradual increase in the abundance of the crustacean group (amphipods) was recorded in the same stations. Generally speaking, none of the zones showed any major changes in either the temporal pattern or the structure of the infaunal community. We did not see any marked increase in opportunistic species or species favoured by the oil spill (i.e. capitellid and spionid polychaetes). Owing to the lack of previous data, we are unable to confirm whether or not mortalities have occurred in species that are sensitive to hydrocarbon contamination (i.e. echinoderms and peracarid crustaceans), although the increasing crustacean populations in some stations could be related to the oil spill. A more comprehensive account and the first pages of two relevant publications can be found in Annex 11, Annex 12 and Annex 13.

8.5.5 Gulf of Gdansk benthic habitat spatial mapping

J. Warzocha reported on ongoing benthic studies in the southern Baltic (Polish EEZ).

The major aim of the project is to describe distribution patterns of macrobenthic species and compare the structure of macrobenthic associations from 1980s and 2000s. The grid of about 350 stations covers the coastal zone from the German border (Pomeranian Bay) to Russia (Gulf of Gdansk), southern parts of Bornholm and Gotland Basins and Slupsk Furrrow.

Samples were taken with a 25 kg van Veen grab (the same grab as used in the 1980s) and additionally with a 60 kg van Veen grab, a 200 kg box corer and a dredge fittedwith underwater video – from 2000 the present day. Results obtained already from the Gulf of Gdansk, allowed us to distinguish five associations correlated (above halocline) mainly to the sediment type. The structure of macrofauna on sandy bottom was rather stable – over 20 years – however, distinct changes were observed in muddy bottom associations, including the impact of invasive species (such as the spionid - *Marenzelleria neglecta*).

These studies will be continued as a contribution to a project on habitat mapping which started at the beginning of 2007, in collaboration with NIVA and is financially supported by Norwegian Financial Mechanism.

8.5.6 Studies in Portugal

Mirjam Guerra from IPIMAR sent a report on ongoing work in Portugal concerning the WFD and the restoration and management of biodiversity in the Marine Park Site Arrábida-and also the biodiversity restoration in the Tagus river estuary. See Annex 9.

9 Assess the effectiveness of any potential performance indicators in identifying cause-effect relationships based on a list of indicators prepared by intersessional work (ToR f)

The group updated the list of metrics from the report of the ICES Study Group on Sensitive and Opportunistic Benthic Species (SGSOBS 2004) (see Annex 14). It was decided that within the scope of this working group it is difficult to come up with a full review of cause-effect relationships for each of the different indicators. The ideal way of answering this question would be to organise an intersessional workshop where the majority of indicators, as defined by the updated list of SGSOBS, can be tested on a series of datasets from different areas with diverse anthropogenic activity. This workshop should be open to anyone, including non BEWG members, with knowledge on indicators. The group therefore advises to wait for the outcome of the Indicator Symposium that will be held in November 2007 in London.

As an example, one of the most tested indices relating to the response to different types of anthropogenic impacts, AMBI, is incorporated in this report (see below). A similar study on the cause-effect relationship should be performed for all other possible indicators to identify the most useful indicator for a specific impact.

WGEXT asked the BEWG to interact in the development of useful and consistent indicators to show the effect of, for example, sand extraction on higher trophic levels. The group agrees it is necessary to combine effort with and have a better interaction between the different WG's (especially WGEXT and WGECO) to cover this subject.

The group also desires to draw attention to the following report concerning the evaluation of indicators. Thisreport mainly focuses on the impact of fisheries on the ecosystem:

Lutchman I., Rochet M.-J., Tasker M. and J. Brown (2007) INDECO (Development of indicators of environmental performance of the common fisheries policy) Final analysis and evaluation of the indicators (www.ieep.eu)

Response of the AMBI to different anthropogenic impacts

This index has been tested by a number of authors, using datasets from different geographical areas (including all European seas, but also North and South America, North Africa, and Asia). Their ecological basis (Pearson and Rosenberg's paradigm) explains how AMBI is able to respond successfully to very different environmental impact sources, including: drill cutting discharges; submarine outfalls; harbour and dyke construction; heavy metal inputs; eutrophication processes; diffuse pollutant inputs; recovery in polluted systems, the impact of sewage schemes; dredging processes; mud disposal; oil spills; etc. (see Table in Annex 15:).

It can be seen that AMBI does not respond to physical impacts (e.g. aggregate extraction). Probably the same can occur with similar impacts, such as fish trawling (but at the moment there are no data on this subject). On the other hand, some other impacts, such as metal pollution, have shown contradictory results in different areas. For remaining impacts, the general response is quite good in terms of gradient detection.

10 Discuss and report on the role of benthos for monitoring under the WFD and the NATURA 2000 regimes (ToR g)

S. Degraer introduced a document on *Benthos ecological status assessment and monitoring for the Water Framework Directive in the Belgian coastal waters*. The document is attached as Annex 16.

The group discussed ongoing projects concerning WFD matters. Benthos is still the major component for WFD investigations and assessments. Phytobenthos is only used in few countries. A. Borja presented Methods used in Europe for the Water Framework Directive and outlined an Atlantic intercalibration exercise. He showed an international Atlantic scenario and compared the different metrics in use. Both documents are in Annex 17 and Annex 18. The table of metric used by different states is given below (Table 10.1)

General discussions on aspects of the AZTI / Spanish programme then commenced. Enquiries were also made as to how animal dry weights were determined. The method adopted here was to dry material at 60°C for 24 hours until the weight was constant however, it was pointed out that in the Baltic, Mytilus material often required up to two weeks for drying . Overall, it was agreed that the work described by A. Borja was the correct way to proceed with WFD driven monitoring. It was also pointed out that Germany was trying to develop a new approach to WFD work which avoided the inclusion of species number and species diversity however a final decision on this approach was still to be taken. Further to this, Estonia has also adopted a system of monitoring which employs different metrics to other countries so making intercalibration exercises very difficult.

Table 10.1. Metrics used for each Member State. Note: Bentix and Medocc are modifications of AMBI.

MEMBER STATE	SENSITIVE/OPPORT.					N°	S	DIVERSITY				OTHERS	
	AMBI	BQI	Sen/opp	Bentix	MEDOCC	Density	Richness	Shannon	Margalef	Simpson	Similarity	Biomass	Feeding guilds
Estonia												X	X
Finland		X				X	X	X					
Sweden		X											
Denmark	X					X	X	X				X	
Germany			X			X	X						
Netherlands						X					X	X	
Belgium						X					X	X	
UK	X						X			X			
Ireland	X						X			X			
France	X						X	X					
Spain (Atl)	X						X	X					
Portugal	X							X	X				
Spain (Med)					X								
Italy	X						X	X					
Slovenia	X						X	X					
Greece				X									
Cyprus				X									

H. Kautsky enquired whether any work on plants was under way in the WFD programmes and was assured that the phytobenthos was included in monitoring. Methods developed by the UK were recently applied along the Spanish Atlantic coast for example. However, this has proved problematic as the method relies on presence / absence assessments only and lacks a system for defining the degree of algal cover. Along the Spanish coast the phytobenthos is dominated by red algae so the UK system always returns a "good" status result. Germany is also developing a programme for defining the status of the phytobenthos under the WFD while in the Baltic work is ongoing employing historical data comparisons with current species occurrence and depth distributions.

The NATURA 2000 regime was then considered. It would appear that very little or no activity is currently taking place under the NATURA 2000 banner as none of the members of the BEWG present at the meeting were engaged in any work included in this initiative. Overall, the question "what is the role of benthos in NATURA 2000" lacks a clear answer. In the WFD, benthic monitoring is well defined; this is not the case with NATURA 2000.

The Group took note of the report submitted from Portugal and will include it in future compilations. (Annex 9)

11 Based on the final SGNSBP report discuss further plans for North Sea benthic surveys (ToR h)

The group recommended that a common survey in 2010 would be ideal but only if externally funded, otherwise incorporation into national programmes will be required. The planning will be taken up in the BEWG meeting in 2008 and will probably results in a future Study Group. The final SGNSBP report was submitted to ICES as a CRR and will be available shortly.

12 Discuss recent developments in benthic sampling methodology with a view on updating the TIMES No. 27 recommendations (1999) (ToR i)

12.1 TIMES no. 27 recommendations

A subgroup reviewed and updated the TIMES no. 27 recommendations. Recent literature and developments were incorporated. The new version shall be published after review by other experts and final editing by ICES.

12.2 Sieving alive or after fixation

S. Degraer gave a presentation on a new paper discussing the difference between sieving samples alive or after fixation (see first page in Annex 19). The main conclusions of the paper were that sieving alive negatively impacted all tested diversity measures (S, N_1, N_2, N_{∞}, H', ES_{100} and J') and community-dependent relative losses of up to 35% were observed. However, most trends were ambiguous and statistically non-significant. Community and taxon-dependent impacts were detected at the level of density. Polychaetes were mainly found to be negatively impacted by sieving alive (relative losses up to 81%): Interstitial and other small polychaetes (e.g. *Hesionura elongata* and *Spio filicornis*) especiallytend to actively escape through the sieve meshes (relative loss up to 100%). Next to size, behaviour, the presence of head appendages, the depth of the sampling stations and sampling season are all believed to influence the sieving impact. While detailed community composition was affected (ANOSIM dissimilarity: maximum 85%), no major impact on the differentiation between the investigated communities was detected. The present study thus demonstrated that combining data, retrieved with a different sieving procedure can be useful, but its reliability will mainly depend on the type of questions one wants to answer. In all cases caution at all levels of ecological organisation is advised.

12.3 Van Veen grab - Hamon grab comparison

I. Moulaert presented some preliminary results on a comparison between samples taken with a Van Veen grab (VV) and with a Hamon grab (HG). At each of 23 locations on the Hinderbanken (offshore Belgian continental Shelf) one sample was taken with a Van Veen grab and one with a Hamon grab. Although the sampling was not designed for a comparison study, results give an idea of the difference between sampling techniques. As only one sample with each of the sampling tools was taken, the effects of the patchiness of the area sampled could not be excluded. Looking at the sample volume a great variation was found for both sampling tools (from 3 to 13 litres for the HG and 4 to 12 litres for the VV). The median grain size calculated from a subsample taken from both grabs at every location showed a relatively good correlation. Total number of individuals, diversity index and number of species were highly variable. For 50% of the locations the numbers of individuals found were higher in the HG and in the other half the densities were higher in the VV. The same was found for species number and diversity. Depth and volume of the sample were not correlated with the differences found in the biological measures.

The group agreed that further analysis on this data should be undertaken as it would be good to have an intercalibration exercise between both sampling devices. Extra sampling in different sediment types might also be interesting.

13 Report on the environmental implications of existing off-shore renewable energy generation installations (wind, wave, tide, etc.) and make proposals to minimize their negative effects (ToR j)

There was no new information to be presented at the meeting. A presentation on effects of Wind farm installations was given on the BSH symposium in Hamburg 2006. In Germany Pilot Wind farms are being erected in the German Bight and the environmental results are awaited eagerly.

14 Any other business

14.1 Upcoming Symposia

14.1.1 42nd European Marine Biology Symposium (EMBS)

The 42nd European Marine Biology Symposium will be held in Kiel, Germany 27–31 August 2007. The symposium's website is at http://www.embs42.meeresbiologie.at/home.htm.

14.1.2 Conference of the Estuarine Research Federation 2007 (ERF 2007)

The Conference of the Estuarine Research Federation 2007 will be held in Providence, Rhode Island, U.S. 4-8 November 2007. The symposium's website is at http://erf.org/erf2007/. A theme session Assessing ecological integrity using multiple indices and ecosystem components is organized, chaired by A. Borja and J. Ananda Ranasinghe.

14.1.3 10th International Conference on Shellfish Restoration (ICSR)

The 10th International Conference on Shellfish Restoration (ICSR) will be held in Vlissingen, The Netherlands, 12–16 November 2007. This year's title is "Innovation in the exploitation and management of shellfish resources". (http://www.icsr2007.wur.nl)

14.1.4 ICES Symposium on Environmental Indicators: Utility in Meeting Regulatory Needs

The ICES Symposium on Environmental Indicators will be held in London, UK, 20-23 November 2007. The program and online registration will be available on 15 May 2007 at the symposium website. (http://envind2007.benthos.be/)

14.2 Workshop/symposia proposals

Workshop on *the role of the need of phytobenthic communities in ICES waters, including epiflora and fauna, population dynamics, WFD, ICZM and socio-economic valuation*. Chaired by H. Kautsky.

Workshop on *the performance testing of indicators*. Chaired by I. Moulaert.

14.3 BEWG website

H. Hillewaert presented an update of the group's website at http://www.bewg.be. Members were called upon to provide links to project websites or other sites of interest to the Working Group.

14.4 LYYN T38 Real time image enhancer

H. Rumohr mentioned a video tool where the visibility enhancement is done in real-time in a live video stream, which also can be used on stored material. An interesting application can be to enhance the feed from a live video system, e.g. in a ROV.

(http://www.lyyn.com/products/T38.html)

LYYN T38 Real time image enhancer

14.5 Taxonomic help

The group gave taxonomic ID help to undetermined species from Belgian samples and was proving its function as a team of colleagues who share their expertise for the mutual benefit.

15 Adoption of report

After review and discussion the group adopted the last version of the draft report

16 Closing of the meeting

The Chair thanked the local host for their generous hospitality and the interesting excursion to the east-Frisian country and moors. He also thanked the contributors for their input especially the rapporteurs and the editing rapporteur and closed the meeting on Friday, 13:00 hours.

Annex 1: List of participants

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Annex 2: BEWG Agenda

Wilhelmshaven, Germany, 23–27 April 2007

Start 23.04, 13:00

Opening & Local Organisation

- Appointment of Rapporteur;
- Terms of Reference;
- Adoption of Agenda.

(ToRs ranked according importance for ICES)

Report on ICES meetings and other meetings of interest

- ASC 2006 (Maastricht) / ICES Annual Report for 2006;
- Marine Habitat Committee, Maastricht 2006;
- ACE , Maastricht 2006;
- ACME Maastricht 2006;
- STGQAB (?);
- WGMHM;
- WGEXT;
- MarBEF;
- WGECO.

TOR e) review and consider recent developments in ongoing benthos research in Europe

- Cooperative studies;
- Benthos and fisheries;
- Benthos of soft sediments;
- Benthos of rocky substrates;
- Other studies.

TOR a) assess and report on changes in the distribution, population abundance and condition of benthic invertebrates in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE);

TOR b) assess and report on the extent to which the changes reported in (a) can reliably be attributed to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE);

TOR c) assess and report on the evidence on which the nomination of Seagrass *Cymodocea* meadows for the OSPAR List of Threatened and/or Declining Species and Habitats is based *[Note: this Term of Reference only has to be addressed if this request has not been fulfilled by an ad-hoc group in advance of the Expert Group meeting. Whether an ad-hoc group will be required can only be decided after further consultations with OSPAR. based on input from OSPAR MASH which meets in October. The ACE Chair will inform the Chair on the outcome of these discussions in November 2006].*

TOR d) discuss and report on quality assurance and control guidelines for sampling and analytical practices for benthos;

TOR f) assess the effectiveness of any potential performance indicators in identifying cause-effect relationships based on a list of indicators prepared by intersessional work;

TOR g) discuss and report on the role of benthos for monitoring under the WFD and the NATURA 2000 regimes;

TOR h) based on the final SGNSBP report discuss further plans for North Sea benthic surveys;

TOR i) discuss recent developments in benthic sampling methodology with a view on updating the TIMES No. 27 recommendations (1999);

TOR j) report on the environmental implications of existing off-shore renewable energygeneration installations (wind, wave, tide, etc.) and make proposals to minimize their negative effects

Any other business

- further theme sessions
- Upcoming symposia etc

Recommendations and Action List

- Recommendations for next years meeting (2008)
- Recommendations for Theme Sessions/ Symposia
- Action List

Adoption of the report (due 15.5.2007)

Closing of the meeting

Local organisation and schedule

- Morning session 9:00–13:00 coffee break 10:30–11:00
- Lunch (in-house catering) 13:00–14:00
- Afternoon session 14:00–18:00 coffee break 15:30–16:00

Annex 3: BEWG Terms of Reference 2006

2006/2/MHC10 The **Benthos Ecology Working Group** [BEWG] (Chair: H. Rumohr) will meet in Wilhelmshaven, Germany, from 23–27 April 2007 to:

a) assess and report on changes in the distribution, population abundance and condition of benthic invertebrates in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE);

b) assess and report on the extent to which the changes reported in (a) can reliably be attributed to changes in hydrodynamics and sea temperature (further details on the interpretation and handling of this ToR will be provided by ACE);

c) assess and report on the evidence on which the nomination of Seagrass *Cymodocea* meadows for the OSPAR List of Threatened and/or Declining Species and Habitats is based

d) discuss and report on quality assurance and control guidelines for sampling and analytical practices for benthos;

e) review and consider recent developments in ongoing benthos research in the ICES area;

f) assess the effectiveness of any potential performance indicators in identifying cause-effect relationships based on a list of indicators prepared by intersessional work;

g) discuss and report on the role of benthos for monitoring under the WFD and the NATURA 2000 regimes;

h) based on the final SGNSBP report discuss further plans for North Sea benthic surveys;

i) discuss recent developments in benthic sampling methodology with a view on updating the TIMES No. 27 recommendations (1999);

j) report on the environmental implications of existing off-shore renewable energy generation installations (wind, wave, tide, etc.) and make proposals to minimize their negative effects.

BEWG will report by 15 May 2007 to the attention of the Marine Habitat Committee and ACE.

Supporting Information

PRIORITY:	The current activities of this Group will lead ICES into issues related to the ecosystem affects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan 1.2.1, 2.2.1, 2.13, 4.12, 2.11 **Term of Reference a, b, c)** These ToRs are set to provide information for a request from OSPAR. **Term of Reference d)** This work is in response to the MOU with OSPAR and HELCOM for the provision of advice on quality assurance of biological measurements. It will be augmented when necessary with specific annual requests from HELCOM and/or OSPAR. **Term of Reference e)** This is a prerequisite for the scientific information status of the group **Term of Reference f)** This is in response to ongoing OSPAR requests and in perspective of the coming ICES Symposium on Indicators in November 2007. This is also in response to a request from ACME. ICES is moving towards providing scientific advice for the integrated management of all human activities that affect marine waters. Information on the quantity and quality of habitat and the health of marine ecosystems will be essential to the achievement of this goal. **Term of Reference g)** Benthos will be a major component in the monitoring regimes of the European WFD and the NATURA 2000 network of nature reserves.

	The BEWG is prepared to evaluate national plans of monitoring and especially how far the comparability is guaranteed to arrive at scientifically suited long-term data sets. **Term of Reference h)** The SGNSBP is a major research activity of the BEWG and the basis for the discussion of future joint activities in the BEWG **Term of Reference i)** This is a needed update of the methods recommendations discussed and formulated 10 years ago. **Term of Reference j)** 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.
RESOURCE REQUIREMENTS:	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
PARTICIPANTS:	The Group is normally attended by some 20–25 members and guests.
SECRETARIAT FACILITIES:	None.
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	There are linkages to ACME and ACE.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	WGMHM, WGEXT, MHC
LINKAGES TO OTHER ORGANIZATIONS:	None

Annex 4: Draft resolutions for next year

The Benthos Ecology Working Group [BEWG] (Chair: H. Rumohr) will meet in Torre Grande, Sardinia, Italy, from 21–25 April 2008 to:

a) plan the next North Sea Benthos Project 2010;

b) review and consider recent developments in ongoing benthos research in the ICES area;

c) discuss and report on new methods for sampling and analytical practices for benthos including electronic ones;

d) report and discuss possible climate enforced changes in the benthos in the Mediterranean compared to ICES waters;

e) consider the Mediterranean phytobenthos in relation to Northern European environments;

f) report and discuss on the outcome of the workshop on Benthos Related Environmental Metrics (WKBEMET).

BEWG will report by 15 May 2008 for the attention of the Marine Habitat Committee and ACME.

Supporting Information

PRIORITY:	The current activities of this Group will lead ICES into issues related to the ecosystem affects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan 1.2.1, 2.2.1, 2.13, 4.12, and 2.11 **Term of Reference a)** This project is one of the central activities throughout the existence of the group and will provide valuable data with relevance to OSPAR and EU requests **Term of Reference b)** This is a prerequisite for the scientific information status of the group **Term of Reference c)** This a prerequisite for update of method recommendations and Quality Control routines **Term of Reference d)** This reflects ICES coperation with the mediterranean CIESM. Input is also awaited from colleagues from the Mediterranean. **Term of Reference e)** This continues the attempts to include phytobenthos in ICES benthos work and make the results ready for potential OSPAR requests. It will shed some light on pan-european environmental dynamics **Term of Reference f)** This a consquence of the proposed workshop on the performance testing of environmental metrics.
JUSTIFICIATION OF VENUE (IN A NON-ICES MEMBER COUNTRY)	**1)** If the ToRs of the group explicitly limit its activities to the ICES area meetings should normally be held in an ICES member country. *This is not the case for BEWG.* **2)** The host country should normally be linked to ICES (member or affiliate country or co-sponsor of the EG). *Italy is not an ICES affiliate but is an EU country and member of CIESM a potential future partner of ICES.* **3)** The host institute should include scientists who are already members of the EG. *This is not the case, the contacts are from earlier IOC group meetings in Torre Grande and from EU sponsored meetings under MARBEF.* **4)** The inviting country should benefit from hosting the meeting. *This is obvious from the agenda and from the fact of the invitation.* **5)** ICES in general and the EG in particular should benefit from the expertise and knowledge of the host country or region. Specifically where the response to the EG ToRs can be enhanced by the proposed hosts. *This is the case and is part of the agenda in TOR d and e. This is a reaction to research in consquences of climate change and global warming and the potential*

	consequences of this. This will be future requests for advice by OSPAR; EU and HELCOM. **6)** The EG should not have held a meeting in a non-member country during the last three years. *BEWG met 2005 in Copenhagen, 2006 in Crete (Greece is an ICES affiliate) and 2007 in Germany.* **7)** The EG should evaluate the cost implications of the venue choice. This should consider what additional cost that would be incurred by the usual attendees, and particularly ICES members. It should also evaluate whether the choice would limit attendance by these members. *There are no additional cost implications. On the contrary, Sardinia is a cheep destination compared to other destinations in Europe and especially in Canada and the US. This is because of cheap charter flights anf cheap accommodation early in the year. It should be noted here that meetings at ICES Headquarters are under the most expensive venues in Europe. This choice of venue does not limit attendance by members it enforces participation of experts because of its attractive character and the chance to meet new colleagues .*
RESOURCE REQUIREMENTS:	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
PARTICIPANTS:	The Group is normally attended by some 20–25 members and guests.
SECRETARIAT FACILITIES:	None.
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	There are linkages to ACME and ACE.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	WGMHM, WGECO, WGEXT, MHC
LINKAGES TO OTHER ORGANIZATIONS:	None

Two workshop recommendations

BEWG recommends the organisation of a Workshop on Benthos Related Environmental Metrics:

The **Workshop on Benthos Related Environmental Metrics** [WKBEMET] (Chair: I. Moulaert, Belgium) will meet in Oostende, Belgium from 11–14 February 2008 to:

a) discuss the outcomes of the "Symposium on "Marine Environmental Indicators: Utility in Meeting Regulatory Needs" held in November 2007 in London and of the Intercalibration working group for the WFD. Look for the gaps in the knowledge of the applicability and performance of different indicators to the impacts of human-induced activities and changes in ecological state;

b) test the applicability of different indicators using multiple datasets from a wide range of regions;

c) use multiple datasets to test the performance of different indicators to human induced activities and changes in ecological state and to assess the effectiveness of performance indicators in identifying cause-effect relationships.

WKBEMET will report by 15 April 2008 for the attention of BEWG, MHC and ACME.

Supporting Information

PRIORITY:	High.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The main aim of this workshop is (1) to relate a list of indicators to the impacts of human-induced activities and changes in ecological state and (2) to assess the effectiveness of any potential performance indicators in identifying cause-effect relationships.
RESOURCE REQUIREMENTS:	None.
PARTICIPANTS:	People are invited with experience in parameter testing and with access to benthos data sets.
SECRETARIAT FACILITIES:	None
FINANCIAL:	None
LINKAGES TO ADVISORY COMMITTEES:	ACME
LINKAGES TO OTHER COMMITTEES OR GROUPS:	BEWG
LINKAGES TO OTHER ORGANIZATIONS:	Cooperation with MarBEF is sought through the VLIZ in Ostende.

Furthermore, BEWG recommends a workshop to be held in 2008 on the role of phytobenthic communities in ICES waters, including epiflora and fauna, exploring population dynamics, connections with WFD, ICZM and socio-economic valuation:

the **Workshop on the role of phytobenthic communities in ICES waters** [WKPHYT] (Co-Chairs: Hans Kautsky, Sweden, N.N. Country) will meet in [venue to be decided] spring 2008 to:

a) Explore and discuss the role of phytobenthic communities in ICES waters, including epiflora and fauna;

b) document the population dynamics and annual cycles of phytobenthos communities on a regional scale;

c) elaborate connections with WFD and the role of phytobenthos in ICZM and its socio-economic valuation;

d) Finalize the ICES TIMES draft on Phytobenthos sampling methodology.

WKPHYT will report by 15 May 2008 for the attention of the Marine Habitat Committee, BEWG, WKBEMET, and WGMHM.

Supporting Information

PRIORITY:	The work of the Group is essential if ICES is to progress the developments of techniques in fish stock assessment.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	The work done within BEWG has been diverse and has included sampling methodology and all aspects of benthos ecology. Since some years phytobenthos has been included in the remits of the Committee since phytobenthos has a natural and logical link with the normally treated zoobenthos part of, benthos ecology. Phytobenthos forms not only the shelter for coastal fish and invertebrate epifauna but is also increasingly an object of harvesting and specialized usage as a valued natural material and thus a source of income for the coastal population.The new WKPHYT will focus on the phytobenthos in the benthos area , a field that has been neglected in ICES work so far. Recent .OSPAR requests asked especially for phytobenthos expertise on a european scale that could not easily provided. This is an act of scientific capacity builiding for ICES. Both methodology and scientific contents need to be updated and collectively documented as work basis in the mentioned contact groups.
RESOURCE REQUIREMENTS:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
PARTICIPANTS:	people from the benthos community and new experts from the phytobenthos scene
SECRETARIAT FACILITIES:	none specific
FINANCIAL:	None specific.
LINKAGES TO ADVISORY COMMITTEES:	A close link with ACME activities.
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Links to BEWG and WGICZM
LINKAGES TO OTHER ORGANIZATIONS:	ICES will seek widened participation for this group from the Baltic (BMB) and from other North Atlantic and North American States

Action list

- Santi - Long term macrofauna communities in La Coruña Bay;
- Hasse - Final draft of TIMES document on phytobenthos sampling;
- Ingrid - Deep sea research in the eastern Mediterranean;
- Mike - Final report on HAPMAP + other work;
- Angel - Integrity of ecological assessments;
- Ine, Hans - Workshop report, intercalibration + other work;
- Sylvana, Ine, Angel - finalize dredging paper;
- Henning (Hubert) - Study group on biodiversity + ecosystem management;
- Jan - Distribution and dynamics of macrozoobenthos in the Baltic.

Annex 5: Benthos and climate change in the Bay of Biscay

By Angel Borja (AZTI-Tecnalia)

The distribution of many benthic species, including macroalgae, molluscs and arthropods, was studied by Alcock (2003) along the Bay of Biscay, between the end of 19th century and 2000-2001. He determined some shifts northwards and southwards, depending on the warm and cool periods, during the 20th century, and several examples were shown for species such as *Fucus spiralis*, *Pelvetia canaliculata*, etc.

Taking into account this evolution and the IPCC scenarios of temperature increase for next 50 years, Alcock (2003) modelled the future shift of some benthic species in the Bay of Biscay, North Sea, and Norwegian Sea. In this presentation, the predicted shifts for *Balanus perforatus*, *Chthamalus montagui*, *Patella rustica* and *Pollicipes Pollicipes* were presented. These scenarios can be useful, for future monitoring programmes, in order to check the northwards migration of benthic species, due to climate change.

Some studies, undertaken in the Basque coast, were presented. Hence, the relationships between NAO and benthic diversity and precipitation and richness, in the Nervion estuary, were presented. Long term series of *Gelidium sesquipedale* biomass have shown a close relationship with irradiance (Borja *et al*., 2004). Finally, strong relationships between wave energy and biomass, abundance and cover of *Pollicipes Pollicipes*, have been found in the area (Borja *et al*., 2006).

Taken into account the predicted increasing NAO values, for the next 50 years, some scenarios have been built for the Basque coast. This fact will lead to an increase of northwesternly wind circulation over the area, and, consequently, to an increase of wave energy and clouds. Hence, there are possibilities of an increase of *Pollicipes* biomass, a decrease of *Gelidium* biomass, and a reduction of richness and diversity of benthic populations.

Annex 6: Red Lists in Germany

Table 1 Categories of species

Tab. 1: Übersicht über die vier Kriterien und ihre Klassen mit den zugehörigen Symbolen.

(1) Bestandssituation		(2) langfristiger Bestandstrend		(3) kurzfristiger Bestandstrend		(4) Risikofaktoren	
ex	ausgestorben	<<<	sehr starker Rückgang	↓↓↓	sehr starke Abnahme	–	negativ wirksam
es	extrem selten	<<	starker Rückgang	↓↓	starke Abnahme		
ss	sehr selten	<	mäßiger Rückgang	(↓)	mäßige Abnahme oder Ausmaß unbekannt		
s	selten	(<)	Rückgang, Ausmaß unbekannt				
mh	mäßig häufig	=	gleich bleibend	=	gleich bleibend	=	nicht feststellbar
sh	sehr häufig	>	deutliche Zunahme	↑	deutliche Zunahme		
?	unbekannt	?	Daten ungenügend	?	Daten ungenügend		

Table 2 Criteria to assign species

Categories

- 0 - extinct
- 1 - critically endangered (threat of extinction)
- 2 - strongly endangered
- 3 - endangered (vulnerable)
- G - endangered, but degree unknown
- R - extremely rare
- V - near threatened („Vorwarnliste")
- D - data deficient
- * - not endangered (least concern)
- • - (not evaluated)

Table 3 Some of the taxa considered in this study.

C9 | Leuconia nivea

	RL Kat.	Kat. +/-	Name	Neo-biota	Kriterien: Bestand aktuell	Kriterien: Bestandstrend lang	Kriterien: Bestandstrend kurz	Kriterien: Risikofaktoren	Letzter Nachweis	Risikofaktoren (Kürzel)	Bearbeitung	Endemit	Verantwortlichkeit	Arealrand	Grund der Kategorieänderung
139			Bivalvia												
140	*		Abra elliptica		ss	?	=	=							
141	G		Abra nitida (O.F.Mueller, 1776) G		mh	(<)	=	=							
142	*		Abra prismatica		ss	?	=	=							
143	G		Acanthocardia echinata G		ss	(<)	(v)	=							
144	R		Aequipecten opercularis		es	=	=	=							
145	R		Angulus donacinus		es	=	=	=							
146	R		Angulus squalidus ??		es	=	=	=							
147	*		Anomia ephippium		ss	=	=	=							
148	3		Arctica islandica 3		s	<	(v)	=							
149	*	+	Astarte borealis 3		s	=	^	=							
150	D		A. falsteri???		?	?	?	=							
151	*	+	Astarte elliptica 3		s	?	^	=							
152	G		Astarte montagui 2		s	(<)	(v)	=							
153	D		Astarte sulcata		?	?	?	=							
154			Barnea candida		s			=							
155	*	+	Cerastobyssum (Cardium) hauniense R		mh	=	?	=							
156	*	+	Cerastoderma edule V		mh	=	=	=							
157	D		Cerastoderma lamarcki (=glaucum) 2 Ostsee sh		s	?	?	=							

Annex 7: Report on benthos changes in the OSPAR area

Introduction

Request

The BEWG was requested "to prepare an assessment of what is known of the changes in the distribution and abundance in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature. The assessment should look at ecologically indicative species, including the threatened and declining species identified by OSPAR, for which adequate time series data exist, in order to assess to what extent there have been changes in distribution, population and condition of species going beyond what might have been expected from natural."

Approach and limitations

In this report, we have selected studies of temporal trends covering all or most of the period between 1980s and present, especially those of a regular rather than intermittent nature. Collectively, these have the potential to throw light on broader-scale influences on the macrobenthic communities.

The interpretation of long-term changes in the benthos is difficult because it is difficult to detect distinct effects of a single impact, since eutrophication and fisheries might cause rather similar effects like increasing abundance and biomass, whereas species numbers might drop under fisheries impact due to the damage of long living species. The same might be true for sand and gravel dredging.

Available information

A compilation (not necessarily complete) of long-term studies in the OSPAR regions is presented in Table A7.1. As can be seen from this table there is a focus of relevant studies on region II (North Sea). Therefore, our main discussion will refer to studies of this region.

Table A7.1. Compilation of metadata of long-term series and long-term comparisons of benthic fauna in the OSPAR regions.

SOFT-BOTTOM INFAUNA			
	OSPAR region	Time scale	References
German Bight (Ziegelmeier)	II	1950s–1970	(Ziegelmeier, 1978)
Dogger Bank	II	1951–52, 1985–87, 1996–98	(Wieking and Kröncke, 2001)
German Bight (AWI)	II	1965– present	(Schroeder, 2003)
Skaggerak	II	1970–1998	--
Northumberland	II	1971–present	(e.g. Frid *et al.*, 1996)
NOR oil platform monitoring	II	1973–present	--
UK oil platform monitoring	II	1977–1998	--
Norderney (Senckenberg)	II	1978–present	(Kröncke *et al.*, 2001)
Norderney (Niedersachsen)	II	1976–1999	--
Northern North Sea	II	1981–1986	--
Dutch oil platform monitoring	II	1985–1993	(Daan and Mulder, 1995)
NSBS, NSBP	II	1986, 2000	(e.g. Rees *et al.*, 2002)
German inshore monitoring	II	1987– present	--
Danish monitoring program	II	1989–1999	--
Dutch monitoring North Sea (BIOMON)	II	1991– present	(e.g. Daan and Mulder, 2001)
Dutch Continental Shelf (MILZON)	II	1988–1993	(Holtmann, 1994)
Shellfish monitoring North Sea	II	1995– present	(Craeymeersch and Perdon, 2004)
Shellfish montoring Waddensea	II	1991–present	(Craeymeersch and van Stralen, 2004)
Dutch monitoring Waddensea	II	1980s–present	(e.g. Dekker and de Bruin, 2001)
Gullmarsfjord	II	1983– ?	--
Danish monitoring Skagerrak	II	? –2004	(Ærtebjerg *et al.*, 1998)
German Bight Transect	II	1990–present	(Kröncke and Rachor, 1992)
Creutzberg Dutch North Sea sampling (NIOZ)	II	>1970	--
German Bight (GB), surveys	II	1923, 1965, 1975, 2000	(Rachor and Nehmer, 2003)
GB Borkum Riffgrund	II	1967–72, 1996, 1999	(Rachor and Nehmer, 2003)
Belgian Continental Shelf	II	1979–present	--
Disposal Sites, Northumberland (UK)	II	1984–present	(Rees *et al.*, 2003)
Disposal Sites, Thames (UK)	II	1985–present	--
Uk National Marine Monitoring Programm	II	1995–present	Anon. 2004
La Coruna Bay, NW Spain	IV	1982–present	(López-Jamar *et al.*, 1995)
Bay of Biscay (Basque coast, Nervion estuary)	IV	1989–present	(Borja *et al.*, 2006)
Bay of Biscay (Basque coast and estuaries)	IV	1995–present	(Borja *et al.*, 2004)
van Mijenfjord	I	1980, 2000–present	--
Svalbard fjords	I	1990s–present	--
western Barents Sea	I	1980, 1992, 2005	--

Table 1. Continued.

SOFT-BOTTOM EPIFAUNA			
	OSPAR region	Time scale	References
Shellfish monitoring North Sea	II	1995–present	(Craeymeersch and Perdon, 2004)
Shellfish montoring Waddensea	II	1991–present	(Craeymeersch and van Stralen, 2004)
MAFF	II	1980–1986	--
NSBS	II	1986	(Duineveld *et al*., 1991)
ZISCH	II	1987–1988	--
EU (Biodiversity, MAFCONS)	II	1986–present	(Zühlke *et al*., 2001)
Epibenthos (GSBTS)	II	1998–present	(Ehrich *et al*., 2007)
Creutzberg's trawl surveys North Sea	II	1970s–1980	Creutzberg & van Noort reports 1–10
German Bight, Epi AWI, incl. Stones	II	1999–present	(Rachor and Nehmer, 2003)
Belgian Continental Shelf	II	1979–present	--
HARD-BOTTOM EPIFAUNA			
South-West Netherlands	II	1985–2004	--
Helgoland	II	1987–1991, 2000–2004	--
Danish monitoring on stone reefs	II	1990–2004	--
Helgoland (BAH-AWI)	II	last 150 years	(Franke and Gutow, 2004)
Svalbard fjords	I	1980s–2006	--

Changes in benthos

Abundance, species number and biomass may be affected by several parameters such as temperature and hydrodynamics (Figure A7.1). Temperature itself will influence the distribution of northern and southern species. Primary production is influenced by temperature and the direction and flow of marine currents (e.g. via the transport of nutrients). The amount of primary production reaching the benthic system strongly influences the trophic structure of the communities in question. Hydrodynamics (e.g. current velocities, stratification of water layers, wave climate) determine the transport of larvae and influence the sediment composition, which reflects food availability. Thus, changes in both factors will affect species composition with regard to sediment preference and the trophic structure of the benthic communities.

It is known that sea temperature and hydrodynamics seldom change independently and are in most instances are expressions of climatic and weather conditions (Kröncke *et al*., 1998; Planque and Taylor, 1998; Dippner and Kröncke, 2003). Many recent studies on changes in the pelagic as well as the benthic system in the North Atlantic describe large scale climatic variability by means of the North Atlantic Oscillation (NAO) index (for a review see Drinkwater *et al*., 2003). The effects on benthos may be seen with a delay of up to several years (Kröncke *et al*., 1998; Tunberg and Nelson, 1998; Schroeder, 2003; Gröger and Rumohr, 2006; Rees *et al*., 2006).

Measures of large-scale climatic changes, such as the NAO Index, are often more effective correlates than locally-measured variables (e.g., temperature) and better integrate the complexities of interactions between local climate and ecological processes (Hallett *et al*., 2004).

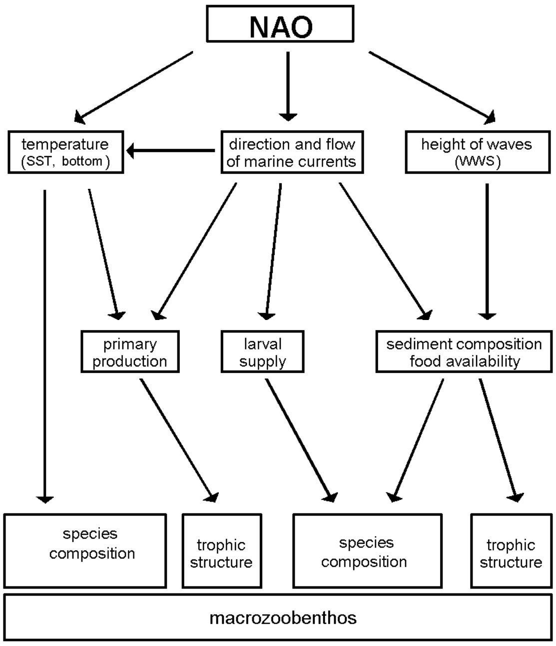

Figure A7.1 Conceptual model of the links between NAO and benthic communities (after Wieking and Kröncke, 2001).

From the above information it is evident that it is hardly feasible to effectively discriminate between effects of temperature changes and changes in hydrodynamics. The following chapters give a presentation of to what extent climate changes (as indicated by the NAOI), and changes in hydrodynamics and sea temperature can be related to changes in benthos.

Changes in benthos related to climatic factors

NAOI

Many recent studies on changes in the benthic system in the North East Atlantic describe large scale climatic variability by means of the NAOI (Drinkwater *et al.*, 2002). Significant correlations between NAOI and changes in abundance and biomass were found in the western North Sea (Rees *et al.* 2006), in the Skagerrak (Tunberg and Nelson 1998), the western Baltic (Gröger and Rumohr, 2006), at the Dogger Bank (Wieking and Kröncke, 2001), in the German Bight (Kröncke *et al.*, 1998; Schroeder, 2003), in all cases with a time lag from months to years.

From these studies we know that in general a negative NAOI is associated with lower than average abundance and biomass, while a positive NAOI is often associated with higher than average values. According to recent insights the NAOI shows a long-term increasing trend with internal oscillations. This increasing trend would therefore mean increasing trends in abundance, species number and biomass of benthos. In specific areas deviations from general "rule" may occur due to specific local forcing (e.g. Tunberg and Nelson, 1998).

However, this pattern can be different depending on the location within the OSPAR region, because For example, in the south of the Bay of Biscay, high NAO values produce lower diversities and negative values produce high diversity values (Borja, com. pers.).

Hydrodynamics

Large-scale hydrodynamic changes were found for the North Sea. Oceanographic models by Siegismund (2001) and Siegismund and Schrum (2001) showed differences between in the current regimes of the North Sea between the 1980s and 1990s due to the increasing inflow of Atlantic water masses mainly through the Fair Isle Current and stronger southwesterly winds.

Hydrographic changes in the Baltic are to a large extent related to inflow of North Sea water masses through the Danish Straits (e.g. Hänninen *et al*., 2000).

The variable inflow of Atlantic water into the North Sea influenced the plankton and fish (Ehrich and Stransky, 2001; Reid and Edwards, 2001; Reid *et al*., 2003).

For the benthos however, only little information is available. This information consists mainly of inferred causal relationship between the benthos and NAO driven hydrodynamics.

Witbaard (1996) assumed that the variations in the ESAI (East Shetland Atlantic Inflow) and the Dooley Current influenced the strength of the eddy system over the Fladen Ground and consequently the accumulation of material in its centre and the eddy mediated food-supply (growth variations of the bivalve *Arctica islandica* from the Fladen Ground).

Hagberg *et al*. (2004) suggest a possible relationship between the NAO and the benthos off Northumberland due to the strong connections between the inflow of North Atlantic Water to the North Sea and the NAO.

Wieking and Kröncke (2001) found that the benthic communities along the northern slope of the Dogger Bank were strongly affected by increasing wind stress and stronger currents at the northern slope of the Dogger Bank in the 1990s compared to the 1980s. Factors which are also influenced by the positive NAO index during the 1990s (Siegismund, 2001; Siegismund and Schrum, 2001). Changes in larval supply, food availability and sediment composition caused by resuspension of fine material lead to a decrease in species occurring on fine sand (e.g. *Ophelia borealis*) compared to the 1980s, whereas abundances and total number of species preferring coarser sediment (e.g. *Echinocyamus pusillus*) increased in the 1990s.

In the Bay of Biscay, Borja *et al*. (2006) have found strong relationships between wave energy and biomass, abundance and cover of *Pollicipes Pollicipes* in hard-bottom communities Consequently, increasing NAO values (as predicted by Cook *et al*. (2005), for the next 50 years), could lead to an increase of northwesterly wind circulation over the area, and to an increase of wave energy (as predicted by several models for the area). Finally, this can lead to an increase of *Pollicipes* biomass.

Laine *et al*. (1997), like many others, describe effects on the benthos in the Baltic Sea. Here variations in North Sea water inflow influence the oxygen concentration in deep waters of the basins and thus the benthos.

Temperature

In this chapter we present a few studies available which refer directly to the influence of sea temperature on the benthos.

Well known is the structuring effect of winter temperatures on benthic communities living in relatively shallow waters. Fromentin and Ibanez (1994) showed that *Abra alba* communities in the Southern Bight responded to mild winters between 1977 and 1991 with maximum densities.

Short-term effects of cold winters on intertidal and subtidal benthic communities include increased mortality among adults and increased recruitment success among e.g. bivalves (Ziegelmeier, 1970; Buchanan *et al*., 1978; Beukema, 1979; Schroeder, 2003; Reiss *et al*., 2006) Essink *et al*. 2006). Beukema (1990; 1992) and Bhaud *et al*. (1995) expected for the future a shift in species composition towards a more diverse, warmer water fauna also for the intertidal and shallow coastal waters, if the trend of increasing water temperature continues.

Also summer temperature has effects on benthic communities. In the Wadden Sea, the Pacific oyster (*Crassostrea gigas*) increased considerably in abundance after 2000, causing the partial disappearance of intertidal beds of *Mytilus edulis*, at the same time creating new oyster reefs with an approximately equally biodiverse accompanying fauna. This increase of the Pacific oyster correlates strongly with the occurrence of higher than average water temperatures during July-August in these years, causing a increased success of settlement of spat (Nehls. 2007-in prep).

For the macrofauna off the Eastfrisian island of Norderney Kröncke *et al.* (1998) found that abundance, species number and biomass in the 2nd quarter of the year are correlated with SST. The SST is the mediator between the benthos and the NAO in late winter and early spring. The results indicate that macrofaunal communities were severely affected by cold winters, whereas storms and hot summers have no impact to the communities. It appears that mild meteorological conditions, probably acting in conjunction with eutrophication, resulted in an increase especially in total biomass since 1989.

On a North Sea wide scale some shifts in the distribution patterns of species have been described (CRR NSBP Sections 5.2 and 5.3). In the German Bight examples are shifts in the distribution of the brittle star *Amphiura brachiata* and the bivalve *Nucula nucleus*, as well as shifts in community boundaries especially the mud-inhabiting *Nucula nitidosa* community. These shifts can be understood as consequences of warming and changes in circulation and eutrophication patterns (e.g. Rehm and Rachor, 2007). A general increase of warm-temperate species in the southern North Sea is evident, e.g. the amphipod *Megaluropus agilis* and *Amphiura brachiata* on the Dogger Bank, whereas cold-temperate species decreased in abundance such as the polychaete *Ophelia borealis* (Wieking and Kröncke, 2001).

Shift in the climate of the North Sea towards more oceanic conditions is regarded an important factor explaining long-term trends and drastic changes in the macrofauna of hard-bottom areas around Helgoland (Franke and Gutow, 2004). Many of the recent records of new warm-temperate species of southern origin are indicating a continued warming since the 1980s.

In this way, Alcock (2003) studied the distribution of many benthic species, including macroalgae, molluscs and arthropods, along the Bay of Biscay, between the end of 19th century and 2000–2001. He determined some shifts northwards and southwards, depending on the warm and cool periods, during the 20th century. Taking into account this development and the IPCC scenarios of temperature increase for next 50 years, Alcock (2003) modelled the future shift of some benthic species in the Bay of Biscay, North Sea, and Norwegian Sea. These scenarios can be useful, for future monitoring programmes, in order to check the northwards migration of benthic species, due to climate change.

Looking beyond the OSPAR regions, Oviatt (2004) also described a variety of temperature-mediated changes in coastal biota of NW Atlantic waters associated with the occurrence of persistently positive values of the NAO Index in the 1980s and 1990s.

Indicative species

In the above sections, there are no presentations of data explicitly showing that observed changes can be directly related to changes in hydrodynamics. The examples presented for the Dogger Bank and coast off East England relate to indirect effects, mediated through larval supply, food availability ad sediment composition.

With reference to the benthos species and habitats in the 2004 Initial List of Threatened and/or Declining Species and Habitats the following remarks ca be made:

- *Arctica islandica* – This is a northern-temperate species. A further decrease of this species is to be expected in the North Sea as the trend of increasing sea temperature continues;
- *Ostrea edulis* – There are no clear indications that the poor status of this bivalve species is caused by changes in temperature;

- *Nucella lapillus* – The condition of populations of this gastropod are influenced by certain polluting substances rather than by hydrodynamics or temperature (however, in the Basque coast, the species has disappear since 1982, due to increasing temperatures);
- *Modiolus modiolus* beds – These habitats represent a poor status since long. No causal relationships with changes in hydrodynamics or temperature are known,
- Intertidal *Mytilus edulis* beds – Data from the Wadden Sea show that part of he beds may be taken over by the invasive Pacific oyster *Crassostrea gigas*. On the other hand, however, beds of the Pacific oyster also provide adequate substrate for settlement of new *Mytilus edulis* (Nehls. 2007in prep);
- Sea-pen and burrowing fauna communities – as sea-pens are cold-temperate species, a future decrease of his species and accompanying change in this community can be foreseen.

Assessment and conclusions

The original question concerning the effects of changing hydrodynamics and sea temperature on benthic communities cannot be answered without difficulties. Observations on a smaller scale may give contradicting results. This may be caused by interference by other forcing factors of local importance. On a large scale, changes in hydrodynamics and sea temperature are often interconnected and are a result of climatic variability as indicated by the NAO index.

With regard to changes of hydrodynamics there is only little information available. On the Dogger Bank increased current velocities caused changes in sediment composition and as a consequence also in the benthic community. Off the English east coast hydrographic changes were considered responsible for changes in food availability (derived from phytoplankton) to the benthic community.

With regard to changes in sea temperature the following can be said: changes in the characteristics of winters and summers play an important role in structuring the benthos.

If the trend of milder winters and warmer summers, also expressed by the NAO index, continues, shifts in species composition and numbers, abundance and biomass can be expected, as it is being recorded now for some of them.

No species can be named as being specifically for changes in hydrodynamic conditions, whereas a temperature increase is indicated by shifts in the distribution of a range of several species, e.g *Megaluropus agilis* and *Amphiura brachiata* in OSPAR region II, e.g. in OSPAR region IV and species region II.

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Annex 8: Long-term series in The Netherlands

By J. Craeymeersch

Since 1995, 800–1,000 stations in the coastal area (up to 12km offshore) have been sampled annually in Spring by Wageningen IMARES following a systematic sampling design. Sampling equipment dredges over 150 m to a sediment depth of 7 cm and a width of 10 cm, i.e. the sample surface is 15–30 m2, and the mesh width is 5 mm. In the coastal area in the SW of the Netherlands, monitoring started in 1993. The surveys provide information on spatio-temporal variations in density, biomass and stocks of commercial species, but also result in a time-series of abundance and biomass data of another 25 infaunal and epifaunal species. Yearly reports (in Dutch) are made on the standing stock, spatial distribution and temporal variation of cockles (*Cerastoderma edule*), through shells (*Spisula subtruncata*) and, recently, razor shells (*Ensis sp.*) although the stocks of the latter are largely underestimated. Different species show different patterns (Figure A8.1). The same hold for other species, as shown by Craeymeersch & Wijsman (2006) in a study on the spatial and temporal variation of selected bivalves in the Voordelta (SW Netherlands) (Figure A8.2).

Wijnhoven *et al* (2006) analysed patterns in total densities, biomasses and diversity (Shannon) in the Voordelta for the period 1983–2004, based on box-corer and van Veen samples (1mm mesh sieve). The data originate from different programmes that many times only covered part the area and used different sampling designs. This, consequently, hampered thorough statistical analyses. The data show, however, that both density and biomass significantly increased. In most subareas, there appeared to be a trend-reversal pattern: a decrease followed by an increase. Minimum values were observed in the period 1995–1997. Diversity did not change significantly, but subareas showed opposite trends: and increase in the northern part of the study area, and decrease in the south.

Craeymeersch and Rietveld (2005) report on the changing distribution of dog whelks (*Nassarius* sp.). In the period 1995–2000 only a single specimen was found, near the harbour of Rotterdam. Since then the number of observations of dog whelk has increased, and the species is extending its distribution northwards (Figure A8.3). Craeymeersch & Perdon (2005) report on the recent appearance of otter shells (*Lutraria* sp.) in the Dutch coastal waters (Figure A8.4). These two examples most likely point to responses to climatic changes.

Analogous monitoring designs as mentioned above are used by Wageningen IMARES in other Dutch marine waters (Wadden Sea, Westerschelde, Oosterschelde), enabling the making a distinction between regional vs. (more) global patterns. A good example is the trend of the Baltic tellin (*Macoma balthica*) in the Dutch waters (Figure A8.5). In the western part of the Wadden Sea a decline in the stock over the last five years has been observed, in contrast to the whole Wadden Sea (although the stock in 2005 was the lowest measured) and other water bodies. The decrease in the western Wadden Sea has been reported before and been ascribed to climate-related changes in the recruitment (Philippart *et al* 2003). But, apparently, the decrease in the western Wadden Sea is a more regional phenomenon (Craeymeersch and Perdon 2005).

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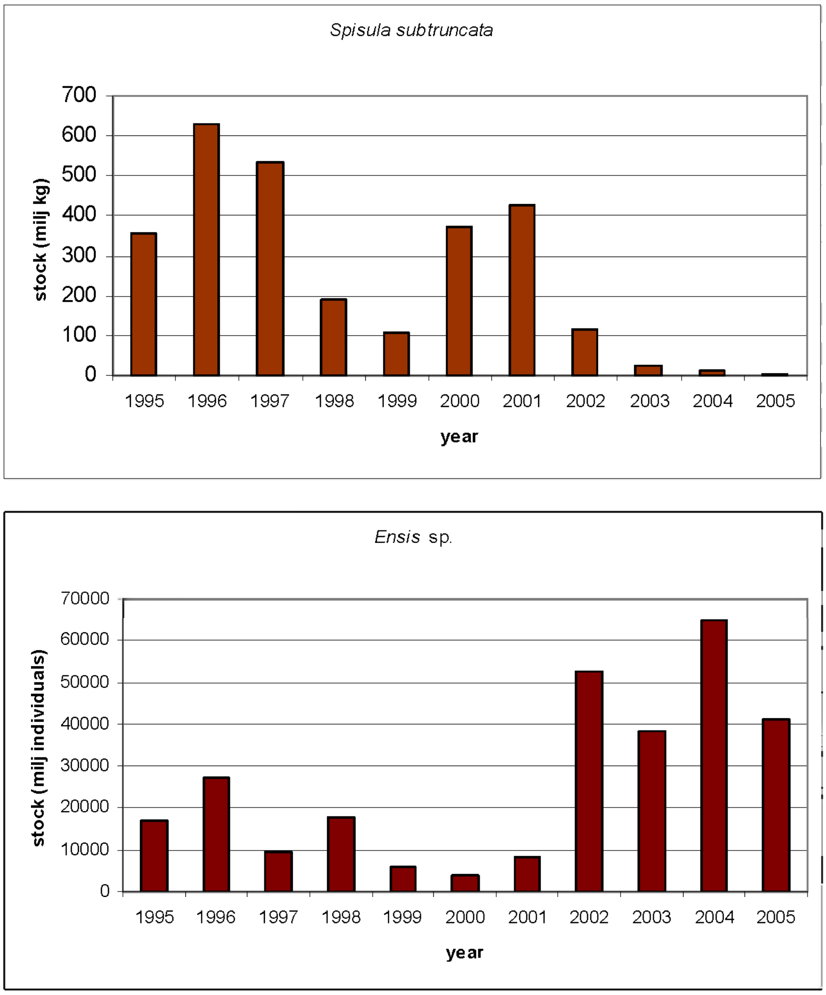


Figure A8.1. Temporal fluctuation of stock of through shells, *Spisula subtruncata* (milj kg freshweight) and razor shells, *Ensis sp.* (milj individuals) in the Dutch coastal area (Craeymeersch & Perdon 2004; Perdon ….. 2006).

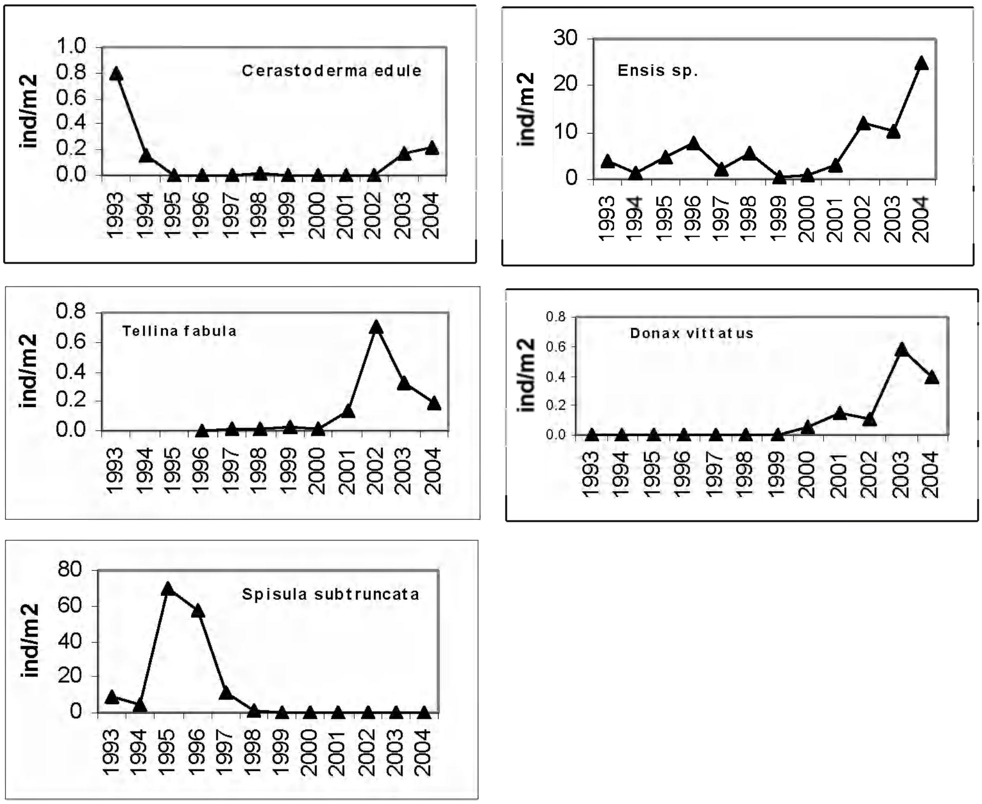


Figure A8.2. Temporal variation of the density (ind/m2) of selected bivalves in the Voordelta (SW Netherlands) (Craeymeersch and Wijsman 2006).

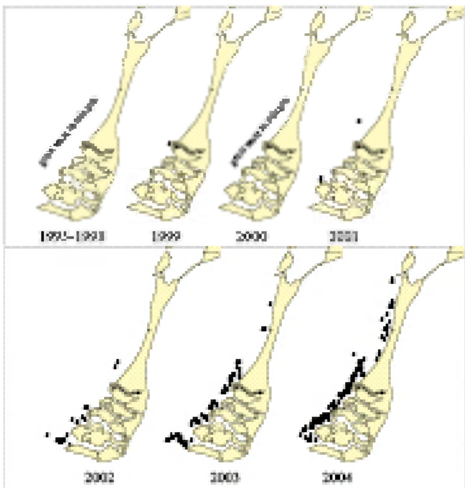


Figure A8.3 Distribution records for Nassarius observed between 1995 and 2004 in the Dutch coastal waters (Craeymeersch and Rietveld 2005).

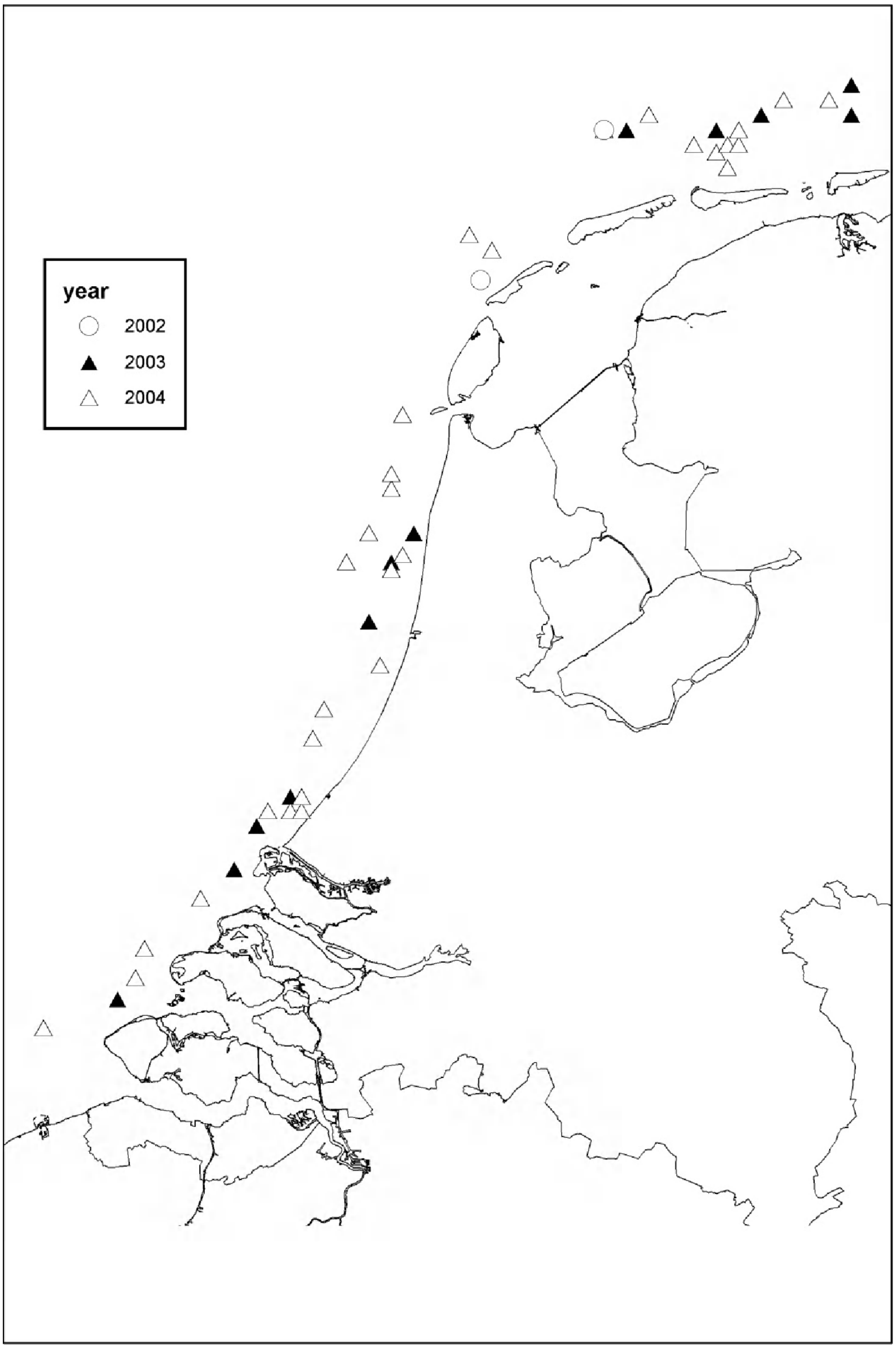


Figure A8.4. Distribution records for Lutraria observed between 1995 and 2004 in the Dutch coastal waters (no records before 2002) (Craeymeersch and Perdon, 2005)

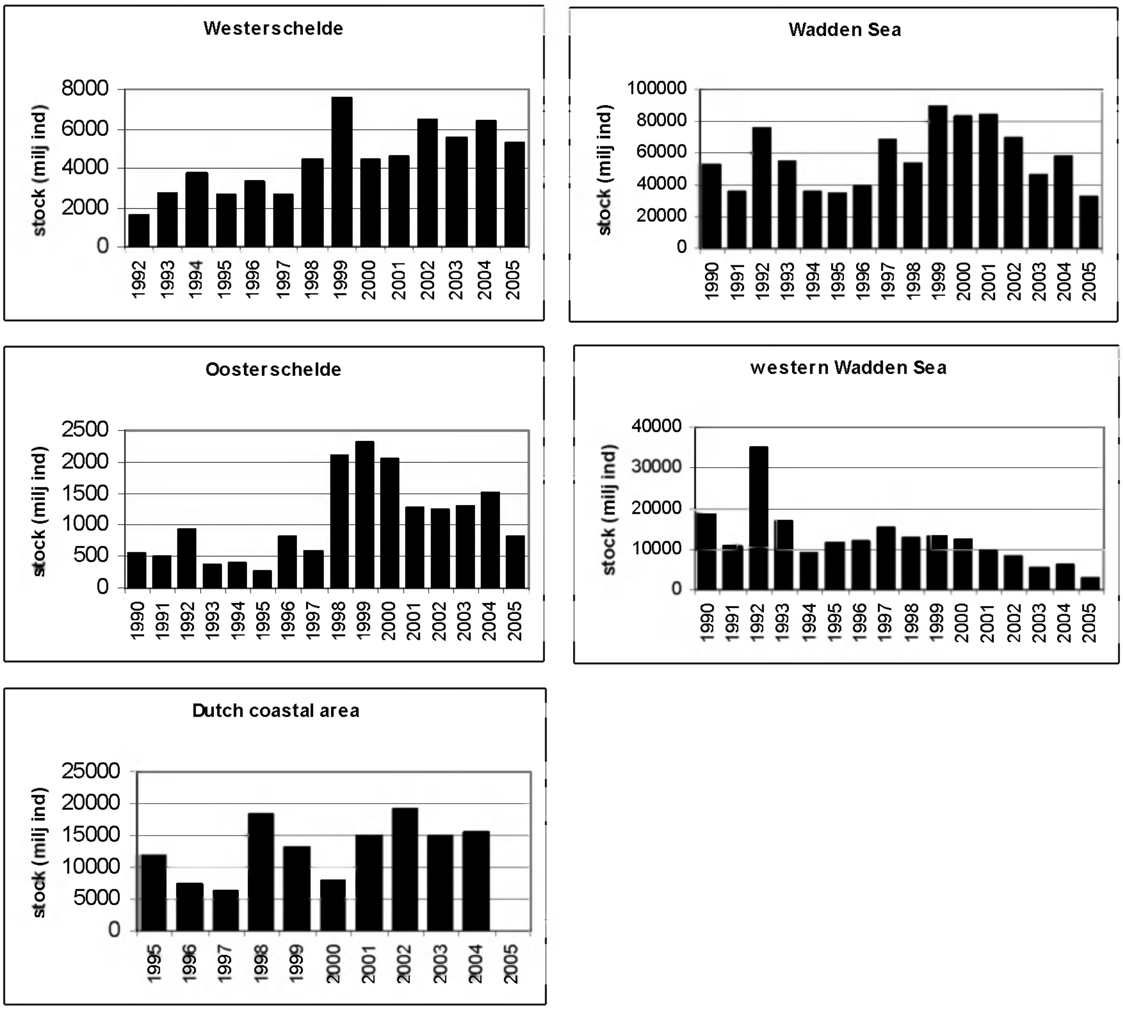


Figure A8.5. Temporal fluctuations in the stock (milj individuals) of the Baltic telllin (*Macoma balthica*) in Dutch waters (Craeymeersch and Perdon, 2006)

Annex 9: Current activities of the benthos group of IPIMAR

By Miriam Tuaty Guerra and Marria José Gaudêncio

WATER FRAME DIRECTIVE

Benthic macroinvertebrates are currently monitored since February 2006 at several locations along the Portuguese coast (Figure A9.1). Basic structural parameters, species richness, abundance and biomass, together with sediment grain size and organic matter are under study.

So far 4 sampling surveys took place: February and July 2006 (coastal waters and emissaries), March and September 2006 (estuaries).

Data are still at an early stage of processing. So far very preliminary results may be provided (Tables A9.1–A9.4) as well as a first approach to the ecological quality status of the estuaries under study based on the M-AMBI index (Table A9.5).

Table A9.1. List of the taxa present at the coastal waters sampling sites (see Figure A9.1 for locations).

ANNELIDA
POLYCHAETA
Aonides paucibranchiata (Southern, 1914)
Diopatra neapolitana (Delle Chiaje, 1841)
Eumida sanguinea (Oersted, 1843)
Glycera lapidum (Quatrefages, 1865)
Glycera tridactyla (Schmarda, 1861)
Goniada emerita (Oersted, 1843; Audouin and Milne-Edwards, 1843)
Lanice conchilega (Pallas, 1766)
Magelona filiformis (Wilson, 1959)
Magelona johnstoni (Fiege, Licher and Mackie, 2000)
Malacoceros ciliatus (Keferstein, 1862)
Mediomastus capensis (Day, 1961)
Nephtys assimilis (Oersted, 1843)
Nephtys cirrosa (Ehlers, 1868)
Nephtys hombergii (Savigny, 1818)
Notomastus latericeus (M. Sars, 1851)
Owenia fusiformis (Delle Chiaje, 1842)
Pherusa monilifera (Delle Chiaje, 1841)
Phyllodoce (Anaitides) maculata (Linné, 1767)
Phyllodoce laminosa (Savigny, 1818)
Prionospio caspersi (Laubier, 1962)
Scolelepis?gilchristi (Day, 1961)
Scoletoma impatiens (Claparède, 1868)
Sigalion mathildae (Audouin and Milne-Edwards in Cuvier, 1830)
Spio decoratus (Bobretzky, 1870)
Spiophanes bombyx (Claparède, 1870)
ARTHROPODA CRUSTACEA
AMPHIPODA
Abludomelita obtusata (Montagu, 1813)
Ampelisca brevicornis (Costa, 1853)
Ampelisca diadema (Costa, 1853)
Ampelisca rubella (A. Costa, 1864)
Ampelisca spooneri (Dauvin and Bellan-Santini, 1982)
Atylus falcatus (Metzger, 1871)
Bathyporeia pelagica (Bate, 1856)
Hippomedon denticulatus (Bate, 1857)
Idunella longirostris (Chevreux, 1820)
Megaluropus agilis (Hoeck, 1889)
Orchomenella nana (Kroyer, 1846)
Pontocrates altamarinus (Bate and Westwood, 1862)
Urothoe pulchella (Costa, 1853)
CUMACEA
Diastylis bradyi Norman, 1879
Iphinoe trispinosa (Goodsir, 1843)

DECAPODA
Diogenes pugilator (Roux, 1829)
Liocarcinus vernalis (Risso, 1816)
Polybius henslowii (Leach, 1820)
Processa sp.
Thia scutellata (Fabricius 1793)
ISOPODA
Eurydice truncata (Norman, 1868)
MYSIDA
Gastrosaccus spinifer (Goës, 1864)
ECHINODERMATA
SPATANGOIDA
Echinocardium cordatum (Pennant, 1777)
OPHIURIDA
Amphiura (Acrocnida)brachiata (Montagu, 1804)
Ophiura grubei (Heller, 1863)
MOLLUSCA
BIVALVIA
Abra alba (Wood W., 1802)
Donax vittatus (Da Costa, 1778)
Ensis?arcuatus (Jeffreys, 1865)
Mactra stultorum (Linné, 1758)
Montacuta ferruginosa (Montagu, 1808)
Mysella bidentata (Montagu, 1803)
Pharus legumen (Linné, 1758)
Phaxas pellucidus (Pennant, 1777)
Spisula solida (Linné, 1758)
Spisula subtruncata (Da Costa, 1778)
*Tellina fabula (*Gmelin, 1791)
Tellina (Moerella) pygmaea (Linné, 1758)
Thracia papyracea (Poli, 1791)
Venus casina (Linné, 1758)
GASTROPODA
Euspira catena (da Costa, 1778)
Nassarius reticulatus (Linné, 1758)
NEMATODA
NEMERTINA

Table A9.2 List of the taxa present at the sampling stations located in the vicinity of urban and industrial emissaries (see Figure A9.1 for locations).

ANNELIDA
POLYCHAETA
Diopatra neapolitana (Delle Chiaje, 1841)
Diplocirrus glaucus (Malmgren, 1867)
Flabelligeridae não identificados
Glycera gigantea (Quatrefages, 1865)
Glycera lapidum (Quatrefages, 1865)
Glycera tridactyla (Schmarda, 1861)
Goniada maculata (Oersted, 1843)
Gyptis capensis (Day, 1963)
Hesionidae (fragments)
Lumbrineridae (fragments)
Magelona filiformis (Wilson, 1959)
Magelona johnstoni (Fiege, Licher and Mackie, 2000)
Maldanidae (fragments)
Mediomastus capensis (Day, 1961)
Nephtys assimilis (Oersted, 1843)
*Nephtys cirrosa (*Ehlers, 1868)
Nephtys hombergii (Savigny, 1818)
Notomastus latericeus (M. Sars, 1851)
Ophelia neglecta (Schneider, 1887)
Orbinia latreilli (Audouin and Milne-Edwards, 1833)
Owenia fusiformis (Delle Chiaje, 1842)
Pherusa monilifera (Delle Chiaje, 1841)
Pherusa sp.
Phyllodoce (Anaitides) maculata (Linné, 1767)
Phyllodoce laminosa (Savigny, 1818)
Phyllodocidae (fragments)
Prionospio cirrifera (Wirén, 1883)
Protodorvillea kefersteini (McIntosh, 1869)
Scolelepis bonnieri (Mesnil, 1896)
Scolelepis squamata (O. F. Müller, 1789)
Scolelepis tridentata (Southern, 1914)
Sigalion mathildae (Audouin and Milne Edwards in Cuvier, 1830)
Spio decoratus (Bobretzky, 1870)
Spionidae (fragments)
Spiophanes bombyx (Claparède, 1870)
Sthenelais limicola (Ehlers, 1864)
ARTHROPODA CRUSTACEA
AMPHIPODA
Ampelisca brevicornis (Costa, 1853)
Ampelisca diadema (Costa, 1853)
Ampelisca spinipes Boeck, 1861
Ampelisca spooneri (Dauvin and Bellan-Santini, 1982)
Ampelisca tenuicornis (Liljeborg, 1855)

Atylus falcatus (Metzger, 1871)
Bathyporeia pelagica (Bate, 1856)
Hippomedon denticulatus (Bate, 1857)
Orchomenella nana (Kroyer, 1846)
Pontocrates altamarinus (Bate andWestwood, 1862)
Tryphosites longipes (Bate and Westwood, 1861)
Urothoe poseidonis (Reibish, 1905)
CUMACEA
Cumopsis longipes (Dohrn, 1869)
Diastylis bradyi (Norman, 1879)
Eocuma dolfusi (Calman, 1907)
Iphinoe trispinosa (Goodsir, 1843)
DECAPODA
Diogenes pugilator (Roux, 1829)
Liocarcinus vernalis (Risso, 1816)
Pagurus bernhardus (Linné, 1758)
Polybius henslowii (Leach, 1820)
ISOPODA
Eurydice spinigera (Hansen, 1890)
MYSIDACEA
Gastrosaccus spinifer (Goës, 1864)
ECHINODERMATA
ECHINOIDEA
Echinocardium cordatum (Pennant, 1777)
Spatangoida (fragments)
OPHIUROIDEA
Amphiura (Acrocnida)?brachiata (Montagu, 1804)
Amphiura chiajei (Forbes, 1843)
Amphiura (Acrocnida)?semisquamata (Koehler, 1914)
Amphiura ?filiformis (O. F. Müller, 1776)
Amphiura sp.
Ophiura albida (Forbes, 1839)
Ophiuroidea (fragments)
MOLLUSCA
BIVALVIA
Abra alba (Wood, 1802)
Clausinella fasciata (Da Costa, 1778)
Donax vittatus (Da Costa, 1778)
Dosinia lupinus (Linné, 1758)
Goodalia triangularis (Montagu, 1803)
Montacuta ferruginosa (Montagu, 1808)
Mysella bidentata (Montagu, 1803)
Pharus legumen (Linné, 1758)
Phaxas pellucidus (Pennant, 1777)
Solenidae (fragments)
Spisula solida (Linné, 1758)
Spisula subtruncata (Da Costa, 1778)
Tellina fabula Gmelin, 1791

Tellina (Moerella) donacina Linné, 1758
Tellina (Moerella) pygmaea Lovén, 1846
Thracia ?papyracea (Poli, 1791)
Venerupis pullastra (Montagu, 1803)
Venus casina Linné, 1758
GASTROPODA
Cylichna cylindracea (Pennant, 1777)
Euspira guillemini (Payraudeau, 1826)
Nassarius reticulatus (Linné, 1758)
NEMATODA
NEMERTINA

Table A9.3. Taxa present at the sampling stations located in the river Minho estuary (mean numbers/0.1 m^2), in September 2007. Stations are cited from downstream (station 1) to downstream (Station 4). Station 5 is intertidal located in the vicinity of the river mouth.

TAXA	SAMPLING STATIONS				
	1	2	3	4	5
ANNELIDA					
OLIGOCHAETA		0	3	2	0
POLYCHAETA					
Chaetozone gibber (Woodham and Chambers, 1994)	-	0	0	0	0
Nephtys assimilis (Oersted, 1843)	-	0	0	0	0
Nephtys cirrosa (Ehlers, 1868)	-	0	0	0	0
Nephtys hombergii (Savigny, 1818)	-	0	0	0	0
Nereis (Hediste) diversicolor (O.F. Müller, 1776)	-	0.3	0.3	0	0
Pectinaria (Lagis) koreni (Malmgren, 1866)	-	0	0	0	0
Pisione remota (Southern, 1914)	-	0	0	0	0
Scolaricia typica (Eisig, 1914)	-	0	0	0	0
ARTHROPODA CRUSTACEA					0
AMPHIPODA					0
Ampelisca brevicornis (Costa, 1853)	-	0	0	0	0
Ampelisca diadema	-	0	0	0	0
Corophium multisetosum (Stock, 1952)	-	0	0	0	430
DECAPODA					
Crangon crangon (Linné, 1758)	-	0	0	0	1
MOLLUSCA					
BIVALVIA					
Abra alba (Wood W., 1802)	-	0	0	0	0
Nucula nitidosa (Winckworth, 1930)	-	0	0	0	0
Spisula subtruncata (da Costa, 1778)	-	0	0	0	0
GASTROPODA					
Nassarius reticulatus (Linné, 1758)	-	0	0	0	0

Table A9.4. Taxa present at the sampling stations located in the river Lima estuary (mean numbers/0.1 m^2), in September 2007. Stations are cited from downstream (station 1) to downstream (station 4).

TAXA	SAMPLING STATIONS			
	1	2	3	4
ANNELIDA				
OLIGOCHAETA	0	2	0	1
POLYCHAETA				
Chaetozone gibber (Woodham and chambers, 1994)	0.3	0	0	0
Nephtys assimilis (Oersted, 1843)	0.3	0	0	0
Nephtys cirrosa (Ehlers, 1868)	0	0.3	0	0
Nephtys hombergii (Savigny, 1818)	1	0	0	0
Nereis (Hediste) diversicolor(O.F. Müller, 1776)	0	0	0	0
Pectinaria (Lagis) koreni (Malmgren, 1866)	1	0	0	0
Pisione remota (Southern, 1914)	0	2	0.3	0.3
Scolaricia typica (Eisig, 1914)	0	1	0	0
ARTHROPODA CRUSTACEA				
AMPHIPODA				
Ampelisca brevicornis (Costa, 1853)	0.3	0	0	0
Ampelisca diadema	0.3	0	0	0
Corophium multisetosum (Stock, 1952)	0	0	10	0
DECAPODA				
Crangon crangon (Linné, 1758)	0	0	0	0
MOLLUSCA				
BIVALVIA				
Abra alba (Wood, 1802)	8	0	0	0
Nucula nitidosa (Winckworth, 1930)	2	0	0	0
Spisula subtruncata (da Costa, 1778)	0.3	0	0	0
GASTROPODA				
Nassarius reticulatus (Linné, 1758)	1	0	0	0

Table A9.5. Minho and Lima estuaries (September, 2007): Diversity indexes and ecological quality status based on AMBI indexes.

SAMPLING STATION	H' (LOG2)	AMBI	M-AMBI	EQS
Minho1	0,00	7,00	–0,07	Bad
Minho2	0,00	3,00	0,25	Poor
Minho3	0,33	5,70	0,17	Bad
Minho4	0,00	6,00	0,04	Bad
Minho5	0,10	2,99	0,35	Poor
Lima1	1,59	2,29	0,99	High
Lima2	1,20	2,68	0,65	Good
Lima3	0,14	2,90	0,33	Poor
Lima4	0,56	4,50	0,31	Poor

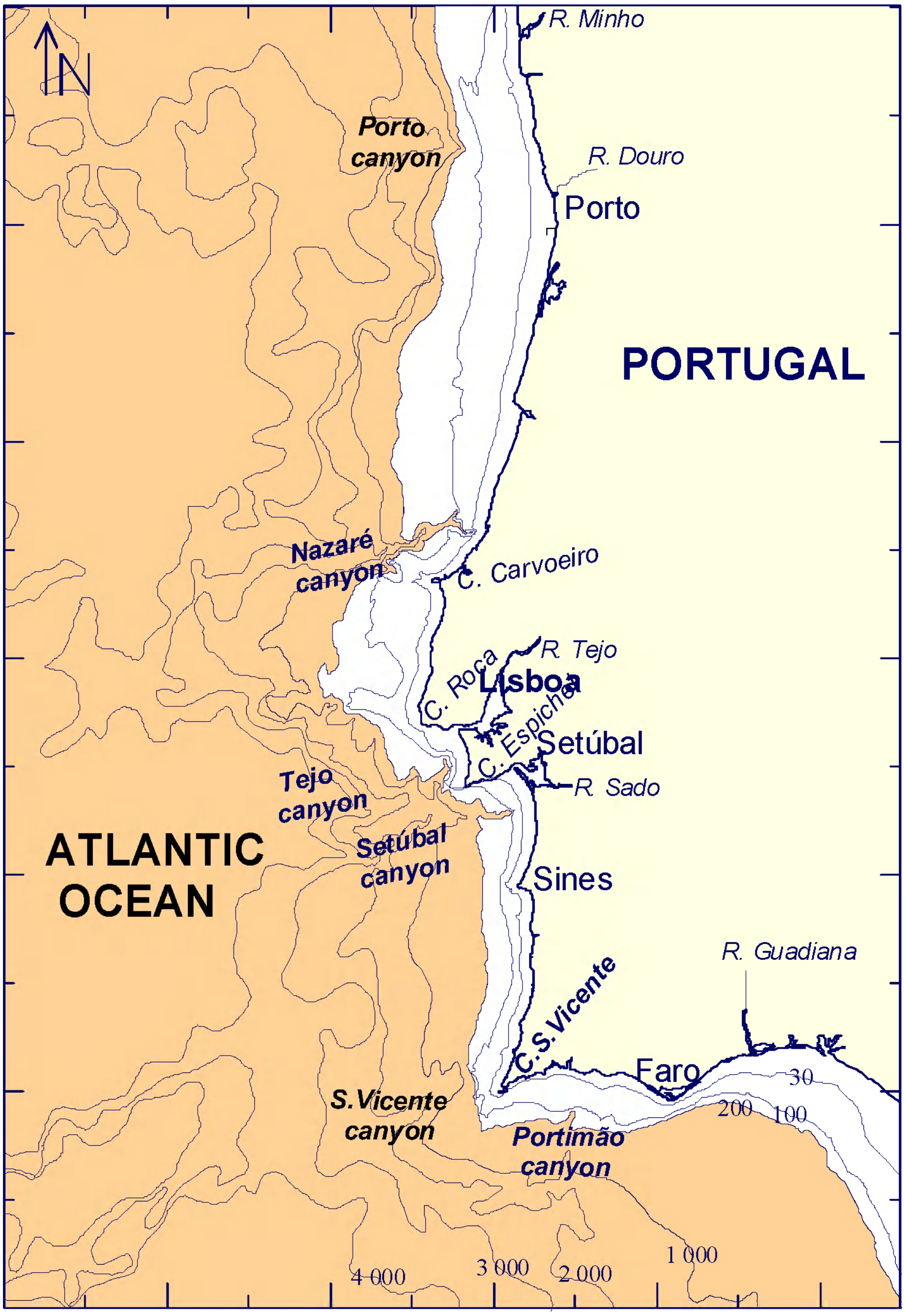


Figure A9.1. Portuguese mainland coast (sampling sites):

WFD: ♦estuaries; ■ coastal waters; ▲vicinity of urban and industrial emissaries.

◙ Tagus estuary: monitoring of the ecological quality.

♣ Arrábida Marine Park: monitoring of sediment and benthic macroinvertebrates within the framework of "BIOMARES"

Project LIFE06 NAT P 192: "BIOMARES"

Restoration and management of biodiversity in the Marine Park Site Arrábida-Espichel (PTCON0010)

The main objective of this EU funded project is the restoration of the seagrass meadow in the Portinho da Arrábida (habitat 1110 - NATURA 2000) by planting 10 ha of seagrass using the species *Zostera marina* and *Cymodocea nodosa*. Natural recovery is expected to continue to 30 ha by natural seagrass growth after the project, which will last until 2010. Seagrass recover is expected to increase biodiversity in the area.

The task of the IPIMAR benthos group is the study of the benthic macroinvertebrates in the transplant areas and in the adjacent areas. Both had very abundant benthos in the 1970s when the seagrass meadow was fully developed. The first sampling survey took place in early April. The sampled areas are shown in Figure A9.2. At the moment sediment grain size and OM are under analysis and the fauna is being sorted.

Figure A9.2. Arrábida Marine Park: planting areas of *Zostera marina* and *Cymodocea nodosa* (dark-red). Adjacent area (dark-blue).

Ecological quality status of the Tagus estuary

Contract with SIMTEJO (Management and treatment of residual waters of the rivers Tagus and Trancão - city of Lisbon)

Since 2004 several physical and chemical parameters and benthic macroinvertebrates have been monitored in order to assess the ecological quality status of the estuary and to provide advice for a sustainable management.

The results of the 2004 surveys (Figure A9.3), suggest a moderate ecological quality, in global terms. Fauna-environment relations are rather puzzling; the main factor structuring the fauna appears to salinity. Nevertheless, in a few sites with high input of contaminants the macrozoobenthos seem to reflect those inputs (see BIO-ENV results, Figure A9.3). We hope that further results will help to clarify the issue.

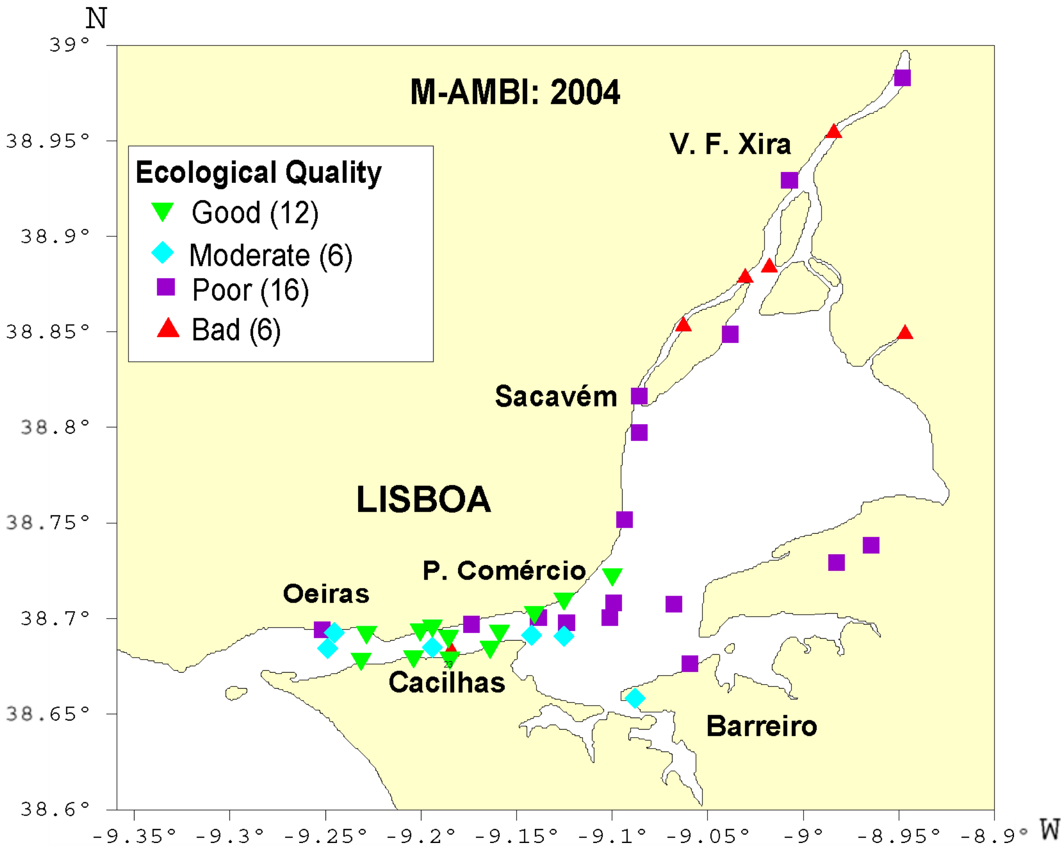


Figure A9.3 The Tagus estuary (Lisbon): Sites distribution according to M-AMBI and BIO-ENV results.

IPIMAR, Lisboa, 23 April 2007

Annex 10: Long term changes in the phytobenthic communities of the Baltic Sea

Long term changes in the plant species depth distribution indicate a recovery of the coastal Baltic Sea systems. Revisit of Mats Waern diving sites in the Gräsö area, Åland Sea, from 1940–1942 in 1984 indicated a drastic decrease of the depth distribution of plants as demonstrated by the bladder wrack (*Fucus vesiculosus*) which on average had reduced its depth distribution by 3 m. A revisit in 1992 indicated an increase in the depth distribution of the plants and in 2006 *Fucus* was found at the same depths as in the 1940th on several of the revisited stations, and all showed an increase in dept distribution.

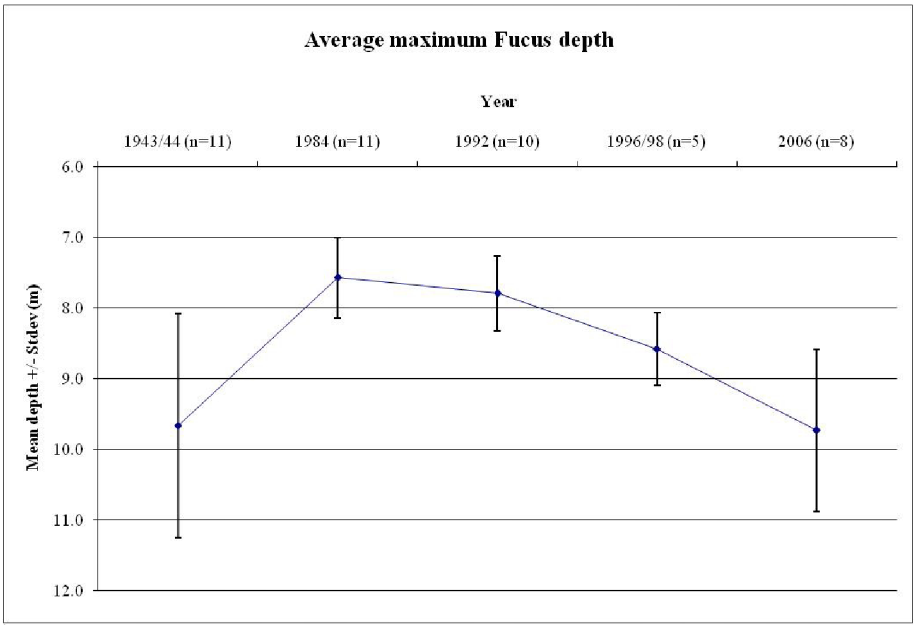
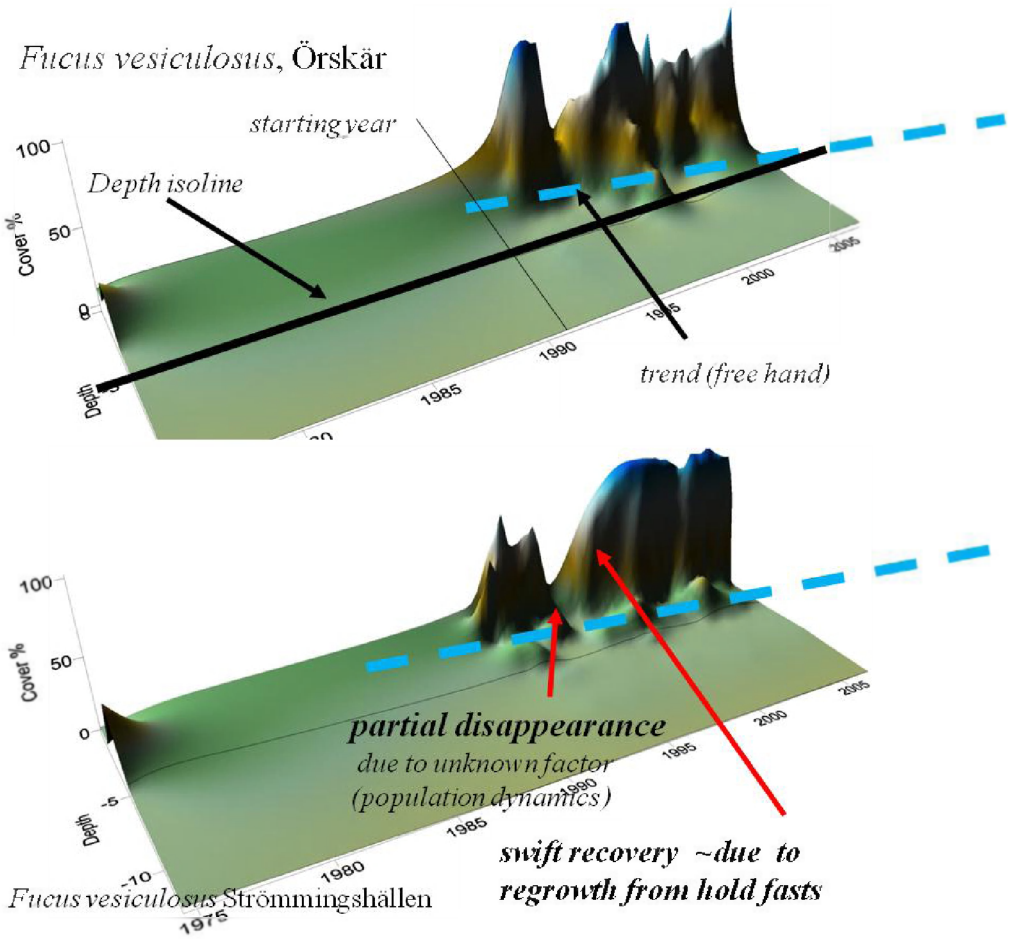


Figure A10.1. The average depth distribution of *Fucus vesiculosus* on the Mats Waern sites, Gräsö area, Åland Sea, comparison between the years 1942, 1984, 1996 and 2006 (from Anders Wallin *et al.* in prep.).

This somewhat sensational result is to a part also verified by the plant species distribution in the northern Baltic proper (the Askö area). In the Askö area, on average *Fucus* has increased its depth distribution since the mid 1990th. This is especially clear when analyzing each station with itself over a given time period. On several stations the *Fucus* communities have increased their depth distribution since the beginning of the 1990th. However, in some places they have disappeared most probably due to population dynamics. In some stations *Fucus* has reoccurred, which also is reported from other areas and therefore seems to be a general trend in the Baltic Sea. On a few stations *Fucus* has not increased the depth distribution due to the lack of suitable substrate deeper down. Also, several other plant species, including higher plants, are growing deeper down today compared to the early 1990th. However, the general trend is not straight forward. Depending on population dynamics and also probably due to a minor decrease in the salinity, some species have decreased (e.g. *Rhodomela confervoides*) or have reappeared and increased their distribution (e.g. *Sphacelaria arctica*). In conclusion, a recovery in the near shore coastal system of the Baltic Sea can be observed. This is also confirmed by the increasing local Secchi depth, decrease in nitrogen load and decreased pelagic primary production during the spring bloom.



Fucus vesiculosus, Örskär
starting year
Depth isoline
trend (free hand)
100
50
0
Cover %
Depth
1985
1990
1995
2000
2005
100
50
0
-5
-10
Cover %
Depth
partial disappearance
due to unknown factor
(population dynamics)
swift recovery ~due to
regrowth from hold fasts
1975
1980
1985
1990
1995
2000
2005
Fucus vesiculosus Strömmingshällen

Annex 11: Final report on the effects of the *Prestige* oil spill on continental shelf macroinfauna (Galicia, NW Spain)

ICES Benthos Ecology Working Group

Working document, Wilhelmshaven, Germany, April 2007

Not to be cited without reference to author(s)

Final report on the effects of the *Prestige* oil spill on continental shelf macroinfauna (Galicia, NW Spain)

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INTRODUCTION

After the grounding of the tanker *Prestige* on November 2002 near the Galician Bank, NW Spain, about 50000 tons of heavy oil (type M-100) was released to the sea, affecting a huge part of the Galician coastline and surroundings areas (Sánchez 2003; Sánchez *et al.*, 2003a). Documents presented in 2003, 2004 and 2005 in this working group dealt with the general information about this oil spill, as well as with its initial effects on the benthic and demersal continental shelf communities. The paper presented in 2003 provided general information on this oil spill, in addition to the actions carried out by the IEO towards the study of its impact on the continental shelf of Galicia and Asturias (Sánchez *et al.*, 2003b). The 2004 report provided new data on the evolution of the benthic and demersal communities of the shelf affected (Sánchez *et al.*, 2004) and the 2005 report presented new results on the infaunal and hyperbenthic communities of this ecosystem (Parra *et al.*, 2005). This final report presents the main results on macroinfaunal communities obtained after three years of sampling (2002-2004) in the Galician continental shelf.

MATERIAL AND METHODS

To study the sediment characteristics, sediment samples were collected from 23 stations distributed over three impact zones (1: min; 2: max; 3: moderate) and three depth strata (A: 70–120 m; B: 121–200 m; C: 201–300 m; Figure A11.1). The sampling procedure was repeated in these stations during five different periods: winter 2002, spring 2003, autumn 2003, spring 2004 and autumn 2004, with the exception of depth stratum C which was only sampled in the spring of 2004. Particle size analysis was performed by a combination of dry sieving and sedimentation techniques (Buchanan, 1984). Organic matter in the sediment was estimated as weight loss of dried (100 °C, 24 h) samples after combustion (500 °C, 24 h). 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.

Infaunal samples were collected with a modified Bouma box corer (0.0175 m2) and 3–5 samples were taken (sampling area = 0.0525–0.0875 m^2) in each station (Figure A11.1). This sampler has been used successfully to study 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 13 stations were collected for the study of the infaunal communities (figure 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 belonging to zone 1, stations 7, 8, 10, 11, 13 and 14 of zone 2 and stations 16, 17 and 19 of zone 3 were studied. To examine the temporal evolution of the infaunal communities, the samplings were repeated in the same stations over the course of five different time periods: winter 2002–2003, spring 2003, autumn 2003, spring 2004 and autumn 2004 (with the exception of zone 1 when only two time periods were studied: winter 2002–2003 and spring 2003).

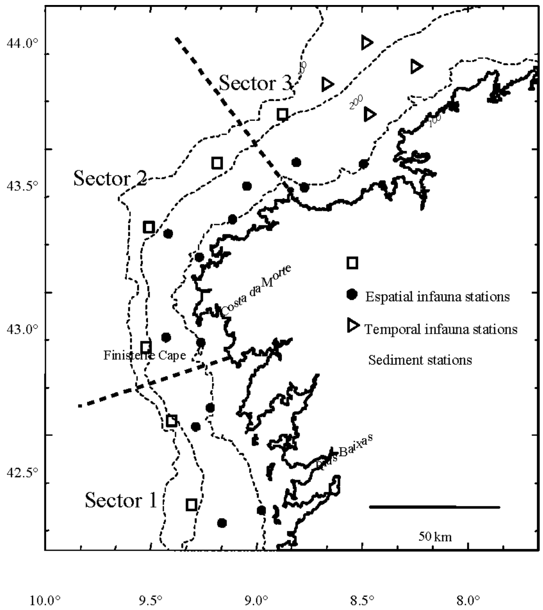

Figure A11.1 General view of sampling and bottom stations.

Macroinfauna samples were sieved on board through a 0.5 mm sieve, anaesthetized with a $MgCl^2$ solution and then preserved with 8 % buffered formaldehyde. Correlations of wet weight (WW) to ash-free dry weight (AFDW) were calculated to estimate the biomass of each individual species (López-Jamar *et al.*, 1996; Parra & López-Jamar, 1997).

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 the very 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 A11.2. The highest mean concentrations of oil were found in winter in Zone 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 Zone 1, the mean density of tar aggregates was always very low (<0.1 kg • km^{-2}). Therefore, this study considers it to be the zone suffering the least impact.

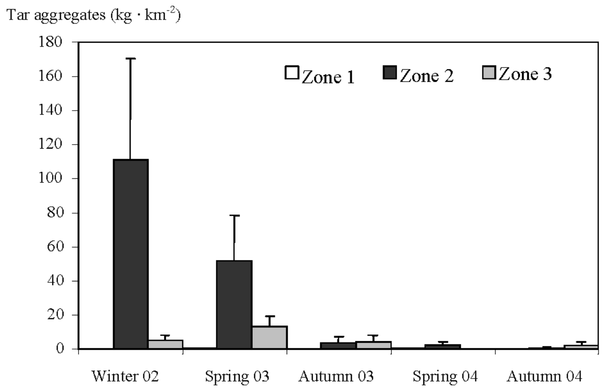

Figure A11.2 Heavy oil (tar aggregates) average concentrations (kg • km^{-2} ± SE) on the Galician continental shelf from five beam-trawl surveys.

Sediment characteristics

Table A11.1 presents the sediment variables in the stations surveyed. The sediment of the shallowest stratum (stratum A) in Zone 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 A.11.3; Table A11.1).

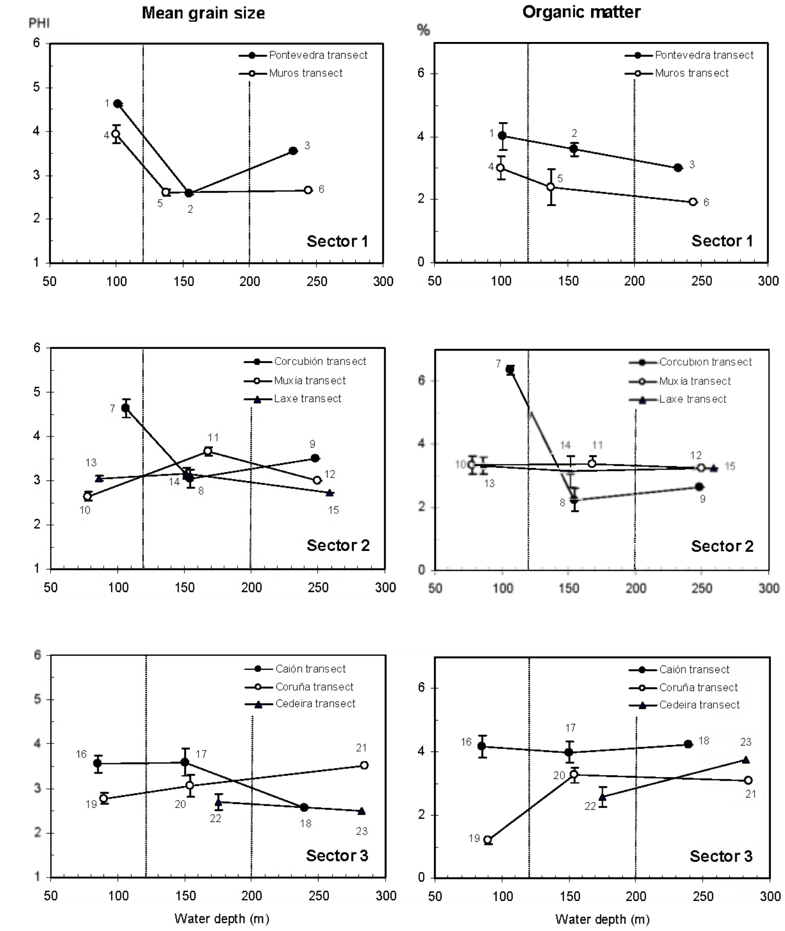

Figure A11.3. Effect of water depth at stations on mean diameter of particle size (Φ Units) and percentage of organic matter in sediments on the continental shelf off Galicia by zones (zones).

The middle stratum (stratum B) of Zone 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 A11.3). The selection of the two stations is fairly good, without exceeding the sorting coefficient of 1.31 ± 0.02 points at station 5 (Figure A11.3; Table A11.1). The temporal variation did not exhibit any major changes, either.

The sediments of the stations located in the deepest stratum (stratum C) in Zone 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 to moderate (S0 between 1.30 and 1.33, stations 6 and 3 respectively; Figure A11.3, Table A11.1).

Nine stations from the maximum-impacted area (Zone 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 (Q50 = 41 ± 6 µm) to fine sands with low organic matter content at station 10 (Q50 = 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 A11.3, Table A11.1). The temporal variation of the sediment in the stations belonging to this stratum, for Zone 2, was minor.

The middle stratum of Zone 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 zone (Figure A11.3; Table A11.1).

The sediments in the stations located in the deepest stratum (stratum C) of Zone 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 (S0 between 1.29 and 1.99, stations 9 and 12 respectively; Figure A11.3; Table A11.1).

In the moderate-impacted zone (Zone 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 zone had very fine sands at station 16 (Q50 = 86 ± 12 µm) with fine sands and low organic matter content at station 19 (Q50 = 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 Zone 3 was minor (Figure A11.3; Table A11.1).

The middle stratum in Zone 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 zone (Figure A11.3; Table A11.1).

The sediments of the stations located in the deepest stratum (stratum C) in zone 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 (S0 between 1.42 and 2.19, stations 23 and 21 respectively; Figure A11.3; Table A11.1)).

General characteristics of infaunal communities

This section offers a brief description of the general faunal characteristics of the macroinfaunal communities studied, by zone and depth stratum. All stations were sampled on a seasonal basis, with data being provided from five surveys between the years 2002 to 2004. The next section will focus on the temporal variation of the community in relation to the possible effects of the oil spill.

In the 71–120 m depth stratum (stratum A) in Zone 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 (Figure A11.3; Table A11.1). The two stations were sampled in the surveys carried out only in winter 2002, spring 2003 and 2004. Polychaetes were the dominant zoological group in abundance in this stratum (as high as 92.31 % in spring at station 4; tables 3 and 4). The communities were dominated by the spionid polychaete *Prionospio fallax*, which reached an average abundance of 2079 ind • m^{-2} in station 4 (table 5). In the 121-200 m depth stratum (stratum B) in Zone 1, the two stations studied (2 and 5) in the same period of time as the previous stratum, presented sediments made up of fine sands with a moderate organic content (Table A11.1), Polychaetes were the dominant zoological group in abundance in this stratum (91.57 % in winter 2002, in station 2), but in biomass Echinoderms were the dominant group in Stn. 10 (Tables A11.3 and A11.4). The infaunal communities were characterized by the predominance of the polychaetes *Prionospio fallax*, *Monticellina dorsobranchialis* and *Aricidea* sp. The main species composition of this stratum is given in Table A11.5 and the community variables in Tables A11.2 and A11.6.

Following is a description of the infaunal communities of the zone most seriously affected by the oil spill, Zone 2. In the shallowest stratum (71–120 m) we analyzed stations 7, 10 and 13, all of which were sampled during the five surveys. Station 7 was composed of a muddy sediment high in organic content, while the sediment of stations 10 and 13 consisted of fine sands low in organic content (Table A11.1). Once again, polychaetes were the dominant group in this stratum, reaching an abundance of 88.44 % in station 13 in autumn 2004 (Tables A11.3 and A11.4). The polychaete *Prionospio fallax* was, once more, the dominant species in the stratum, along with the echinoderm *Amphiura filiformis* (Stn. 10) and the polychaetes *Magelona minuta* (Stn. 13) and Tharyx sp. (Stn. 10). In the 21–200 m depth stratum (stratum B) in Zone 2 three stations were studied (8, 11 and 14). The three stations were sampled in the five study periods (winter 2002, spring and autumn 2003 and spring and autumn 2004). 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 88 % in spring 2004, Stn.8), followed by the crustaceans which accounted for up to 31 % in autumn 2003 (Stn. 11; Tables A11.3 and A11.4). 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* (Table A11.5). The community variables are given in Tables A11.2 and A11.6.

Zona 3 is considered to be a zone of average or moderate impact. In the shallowest stratum, stratum A (71–120 m), we examined two stations (16 and 19) which are characterized by a sandy sediment with a low organic content. Again, polychaetes were the typical zoological group in this stratum (as high as 90.69 % in winter 2002, Stn. 19; Tables A11.3 and A11.4). *Prionospio fallax* was the dominant species, reaching a mean abundance of up to 4309 ind•m^{-2} in station 19. Other characteristic species were the polychaetes *Magelona minuta*, *Spio decoratus* and *Levinsenia gracilis*. In the 21–200 m depth stratum (stratum B) in Zone 3 we were only able to study one station characterized by a sediment composed of fine sands and a moderate organic content. Once more, the polychaetes were the stratum's dominant group, accounting for over 79% (Tables A11.3 and A11.4). The characteristic species in this stratum were the polychaetes *Prionospio fallax* and *Monticellina dorsobranchialis*. The main species composition in this stratum is given in Table A11.5 and the community variables in Tables A11.2 and A11.6.

Temporal evolution of the infaunal communities

In the shallowest area of Zone 1 (stratum A: 70–120 m) in station 1 we observed a decrease in total abundance during the study period, especially in the main species consisting of spionid polychaetes and oligochaetes in spring 2003 (Figure A11.4). Species richness and diversity also decreased moderately in spring 2003, but rose sharply in spring 2004. In 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 A11.4). Similar to the previous station, species richness, diversity and evenness decreased slightly in spring (Tables A11.2 and A11.6).

Upon an examination of the stations located in the deepest stratum (stratum B: 121–200 m), we observed that station 2 showed a modest increase in total abundance in spring 2003 and 2004, owing to the growing number of polychaetes of the genus *Aricidea* and to *Prionospio fallax* (Figure A11.4; Table A11.5). This is the station that exhibited the lowest abundance values, and never exceeded 1340 ind•m^{-2} in spring 2004 (Table A11.6). Species richness, diversity (with a considerably high value – over 5 points) and evenness also underwent a slight decrease in spring 2003 (Table A11.2). In contrast, station 5, which had a relatively high infaunal abundance (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 A11.4; Tables A11.5). Unlike the other station in Zone 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 A11.2).

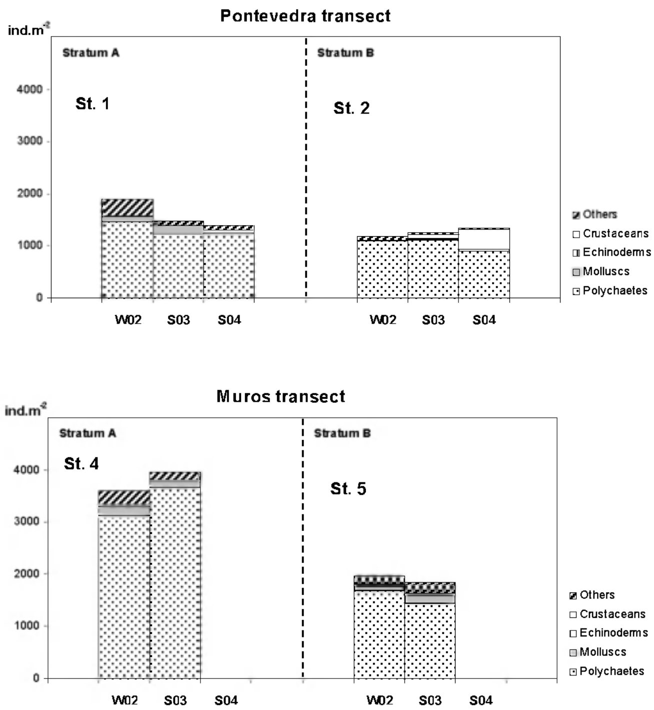

Figure A11.4. Temporal total abundance (ind•m^{-2}) by taxonomic group in the stations 1, 2, 4 and 5 of the Zone 1. Distribution is shown by transect and depth strata.

Overall, in the zone that suffered the greatest impact from the oil spill (Zone 2), there were slight variations between the different time periods studied. In general we can point to a slight increase in the abundance of some of the zoological groups, such as the increasing numbers of crustaceans (particularly, the amphipods) recorded in stations 10 and 14 (Figure A11.5). We also witnessed a general rise in the total biomass in most of the stations in the samplings conducted in 2004. Lastly, worthy of note was the gradual decline in total abundance and specific richness in the first three samplings (winter 2002, spring and autumn, 2003) of the stations located in stratum B (121–200 m) of this high-impact zone (stations 8, 11 and 14).

In a more detailed examination of the shallowest station (stratum A: 70–120 m) of Zone 2, we have data available from three stations (7, 10 and 13) which were sampled during five different seasons (winter 2002, spring 2003 and 2004, and autumn 2003 and 2004), with the exception of station 7 which was not able to be sampled in winter 2002. Station 7, near the Ría de Corcubión, presented the lowest values of total abundance in Zone 2. This station did not exhibit a clear pattern of temporal variation in total abundance, reaching a maximum value of 3985 ind•m^{-2} in spring 2004; Figure A11.5; Table A11.6). In terms of the temporal evolution of the main infaunal species, we can highlight the gradual decrease in the abundance of the polychaete *Prionospio steentrupii* (from 381 to 0 ind•m^{-2}). Total biomass increased substantially in spring 2004 owing mainly to the polychaete group with the appearance of a large number of individuals having a high level of biomass (*Sternaspis scutata*). Diversity and evenness reached maximum values in autumn 2003 (H' = 4.17 and J' = 0.94; Table A11.2) and subsequently decreased until the end of the study.

In station 10, in terms of total abundance, low values were observed in winter and autumn, with increasing abundance in spring. The rise in spring 2004 was the most important in the entire period under study (up to 6687 ind•m^{-2}). Hence, the variation in this variable did not follow a clear pattern. As regards faunal groups, there was a gradual increase in the abundance of the crustacean group until the end of the study, particularly of the amphipods *Urothoe brevicornis* (which increased from 126 to 286 ind•m^{-2}) and *Perioculodes longimanus* (from 11 to 133 ind•m^{-2}), and, to a lesser extent, the amphipod *Pontocrates* sp. and the group of undet. Tanaidaceans. In contrast, the polychaete, *Magelona minuta* and the mollusc *Mysella bidentata* declined in number over the course of the study period. Moreover, the total biomass increased during the first four samplings (maximum 3.96 g•m^{-2} AFDW, in spring 2004), but decreased in autumn 2004 (Figure A11.5; Table A11.6). The number of species diminished in spring 2003, going from 46 to 31 species, and recovering, once again to reach a maximum in spring 2004 (K = 68). Diversity reached its highest value in spring 2004 (H' = 4.75) and evenness gradually increased until it attained a maximum in the same season, similar to diversity (J' = 0.78; Table A11.2).

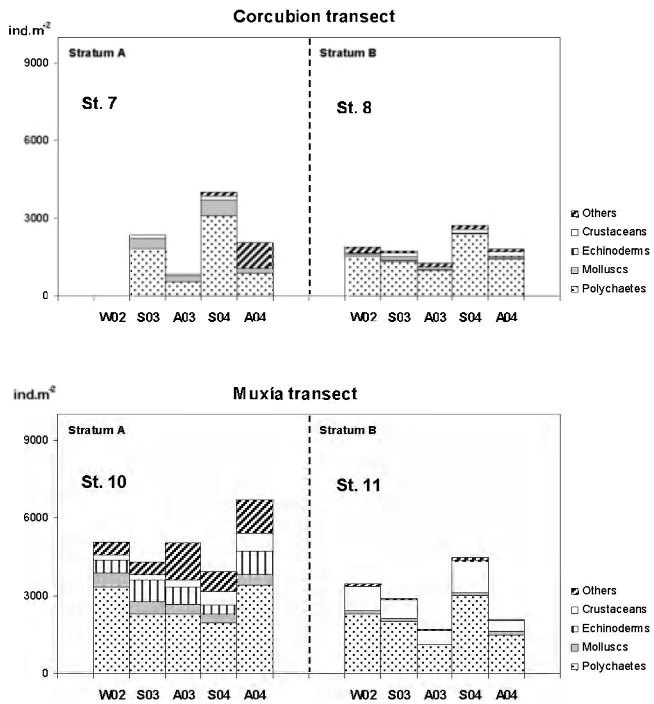

Figure A11.5. Temporal total abundance (ind•m^{-2}) by taxonomic group in the stations 7, 8, 10 and 11 of the Zone 2. Distribution is shown by transect and depth strata.

The temporal variation of total abundance by group in station 13 of the highest impact zone (Zona 2) is presented in figure 6. It had the highest abundance values of all of Zone 2, reaching 8553 ind•m^{-2} in spring 2003, five months after the oil spill. It underwent a rapid decrease in autumn 2003, experiencing a gradual increase until the end of the study, presenting values of nearly 7600 ind•m^{-2} (Table A11.6). Some of the polychaetes like *Levinsenia gracilis*, *Spiophanes bombyx* and *Monticellina dorsobranchialis*, along with the bivalve mollusc *Tellina pygmaea* exhibited an increasing pattern over time, which might suggest that the initial effect on these species was negative, and then they later went on to recover their abundance levels. Similarly, other species, whose values in the early studies were relatively high, decreased progressively over time (i.e. the polychaetes *Prionospio steenstrupii* and *Paradoneis lyra*). Both of these statements are risky, since the abundance values of these species prior to the oil spill are not known. Similar to what occurred in station 7, the total biomass tended to increase, exhibiting a pronounced maximum in autumn 2003 which may be attributed to the presence of large-sized molluscs and crustaceans. The number of species was relatively constant over the whole period with the exception of spring 2004 when the maximum value was attained (K = 98). Diversity and evenness reached maximum values in spring 2003 (H' = 4.97 y J' = 0.83; Table A11.2) and then started to decrease little by little until the end of the study.

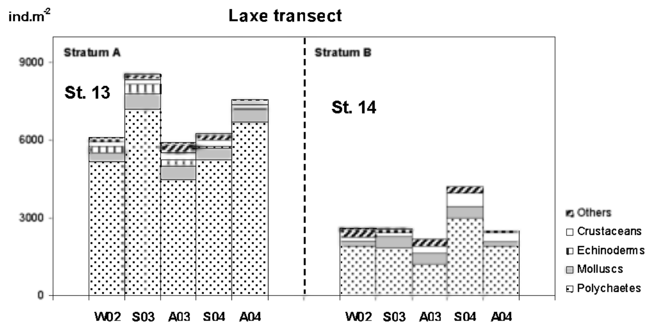

Figure A11.6. Temporal total abundance (ind•m^{-2}) by taxonomic group in the stations 13 and 14 of the Zone 2. Distribution is shown by depth strata.

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 in five different seasons, there was a gradual decrease in total abundance during the first three samplings, from 1897 ind•m^{-2} in winter 2002 to 1238 ind•m^{-2} in autumn 2003. Subsequently, in spring 2004 there was an increase, leading to the maximum total abundance for the entire period studied (2711 ind•m^{-2}; Figure A11.5; Table A11.6). No clear distribution pattern was observed in the main infaunal species. The dominant specie *Prionospio fallax*, which declined initially during the early samplings, recovered its abundance in spring 2004 (reaching up to 356 ind•m^{-2};). Similarly, *P. steenstrupii*, which at first increased in, started to decrease as of spring 2003 going from 324 to 114 ind•m^{-2};. Infaunal biomass behaved irregularly, with high values being recorded in the two autumn samplings (máx 4.67 g•m^{-2} AFDW, in 2004; Table A11.6) and very low values in the spring samplings. The number of species diminished during the first three samplings, and then rose sharply in spring 2004, reaching the maximum of the period under study (K = 60). Diversity, which was high, ranged in value from 4.02 to 4.90, both in spring, 2003 and 2004, respectively. Evenness remained relatively stable at around 0.83 points, presenting its maximum value of 0.92 in the last sampling (Table A11.2).

Other stations studied in this deep stratum of Zone 2 were numbers 11 and 14, which were sampled in the five time periods and exhibited a similar temporal variation pattern. Initially, in Station 11 total abundance decreased until autumn 2003 (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* (Figure A11.5). Later, however, there was a substantial increase in abundance and total biomass in spring 2004 (4483 ind•m^{-2} and 3.96 g•m^{-2} AFDW, respectively), only to decrease again during the last sampling (Table A11.6). Specific richness exhibited a similar temporal evolution, with a maximum in spring 2004 of 67 species. Diversity and evenness, which behaved in an irregular fashion, reached their highest values in autumn 2004 (H' = 4.35 and J' = 0.86; Table A11.2).

Similar to what occurred in station 11, in station 14 we initially observed a slight drop in total abundance until autumn 2003 and then a subsequent rapid increase of this variable and total biomass in spring 2004 attaining values of 4208 ind•m^{-2} and 6.81 g•m^{-2} AFDW, respectively. Afterwards, the two variables decreased in autumn 2004, which was the last month of sampling (Figure A11.6, Table A11.6). This increase in abundance coincided with a major increase in the peracarid group (up to 489 ind•m^{-2} in spring 2004), which are considered to be sensitive to hydrocarbon contamination and would therefore indicate that the early samplings might be affected by the oil spill. Amphipods are considered to be the most sensitive species to hydrocarbons in sediments (Dauvin, 1987; Dauvin and Gentil, 1990; Parra *et al.*, 1997b; Gómez Gesteira and Dauvin, 2000)

Similarly, in the two previous stations, the number of species declined during the first three samplings and then rose substantially in spring 2004 when the maximum value was reached (K = 83), while diversity and evenness had relatively constant values throughout the period under study, with maximum values of 4.86 and 0.89, in spring and autumn 2003, respectively (Table A11.2).

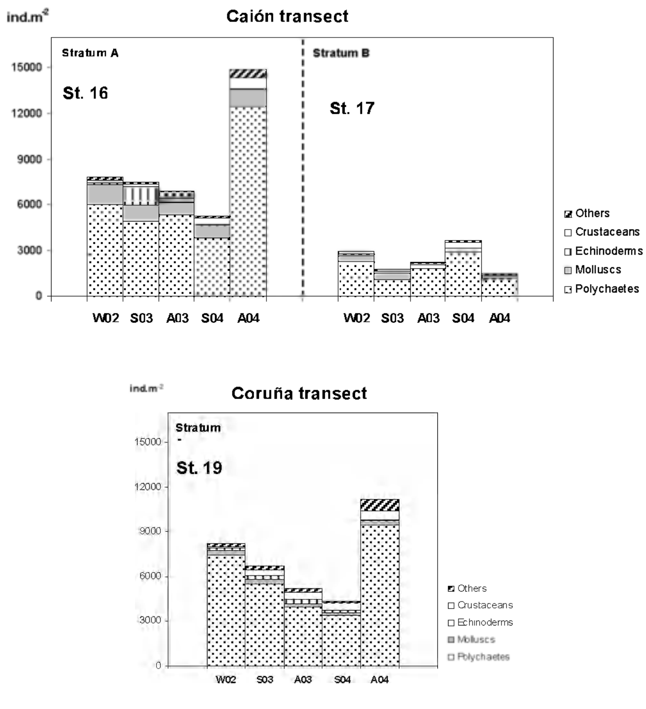

Figure A11.7. Temporal total abundance (ind•m^{-2}) by taxonomic group in the stations 16, 17 and 19 of the Zone 3. Distribution is shown by transect and depth strata.

In the moderately-impacted zone (Zone 3), we only examined the temporal evolution (in five periods) of the infaunal communities inhabiting the continental shelf in two stations belonging to shallow stratum A (Stns. 16 y 19) and one in the deepest stratum B, (Stn. 17). In general, a progressive decrease was seen in the total abundance during the first four samplings (W02, S03, A03 and S04) and in richness during the first three samplings, in stations belonging to stratum A. In contrast, we recorded a gradual increase in the abundance of the crustacean group, particularly amphipods, in these stations (Figure A11.7).

In a more detailed examination of the shallowest station number 16 of Zone 3 (stratum A: 70–120 m), we can see a gradual decline in total infaunal abundance during the first four samplings (from 7875 to 5277 ind•m^{-2}), followed by a major rise in this variable which reached 14878 ind•m^{-2}-the highest value recorded in the whole study. On the other hand, the amphipod group underwent a gradual increase throughout the study period, particularly *Ampelisca* spp. and the family Phoxocephalidae, which could mean that this crustacean group might be negatively affected by the *Prestige* oil spill. The assumption of this hypothesis is very complicated owing to the lack of available data prior to the spill. Total biomass was dominated by the polychaetes and its temporal variation did not follow any specific pattern, reaching a maximum of 4.43 g•m^{-2} AFDW in autumn 2003 (Table A11.6). The behavior of species number was similar to that of the stations located in the same stratum of Zone 2, with a maximum of 81 species in spring 2004. Diversity and evenness were relatively stable and attained their highest values in spring 2004 and autumn 2003, respectively (H' = 4.53 and J' = 0.73; Table A11.2).

Like the station discussed above, in terms of total abundance, station 19 (stratum A, Zone 3), underwent a sharp drop during the first four samplings, going from an abundance of 8230 ind•m^{-2} in winter 2002 to 4356 ind•m^{-2} in spring 2004. The total abundance later increased considerably in autumn 2004, the last month of sampling, when a value of 11220 ind•m^{-2} was attained. Again, we must underline the importance of the gradual increase in the amphipod group (*Ampelisca* spp.) and the cumaceans, owing to their possible link to the oil spill (Figure A11.7). With the exception of the total biomass value during the first month of sampling (owing to the presence of a large-sized echinoderm), we can see that this variable increased gradually throughout the entire study period, with a final value of around 4.60 g•m^{-2} AFDW (Table A11.6) The variation in number of species behaved similarly to station 16, although with higher values, reaching a maximum of 103 species in spring de 2004. This is the highest value of all the stations in this study. Diversity and evenness attained their maximum values in spring 2004 and autumn 2003 respectively (H' = 4.97 y J' = 0.83; Table A11.2).

Lastly, station 17 located in stratum B of Zone 3, exhibited the lowest total abundance and total biomass values in this zone over the course of the whole study. The temporal variation of total abundance was irregular, presenting a maximum of 3677 ind•m^{-2} in spring 2004 and the highest values for variation in total biomass were found in the last two seasons sampled (a maximum of 2.03 g•m^{-2} AFDW in spring 2004; Figure A11.7; Table A11.6). The number of species was similar to that of the other stations in Zone 3, with a maximum of 79 species in spring 2004. Diversity and evenness were relatively stable, reaching their highest values in spring 2004 and autumn 2003, respectively (H' = 5.21 and J' = 0.81; Table A11.2).

CONCLUSIONS

The sediment is dominated by fine sands having a low organic content. No temporal changes that may be attributed to the impact of the oil spill were observed in the sedimentary variables.

The temporal evolution of the structural parameters of Zone 1 would not suggest that they suffered any effect from the oil spill. In Zone 2 by contrast, we found an increase in the abundance of the crustacean group (amphipods) in stations 10 and 14, a general increase in the total biomass in the 2004 samplings and a gradual decline in the total abundance and specific richness during the first three samplings of the stations located in stratum B (stations 8, 11 and 14). Zone 3 underwent a progressive decrease in total abundance during the first four samplings and of richness during the first three samplings in the stations belonging to stratum A (stations 16 and 19). In contrast, a gradual increase in the abundance of the crustacean group (amphipods) was recorded in the same stations.

Generally speaking, none of the zones showed any major changes in either the temporal pattern or the structure of the infaunal community. We did not see any marked increase in opportunistic species or species favoured by the oil spill (i.e., capitelid and spionids polychaetes; Pearson, 1975; Pearson and Rosenberg, 1978; Plante-Cuny *et al*., 1993). Owing to the lack of previous data, we are unable to confirm whether or not mortalities have occurred in species that are sensitive to hydrocarbon contamination (i.e. echinoderms and peracarid crustaceans), although the increasing crustacean populations in some stations could be related to the oil spill.

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Tables

Table A11.1. Sediment variables. Symbols: % O.M.: organic content; Q50: mean diameter (Φ Units and µm); S0: sorting coefficient (√Q25/Q75).

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 A11.2. Macrofauna richness (K), diversity (H') and evenness (J') at each station by season (W: winter; S: spring; A: autumn).

	K					H'					J'				
Season	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04
Station															
1	22	18	-	30	-	2.84	2.54	-	3.33	-	0.64	0.61	-	0.68	-
2	28	27	-	64	-	4.12	4.05	-	5.16	-	0.86	0.85	-	0.86	-
4	36	30	-	-	-	3.15	2.62	-	-	-	0.61	0.53	-	-	-
5	30	35	-	-	-	3.89	4.57	-	-	-	0.79	0.89	-	-	-
7	-	21	22	50	15	-	3.05	4.17	4.09	2.62	-	0.69	0.94	0.72	0.67
8	45	29	27	60	37	4.56	4.02	4.16	4.90	4.78	0.83	0.83	0.87	0.83	0.92
10	44	31	47	68	56	3.78	3.60	4.25	4.75	4.22	0.69	0.73	0.76	0.78	0.73
11	41	37	23	67	34	3.90	4.06	3.27	4.16	4.35	0.73	0.78	0.72	0.69	0.86
13	66	64	63	98	53	4.04	3.99	4.97	4.73	3.70	0.67	0.66	0.83	0.72	0.65
14	48	43	40	83	42	4.57	4.81	4.86	5.06	4.70	0.82	0.89	0.91	0.79	0.87
16	72	50	51	81	68	3.81	3.55	4.13	4.53	3.59	0.61	0.63	0.73	0.71	0.59
17	48	31	39	79	31	4.59	4.51	4.57	5.15	4.34	0.82	0.91	0.86	0.82	0.88
19	81	71	58	103	72	3.53	4.02	4.72	5.21	3.96	0.56	0.65	0.81	0.78	0.64

Table A11.3. Macroinfaunal percentage made up of each group (P: polychaetes; M: molluscs; E: echinoderms) of total abundance at each station by season (W: winter; S: spring; A: autumn).

	% P					% M					% E				
Season	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04
Station															
1	77.11	82.89	-	88.99	-	5.42	10.53	-	1.38	-	0.60	0.00	-	0.00	-
2	91.57	87.88	-	67.30	-	0.00	1.52	-	2.37	-	1.20	1.52	-	0.47	-
4	86.67	92.31	-	-	-	4.76	2.88	-	-	-	0.00	0.00	-	-	-
5	86.55	78.35	-	-	-	3.51	7.22	-	-	-	0.58	0.00	-	-	-
7	-	77.42	65.91	77.69	42.06	-	16.94	27.27	15.46	11.21	-	0.00	0.00	0.00	0.00
8	82.53	80.22	80.00	88.76	78.72	4.22	9.89	3.08	0.47	5.32	0.60	1.10	0.00	0.23	2.13
10	66.06	53.54	45.66	49.11	50.71	10.41	11.06	7.55	9.05	6.55	10.18	19.47	12.83	9.37	13.39
11	65.23	70.20	65.17	67.56	71.82	4.30	3.31	1.12	1.84	5.45	0.00	0.00	0.00	0.00	0.00
13	85.02	84.19	76.05	83.81	88.44	5.62	6.90	8.74	7.74	6.53	3.75	4.45	4.53	1.12	0.25
14	73.80	70.99	55.26	70.69	76.34	7.42	18.32	20.18	10.73	6.87	0.00	0.76	0.00	0.00	0.00
16	76.20	66.16	78.39	72.20	83.74	16.84	13.74	10.53	16.00	7.68	1.45	16.03	1.11	1.44	0.13
17	77.13	62.37	79.83	78.93	79.22	13.18	25.81	10.92	7.25	12.99	0.39	0.00	0.00	0.00	0.00
19	90.69	82.10	75.18	77.26	84.04	3.75	4.55	4.74	4.08	2.89	1.53	3.41	6.20	4.96	0.51

Table A11.4. Macroinfaunal percentage made up of each group (C: crustaceans; O: others minor groups) of total abundance at each station by season (W: winter; S: spring; A: autumn).

	% C					% O				
Season	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04
Station										
1	0.00	0.00	-	3.67	-	16.87	6.58	-	5.96	-
2	1.20	6.06	-	28.91	-	6.02	3.03	-	0.95	-
4	0.95	0.96	-	-	-	7.62	3.85	-	-	-
5	1.75	3.09	-	-	-	7.60	11.34	-	-	-
7	-	5.65	4.55	3.35	0.00	-	0.00	2.27	3.51	46.73
8	2.41	7.69	6.15	5.62	8.51	10.24	1.10	10.77	4.92	5.32
10	3.85	4.42	5.66	12.60	10.54	9.50	11.50	28.30	19.87	18.80
11	27.15	25.17	31.46	27.20	20.00	3.31	1.32	2.25	3.40	2.73
13	2.62	2.00	4.21	3.77	2.01	3.00	2.45	6.47	3.56	2.76
14	5.68	5.34	12.28	12.39	13.74	13.10	4.58	12.28	6.19	3.05
16	1.89	2.29	3.32	7.22	4.74	3.63	1.78	6.65	3.13	3.71
17	3.88	5.38	5.88	9.50	3.90	5.43	6.45	3.36	4.32	3.90
19	1.25	6.25	8.76	10.64	5.26	2.78	3.69	5.11	3.06	7.30

Table A11.5. The most important macroinfaunal taxa (ten most important species by station, in abundance; ind•m^{-2}).

ZONE			1					2				3	
Station	1	2	4	5	7	8	10	11	13	14	16	17	19
Species													
Polychaetes													
Prionospio fallax	808	250	2079	250	727	284	1026	348	2182	337	3412	560	4309
Magelona minuta	.	.	.	.	109	99	176	70	501	197	405	.	606
Prionospio steenstrupii	131	.	172	61	171	218	.	517	211	223	.	103	.
Monticellina dorsobranchialis	.	43	160	234	71	120	.	225	292	226	.	286	.
Lumbrineris gracilis	31	.	.	.	101	.	.	.	472	.	212	.	240
Levinsenia gracilis	60	.	.	.	64	64	.	43	221	.	428	.	.
Spio decoratus	.	.	.	.	.	.	.	.	.	.	512	.	103
Aricidea sp.	.	130	173	250	.	.	.	.	.	.	.	.	.
Spiophanes bombyx	.	.	.	.	.	.	120	.	147	.	231	.	.
Mediomastus fragilis	31	58	54	.	.	52	.	97	.	116	.	.	.
Tharyx sp.	.	.	.	.	.	.	407	.	.	.	.	.	.
Archiannelida undet.	.	.	.	.	137	.	.	.	.	.	.	263	.
Paraonidae undet.	.	89	248	61	.	.	.	.	.	.	.	.	.
Aricidea claudiae	.	.	.	.	.	88	.	.	292	.	.	.	.
Aricidea fragilis mediterranea	.	.	.	.	.	.	.	.	.	.	.	.	366
Ampharete finmarchica	.	.	.	.	.	83	.	106	.	.	.	137	.
Magelona wilsoni	.	33	183	71	.	.	.	.	.	.	.	.	.
Galatowenia oculata	.	68	.	.	.	.	.	97	.	79	.	.	.
Ampharetidae undet.	.	.	.	162	.	48	.	.	.	.	.	.	.
Paradoneis lyra	.	.	.	.	.	.	.	.	178	.	.	.	.
Aphonuphis bilineata	.	.	.	.	.	.	.	.	.	.	.	.	137
Aricidea claudiae	.	.	.	.	.	.	.	.	.	.	.	.	126
Aricidea catherinae	.	.	.	.	.	.	.	.	.	.	.	.	126
Sternaspis scutata	40	.	.	.	78	.	.	.	.	.	.	.	.
Ariciidae undet.	.	.	.	.	.	.	.	.	.	.	.	.	103
Chone filicaudata	.	.	.	.	.	.	.	.	.	.	.	91	.
Aricidea laubieri	.	.	.	.	.	.	.	.	.	.	.	80	.
Exogone hebes	.	.	.	.	.	.	78	.	.	.	.	.	.

Zone			1					2				3	
Station	1	2	4	5	7	8	10	11	13	14	16	17	19
Hyalinoecia brementi	.	.	.	55	.	.	.	.	.	.	.	.	.
Cirratulidae undet.	.	48	.	.	.	.	.	.	.	.	.	.	.
Notomastus latericeus	37	.	.	.	.	.	.	.	.	.	.	.	.
Molluscs													
Thyasira obsoleta	.	.	.	.	.	.	.	.	.	100	244	160	.
Tellina pygmaea	.	.	.	.	.	.	.	.	.	.	352	.	.
Mysella bidentata	.	.	.	.	.	.	228	.	.	.	.	.	.
Onova vitrea	.	.	.	.	183	.	.	.	.	.	.	.	.
Abra sp.	137	.	.	.	.	.	.	.	.	.	.	.	.
Veneridae undet.	.	.	.	.	.	.	.	.	.	.	.	114	.
Thyasira ferruginea	.	.	.	.	97	.	.	.	.	.	.	.	.
Bathyarca glacialis	.	.	.	.	.	.	.	.	.	76	.	.	.
Thyasira sp.	.	.	44	.	.	.	.	.	.	.	.	.	.
Echinoderms													
Amphiura filiformis	.	.	.	.	.	.	596	.	.	.	.	.	.
Ophiurid undet.	.	.	.	.	.	.	.	.	.	.	318	.	.
Crustaceans													
Ampelisca sp.	.	.	.	.	.	.	.	679	.	97	.	.	.
Euphausid undet.	.	171	.	.	.	.	.	.	.	.	.	.	.
Urothoe brevicornis	.	.	.	.	.	.	161	.	.	.	.	.	.
Callianassa subterranea	.	70	.	.	.	.	.	.	.	.	.	.	.
Others													
Nemertinos undet.	80	.	124	57	.	65	201	62	187	127	249	137	183
Oligochaete undet.	117	.	126	.	.	.	679	.	.	.	.	.	.
Onchnesoma steentrupii	.	.	.	101	.	.	.	.	.	.	.	.	.

Table A11.6. Macroinfaunal total abundance (ind•m^{-2}) and biomass (g•m^{-2}) at each station by season (W: winter; S: spring; A: autumn).

	Total Abundance					Total Biomass				
	Ind·m^{-2}					g·m^{-2}				
Season	W02	S03	A03	S04	A04	W02	S03	A03	S04	A04
Station										
1	1897	1482	-	1384	-	-	-	-	5.54	-
2	1186	1257	-	1340	-	-	-	-	2.90	-
4	3601	3962	-	-	-	-	-	-	-	-
5	1955	1848	-	-	-	-	-	-	-	-
7	-	2362	838	3985	1105	-	1.08	1.55	8.77	1.56
8	1897	1734	1238	2711	1791	1.42	0.56	3.18	1.32	4.67
10	5052	4305	5048	3931	6687	2.20	2.95	3.58	3.96	2.52
11	3552	2877	1695	4483	2096	0.42	0.66	1.40	3.96	0.70
13	6104	8553	5886	6236	7582	1.73	1.63	7.82	3.58	1.86
14	2617	2496	2172	4204	2496	0.79	0.77	0.70	6.81	1.55
16	7875	7487	6877	5277	14878	2.77	2.57	4.43	4.05	2.49
17	2949	1772	2267	3677	1467	0.36	0.14	0.49	2.03	0.96
19	8230	6706	5220	4356	11220	5.66	2.53	5.12	4.67	4.63

Annex 12: Spatial and temporal changes in benthic communities of the Galician continental shelf after the *Prestige* oil spill

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Spatial and temporal changes in benthic communities of the Galician continental shelf after the *Prestige* oil spill

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Abstract

Two years after the *Prestige* oil spill (POS) an assessment of the effects on benthic fauna was carried out using the data obtained in five multidisciplinary surveys. Otter trawl, beam trawl, suprabenthic sled and box corer were used to study the main benthic compartments, along eight transects perpendicular to the coastline. Beam trawl was also employed to quantify the amount of tar aggregates on the continental shelf. No significant correlations between tar aggregates and species richness, biomass and diversity of benthic communities were found. 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 low influence on spatial distribution patterns. Depth and sediment grain diameter profoundly influence epibenthic communities. Sediment organic content is a third key variable for the infaunal, suprabenthic and lower-sized epibenthic communities, but not for the larger epibenthic communities. Nevertheless, a decrease in the densities of several epibenthic indicators was detected the first year after spill, followed by a noteworthy recovery in 2004. Non-macroscopic toxicity and some oceanographic agents are suggested as possible causes of these shifts.

Keywords: *Prestige* oil spill; Galician shelf; Tar aggregates; Benthic communities; Oil impact indicators; Canonical ordination

1. 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). This 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. This toxic component of sea snow may have been made up of degraded oil components and dead agglutinate planktonic organisms. Tar aggregates (with the *Prestige* chromatographic fingerprint according to analysis of 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 those 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). In the Baltic, following the *Tsesis* spill, trophic

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Annex 13: Monitoring the *Prestige* oil spill impacts on some key species of the Northern Iberian shelf

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Monitoring the *Prestige* oil spill impacts on some key species of the Northern Iberian shelf

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Abstract

Selected key components of the continental shelf benthic and demersal communities were monitored for the two years following the *Prestige* oil spill (POS) in order to identify the possible ecological effects of the oil. This work includes the first results regarding changes in abundance, distribution and food habits of hake (*Merluccius merluccius*), four-spot megrim (*Lepidorhombus boscii*), Norway lobster (*Nephrops norvegicus*) and Pandalid shrimp (*Plesionika heterocarpus*) populations of Galician and Cantabrian Sea shelves following the POS.

Significant reductions in the abundance of Norway lobster, *Plesionika heterocarpus* and four-spot megrim were detected in the POS maximum impact area, located over the Galician shelf. Noteworthy recoveries were observed in the 2004 abundance indices of four-spot megrim and *Plesionika*. On the other hand, no significant effects were detected in the abundance or distribution of hake juveniles even though the tar aggregates were bound by the same oceanographic drift events as the hake recruits were during the winter of 2003 (*Navidad* current) in different water column layers of the Cantabrian Sea. Feeding patterns of the four species analysed did not present apparent modifications that can be related to the POS.

Keywords: *Prestige* oil spill; Cantabrian Sea; Galicia; Food web; Hake; Four-spot megrim; Norway lobster; Pandalid shrimp; Tar aggregates

1. Introduction

The oil spill resulting from the accident of the oil tanker *Prestige*, initially during the towing operation (14–18 November 2002) and later during the breaking-up and sinking of the vessel 250 miles from the Galician coastline (19 November 2002), released about 50,000 tonnes of drifting heavy oil (type M-100) in an oceanic area and in the continental shelf waters off Northern Spain. In general terms, most of the surface of the northern Spanish shelf (Cantabrian Sea and Galician waters, ~30,000 km^2) was affected. This shelf includes unique habitats and communities, high biodiversity and species richness, and important fisheries (OSPAR, 2000; Sánchez and Olaso, 2004). During the first phase, the oil floated on the sea surface affecting organisms that inhabit the upper water layers (plankton, seabirds, etc.). Due to the rough winter weather conditions following the oil spill and the wave action, the oil might also have been mixed to a certain depth within the water column, where sensitive organisms may have been exposed and affected. Finally, a spill of this nature involves the deposition of oil in particulate and aggregate form on the sea floor, where it can also affect the benthic ecosystem. A particular characteristic of the *Prestige* oil spill (POS) is the large area and variety of habitats affected, covering tidal and subtidal levels to oceanic and bathyal habitats. The effects of oil spills on fisheries resources and marine communities have been well documented at tidal and subtidal levels (Dauvin, 1998; Gómez-Gesteira and Dauvin, 2000; Peterson et al., 2001, 2003), however scarce information is available on possible effects offshore, in deep shelf and bathyal communities.

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Annex 14: List of metrics (updated from SGSOBS 2004)

Univariate indices:

Shannon-Wiener Diversity Index

Shannon, C.E. and Weaver, W., 1949. The Mathematical Theory of Communication. The University of Illinois Press, Urbana, Illinois, USA, 115 pp.

Benthic Pollution Index (BPI)

Leppäkoski, E. 1975. Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackish-water environments. Acta Academiae Aboensis, Ser., B 35: 1–89.

Infauna Trophic Index (ITI)

Word, J. Q. 1979. The Infaunal Trophic Index. Sth Calif. Coast. Water Research Project. Annual Report, El Segundo, California. 19–39.

Word, J. Q. 1980. Classification of benthic invertebrates into Infaunal Trophic Index feeding groups. *In* Coastal Water Research Project Biennial Report 1979–1980, 103-121 pp. SCCWRP, Long Beach, California, USA,

ABC curves

Warwick, R. and Clarke, K.R. 1994. Relating the ABC: taxonomic changes and abundance/biomass relationship in disturbed benthic communities. Marine Biology, 118 (4): 739–744.

Annelid Index of Pollution

Bellan, G. 1980. Relationships of pollution to rocky substratum polychaetes on the French Mediterranean coast. Marine Pollution Bulletin, 11: 318–321.

Shannon Wiener Evenness Proportion Index

McManus, J.W., and Pauly, D., 1990. Measuring ecological stress: variations on a theme by R.M. Warwick. Marine Biology, 106: 305–308.

Taxonomic diversity index and Taxonomic distinctness

Warwick, R.M., and Clarke, K.R., 1995. New "biodiversity" measures reveal a decrease in taxonomic distinctness with increasing stress. Marine Ecology Progress Series, 129: 301–305.

Ecological Evaluation Index (EEI)

Orfanidis, S., Panayotidis, P., and Stamatis, N. 2001. Ecological evaluation of transitional and coastal waters: a marine benthic macrophytes-based model. Mediterranean Marine Science, 2: 45–65.

Hurlbert Index

Hurlbert, S. H. 1971. The non-concept of species diversity: A critique and alternative parameters. Ecology 52, 577–586.

Coastal Endofaunic Evaluation Index (I2EC)

Grall, J., and Glemarec, M. 2003. L'indice d'évaluation de l'endofaune côtiere. *In* Bioévaluation de la qualité environnementale des sediments portuaires et des zones d'immersion, pp. 51–85. Ed. by C. Alzieu (coord.). Ifremer.

Benthic opportunistic polychaetes amphipods index (BOPA)

Gomez Gesteira, L., and Dauvin, J. C. 2000. Amphipods are good bioindicators of te impact of opil spills on soft-bottom macrobenthic communities. Marine Pollution Bulletin 40: 1017–1027.

Dauvin, J. C. and Ruellet, T. 2007. Polychaete/amphipod ratio revisited. Marine Pollution Bulletin, 55: 215–224.

Several other simple univariate metrics are of common use e.g. species number, number of individuals, biomass.

Multimetric indices:

Pollution Coefficient

Satsmadjis, J. 1982. Analysis of benthic data and measurement of pollution. Revue internationale d'Océanographie Medicale, 66–67: 103–107.

Satsmadjis, J. 1985. Comparison of indicators of pollution in the Mediterranean. Marine Pollution Bulletin, 16: 395–400.

Biological Quality Index (BQI)

Jeffrey, D. W., Wilson, J. G., Harris, C. R., and Tomlinson, D.L. 1985. The application of two simple indices to Irish estuary pollution status. Estuarine management and quality assessment. Plenum Press, London. 147–165 pp.

Infauna Ratio-to-Reference of Sediment Quality Triad (RTR)

Chapman, P. M., Dexter, R. N. and Long. E. R. 1987. Synoptic measures of sediment contamination, toxicity and infauna community composition (the Sediment Quality Triad) in San Francisco Bay. Marine Ecology Progress Series, 37: 75–96.

Biotic Index

Majeed, S.A., 1987. Organic matter and biotic indices on the beaches of North Brittany. Marine Pollution Bulletin, 18: 490–495.

Grall, J., and Glémarec, M. 1997. Using biotic indices to estimate macrobenthic community perturbations in the bay of Brest. Estuarine, Coastal and Shelf Science, 44: 43–53.

Hily, C. 1984. Variabilité de la macrofaune benthique dans les milieux hypertrophiques de la Rade de Brest. Thèse de Doctorat d'Etat, Univ. Bretagne Occidentale. Vol. 1: 359 pp., Vol. 2: 337 pp.

Hily, C., Le Bris, H., and Glémarec, M. 1986. Impacts biologiques des émissaires urbains sur les écosystèmes benthiques. Oceanis, 12: 419–426.

Benthic Index of Estuarine Condition

Weisberg, S. B., Frithsen, J. B., Holland, A. F., Paul, J. F., Scott, K. J., Summers, J. K., Wilson H. T., Heimbuch, D. G., Gerritsen, J., Schimmel, S. C. and Latimer, R. W., 1993. Virginian Province Demonstration Project Report, EMAP-Estuaries, 1990. EPA/620/R-93/006, Office of Research and Development, USEPA, Washington, DC., USA.

Schimmel, S. C., Melzian, B. D., Campbell, D. E., Benyi, S. J., Rosen, J. S. and. Buffum, H. W. 1994. Statistical Summary: EMAP- Estuaries Virginian Province, 1991. Office of Research and Development, Environmental Research Laboratory, USEPA, Narragansett, Rhode Island, USA, 77 pp.

Strobel, C. J., Buffum, H. W., Benyi, S. J., Petrocelli, E. A., Reifsteck, D. R. and Keith, D. J. 1995. Statistical Summary. EMAP- Estuaries Virginian Province – 1990 to 1993.

National Health Environmental Effects Research Laboratory, Atlantic Ecology Division, USEPA, Narragansett, RI, USA, 72 pp.

Benthic condition Index (BCI)

Engle, V. D., Summers, J. K., and Gaston, G. R. 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. Estuaries, 17: 372–384.

Engle, V. D. and Summers, J.K. 1999. Refinement, validation and application of a benthic condition index for Northern Gulf of Mexico estuaries. Estuaries, 22: 624–635.

Paul, J.F., Scott, K. J., Campbell, D. E., Gentile, J. H., Strobel, C. S., Valente, R. M., Weisberg, S. B., Holland, A. F., and Ranasinghe, J.A. 2001. Developing and applying a benthic index of estuarine condition for the Virginian biogeographic province. Ecological Indicators, 1: 83–99.

Benthic Index of biotic integrity (B-IBI)

Ranasinghe, J.A., Weisberg, S.B., Dauer, D.M., Schaffner, L.C., Diaz, R.J. and Frithsen, J.B., 1994. Chesapeake Bay Benthic Community Restoration Goals. CBP/TRS 107/94, Chesapeake Bay program Office, USEPA, Annapolis, Maryland, USA, 49 pp.

Weisberg, S. B., Ranasinghe, J. A. 1997. An estuarine benthic index of biotic integrity (B-BY) for Chesapeake Bay. Estuaries, 20: 149–158.

Van Dolah, R. F., Hyland, J. L., Holland, A. F., Rosen, J. S., and Snoots, T. R. 1999. A benthic index of biological integrity for assessing habitat quality in estuaries of the southeastern USA. Marine Environmental Research, 48: 269–283.

Llansó, R. J., Scott, L. C., Dauer, D. M., Hyland, J. L., Russell, D. E. 2002. An estuarine benthic index of biotic integrity for the mid-Atlantic region of the United States. I. Classification of assemblages and habitat definition. Estuaries, 25: 1219–1230.

Llansó, R. J., Scott, L. C., Hyland, J. L., Dauer, D. M., Russell, D. E., and Kutz, F. W. 2002. An estuarine benthic index of biotic integrity for the mid-Atlantic region of the United States. II. Index development. Estuaries, 25: 1231–1242.

AMBI (AZTI Marine Biotic Index)

Borja, A., Franco, J., and Pérez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin, 40: 1100–1114.

Borja, A., Muxika, I., and Franco, J. 2003. The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. Marine Pollution Bulletin, 46: 835–845.

Borja, A., Franco, J., and Muxika, I. 2004. The Biotic Indices and the Water Framework Directive: the required consensus in the new benthic monitoring tools. Marine Pollution Bulletin, 48: 405–408.

Bentix

Simboura, N., and Zenetos, A. 2002. Benthic indicators to use in ecological quality classification of Mediterranean soft bottom marine ecosystems, including a new biotic index. Mediterranean Marine Science, 3: 77–111.

Ecofunctional Quality Index (EQI)

Fano, E.A., Mistri, M., and Rossi, R. 2003. The ecofunctional quality index (EQI): a new tool for assessing lagoonal ecosystem impairment. Estuarine, Coastal and Shelf Science, 56: 709–716.

Indicator Species Index

Rygg, B. 2002. Indicator species index for assessing benthic ecological quality in marine waters of Norway. Norwegian Institute for Water Research, Report N° 40114: 1–32.

Benthic Quality Index

Rosenberg, R., Blomqvist, M., Nilsson, H. C., Dimming, A., 2004. Marine quality assessment by use of benthic species-abundance distributions: a proposed new protocol within the European Union Water Framework Directive. Marine Pollution Bulletin 49 (9–10), 728–739.

DKI (Danske Kvalitet Indeks)

Borja, A., Josefson, A.B., Miles, A., Muxika, I., Olsgard, F., Phillips, G., Rodríguez, J.G., and Rygg, B. 2007. An approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. Marine Pollution Bulletin, 55: 42–52.

IQI (Infaunal Quality Index)

Prior, A., Miles, A. C., Sparrow, A. J., and Price, N. 2004. Development of a classification scheme for the marine benthic invertebrate component, Water Framework Directive. Phase I & II- Transitional and coastal waters. Environment Agency (UK), R&D Interim Technical Report, E1–116, E1–132: 103 p (+appendix).

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Miles, A. C., Phillips, G. R., Brooks, L. F, and Martina, L. J., in prep. The development of a Marine Infaunal Quality Index (IQI) for UK WFD assessment. Environment Agency (UK), R&D Technical Report.

NQI (Norwegian Quality Index)

Rygg, B. 2002. Indicator species index for assessing benthic ecological quality in marine waters of Norway. Norwegian Institute for Water Research, Report N° 40114: 1–32.

Rygg, B. 2006. Developing indices for quality-status classification of marine sort-bottom fauna in Norway. Norwegian Institute for Water Research, Report N° 5208: 1–32.

Borja, A., Josefson, A. B., Miles, A., Muxika, I., Olsgard, F., Phillips, G., Rodríguez, J. G., and Rygg, B. 2007. An approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. Marine Pollution Bulletin, 55: 42–52.

Multivariate and modelling approaches:

Several software packages can be used for multivariate and modelling approaches e.g. PRIMER, Canoco.

Benthic Response Index

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull and R.G. Velarde, 2001. Benthic response index for assessing infaunal communities on the southern California mainland shelf. Ecological Applications, 11: 1073–1087.

Estuarine Trophic status

Bricker, S. B., Ferreira, J. G., and Simas, T. 2003. An integrated methodology for assessment of estuarine trophic status. Ecological Modelling, 169: 39–60.

Principal Response Curves (PRC)

Pardal, M. A., Cardoso, P. G., Sousa, J. P., Marques, J. C. and Raffaelli, D. 2004. Assessing environmental quality: a novel approach. Marine Ecology Progress Series, 267: 1–8.

m-AMBI

Borja, A., Franco, J., Valencia, V., Bald, J., Muxika, I., Belzunce, M. J., and Solaun, O. 2004. Implementation of the European Water Framework Directive from the Basque Country (northern Spain): a methodological approach, Marine Pollution Bulletin, 48(3-4): 209–218.

Muxika, I., Borja, Á. and Bald, J. 2007. Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive, Marine Pollution Bulletin, 55: 16–29.

Annex 15: Different impact sources and geographical areas for which AMBI has been applied, in recent years

Table A15.1: Different impact sources and geographical areas for which AMBI has been applied, in recent years. Response: (+) when the AMBI responds to the pressure or impact gradient; (-) when it does not respond; (+/-) when there are examples of both or it is not conclusive. P.c.: personal communication.

IMPACT SOURCES	LOCATIONS (COUNTRIES)	SEAS	AUTHOR	RESPONSE
Eutrophication, sewage sludge disposal	(United Kingdom)	Atlantic	A. Miles in Borja *et al.* (2007)	+
Oil platforms	Norway	Atlantic	Flaten *et al* 2007	+/-
Outfall and harbour	Brittany (France)	Atlantic	Borja *et al.*, 2003a	+
Metal pollution	Adour (France)	Atlantic	Monperrus *et al.* 2005	+/-
Recovery of mudflats	Basque Country (Spain)	Atlantic	Aguirrezabalaga *et al.* 2004	+
Engineering works (dyke)	Basque Country (Spain)	Atlantic	Borja *et al.*, 2000, 2003a	+
Sewerage works	Basque Country (Spain)	Atlantic	Borja *et al.*, 2000, 2003a	+
Harbour construction	Basque Country (Spain)	Atlantic	Muxika *et al.*, 2005	+
Submarine outfall	Basque Country (Spain)	Atlantic	Borja *et al.*, 2000; 2003b	+
Anoxia-hypoxia, water treatment	Basque Country (Spain)	Atlantic	Borja *et al.*, 2006	+
Harbour and river inputs	Basque Country (Spain)	Atlantic	Muxika *et al.*, 2003	+
Various sources	Tejo estuary (Portugal)	Atlantic	M.J. Gaudencio (p.c., 2003)	+
Eutrophy	Mondego estuary (Portugal)	Atlantic	Salas *et al.*, 2004	+
Eutrophy	Mondego estuary (Portugal)	Atlantic	Chainho *et al.*, 2006	+
Organic and inorganic pollutants	Obidos lagoon (Portugal)	Atlantic	Carvalho *et al.* 2006a	+
Pond aquaculture	Ria Formosa lagoon (Portugal)	Atlantic	Carvalho *et al.* 2006b	+
Impact gradient (outfall?)	Portugal	Atlantic	Chenery and Mudge (2005)	+
Heavy metals	Huelva (Spain)	Atlantic	Borja *et al.*, 2003a	+
Estuarine inputs	Cádiz (Spain)	Atlantic	A. Rodríguez-Martín (p.c., 2003)	+
Various sources	(Morocco)	Atlantic	Bazairi *et al.* 2005	+
Various sources	Latvia	Baltic	V. Jermakovs (p.c., 2004)	+
Anoxia-hypoxia	Sweden	Baltic	Muxika *et al.*, 2005	+
Dredging mud disposal	Sweden	Baltic	S. Smith (p.c., 2003)	+/-
Various sources in a lagoon	Smir (Morocco)	Mediterranean	A. Chaouti (p.c., 2003)	+
Dredging in harbour	Ceuta (Spain)	Mediterranean	Muxika *et al.*, 2005	+
Diffuse pollution (mines, agriculture...)	Almería and Murcia (Spain)	Mediterranean	Borja *et al.*, 2003a	+
Mining debris	Mar Menor (Spain)	Mediterranean	Marín-Guirao *et al.* 2005	+/-
Recovery after aquaculture	Murcia (Spain)	Mediterranean	Sanz-Lázaro and Marín, 2006	+
Submarine outfall	Catalonia (Spain)	Mediterranean	M.J. Cardell (p.c., 2003)	+
Marina	Catalonia (Spain)	Mediterranean	S. Pinedo (p.c., 2003)	+
Various sources	Gula of Lions (France)	Mediterranean	Labrune *et al* 2006	+/-
Wastewater discharge in a lagoon	(France)	Mediterranean	G. Reimonenq (p.c., 2003)	+
Inputs to a coastal lagoon	Adriatic Sea (Italy)	Mediterranean	Caselli *et al.*, 2003	+
Inputs to a coastal lagoon	Pialassa Baiona (Italy)	Mediterranean	Ponti *et al.*, 2002; Ponti & Abiatti 2004	+
Various sources	Adriatic Sea (Italy)	Mediterranean	Forni and Occhipinti Ambroggi, 2004	+
Submarine outfall	Gulf of Trieste (Italy)	Mediterranean	Solis-Weiss *et al.*, 2004	+
Various sources	Adriatic Sea (Italy)	Mediterranean	R. Simonini (p.c., 2004)	+
Submarine outfall	Saronikos Gulf (Greece)	Mediterranean	Borja *et al.*, 2003a	+
Aquaculture cages	3 locations (Greece)	Mediterranean	Muxika *et al.*, 2005	+
River inputs	Thames (United Kingdom)	North Sea	M. Davison (p.c., 2002)	+
Undefined	German Bight (Germany)	North Sea	Reiss and Kroncke, 2005	+

Impact Sources	Locations (Countries)	Seas	Author	Response
Industrial and urban pollution	Seine estuary (France)	North Sea	Dauvin *et al.*, 2007	+/-
Oil-based drilling muds (oil platforms)	11 locations (United Kingdom)	North Sea	Muxika *et al.*, 2005	+
Ester-based drilling muds (oil platforms)	North Sea (Netherlands)	North Sea	Borja *et al.*, 2003a	+
Sand extraction	Belgium	North Sea	Bonne *et al.*, 2003; Muxika *et al.*, 2007	-

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Annex 16: Benthos ecological status assessment and monitoring for the Water Framework Directive in the Belgian coastal waters

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Macrobenthos habitat typology

The habitat typology of the Belgian continental shelf is based on macrobenthic communities and is in detailed described in Van Hoey *et al.* (2004). Four macrobenthic communities could be discerned with typical species associations in between. These communities were each characterized by different habitat specifications as briefly illustrated below.

Macrobenthic communities (habitats):

- *Abra alba* community: shallow muddy sand
- *Nephtys cirrosa* community: well-sorted mobile sands
- *Ophelia limacina – Glycera lapidum* community: medium to coarse sand
- *Macoma balthica* community: shallow sandy mud.

The macrobenthos status classification will be performed for these four communities separately, based on community-oriented monitoring, to come to an overall macrobenthos assessment for the Belgian coastal waters.

Assessment method

For the ecological quality assessment and the status classification of the benthos of the Belgian coastal waters the BEQI method has been applied and will be used for the future monitoring as well. The method (BEQI; Benthic ecosystem quality index), developed in the Netherlands (NIOO), is based on the approach developed by Ysebaert and Herman (2004), which aims to give an indication about ecosystem structure and functioning, and biological relationships. As explained in van Hoey *et al.* (2007a) and as explained in the ECOSTAT intercalibration report, this method differs from other methods developed by member states as it does not evaluate the ecological status sampling station by sampling station, but rather uses a set of indicators that take into account the different scales of variability in coastal and transitional waters and aims at evaluating the water body (ecosystem) as a whole. Briefly, on the level of the entire ecosystem (e.g. a water body) one can evaluate if the benthic macrofauna fulfils the functional role one might expect given the current ecological circumstances. At this level also integration with other quality measures is most appropriate, and information on the water body can be summarised. On the subsequent level the distribution of habitats (habitat completeness and complexity) can be evaluated. Finally the biological quality of each distinguished habitat based on benthic macrofauna can be evaluated (within-habitat level), with indicators that are sensitive to different types of stress and that can explain possible deviations. The BEQI-method on the third level evaluates the state of the benthos within a habitat based on 4 parameters (sub-indicators): number of species, density, biomass and species composition changes. These parameters reflect the normative definitions as defined by the WFD. The parameter results strongly depend on the sampling effort (sediment surface) that is deployed. Therefore, the reference values for the parameters were calculated per ecotope from permutations (KRW program, version 1.0 developed by Peter Herman in FORTRAN) executed over increased sampling surfaces. A minimum required sampling surface is defined for reference values specification and status assessment.

The overall indicator primarily aims at providing a signal that is capable of showing significant changes/deviations from a certain reference state.

Reference values and assessment

Level 1 of the BEQI method (macrobenthos' functional role of consumption of primary production)

Status of Belgian coastal macrobenthos: moderate (Van Damme *et al.*, 2006)

Level 3 of the BEQI method (van Hoey *et al.*, 2007b)

Too few data was available in the Belgian WFD benthos dataset to determine the reference conditions for the different habitats, this could only be done for the *Abra alba* community (minimal total sampling surface > 1 m^2). The reference values for the three other communities will have to be determined in future research on historical data or monitoring in the future. Since for the *Nephtys cirrosa* community sufficient assessment data were available but not enough reference data, an attempt of assessment has been made using the reference values for the Zeeuwse kust of the Netherlands, which yields also the same community.

For the *Abra alba* community the indicator density is evaluated as bad, due to the very low assessment density, whereas the number of species and similarity were evaluated as poor. The overall EcoQ score and status for the *Abra alba* community in the coastal zone is poor.

The Nephtys cirrosa community is evaluated as moderate, due to the poor status of the indicator similarity and moderate status for number of species. The density is evaluated as good.

Some further important issues and difficulties to be highlighted:

The Belgian reference data for the different habitats is gathered in the period 1994 – 2000 and comes not from a `natural, undisturbed` reference period, as required by the WFD. But this reference dataset has the aim to give a reflection of the spatial and temporal variability within the habitats.

Using the BEQI method, the changes in species richness, species composition and density have been evaluated. Assessment and reference biomass data was not available and therefore this indicator has not been evaluated for the Belgian coast.

The present assessment is not representative for the entire Belgian coast. The assessment dataset is originating from a small sub-area of the Belgian coast (nearby the harbor of Oostende). This site is strongly affected by the harbour of Oostende and beach restoration works, it can thus be expected that the communities are considerably negatively influenced. In the future, the monitoring will cover a wider spatial (entire coast) and temporal (few years) scale, to have a more acceptable assessment for the entire Belgian coast for all the communities.

Monitoring within the WFD

In order to make an appropriate assessment of the macrobenthos, representative for the entire coastal area, a surveillance monitoring will be performed in 2007–2008. Two times in a year the four communities will be sampled. This will be repeated when operational monitoring is considered necessary. For surveillance monitoring of those communities that are assessed to have a good or high status a frequency will be applied of two times a year every three years.

For the monitoring stations plan three zones are distinguished in the Belgian coastal waters. In each of these zones one station is located to sample nutrients, phytoplankton (chl a, Phaeocystis). These three stations are each located in a separate Bird Directive protected area and the two stations in the western and central zone are also located in a Habitat Directive protected area. For the benthos four communities will be monitored with a specific amount of samples per community spread over each of the three zones in order to give a spatially representative data set of each community per zone.

Investigative monitoring will be further defined in autumn 2007.

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Annex 17: Methods used in Europe, for the Water Framework Directive By Angel Borja (AZTI-Tecnalia, Spain)

The Water Framework Directive (WFD) establishes that the ecological status of surface water bodies must be assessed, by comparing monitoring data with reference conditions (from undisturbed areas) for each of the typologies.

When assessing the status of benthic communities, it must be taken into account the next structural parameters:

- The taxonomic composition and abundance
- The ratio of disturbance sensitive taxa to insensitive taxa (by means of some indices, such as AMBI, BQI, etc.)
- The level of diversity

In order to accomplish with these requirements, several methods have been applied through Europe. The metrics included in such methods can be seen in Annex 14.

Annex 18: Atlantic intercalibration

By Angel Borja (AZTI-Tecnalia, Spain)

The intercalibration was made for the coastal typology NEA-1, which is characterised by an exposed poly- to euhaline subtidal habitat, with soft sediment. We used data from pollution gradients and agreed intercalibration sites (in Good-High status), in order to have ecological assessments from Bad to High status. The impacted areas represent different pressures: sewage sludge dumping, submarine outfalls, etc., producing eutrophication, hypoxia, metal pollution, etc.

We obtained a data set of 708 samples from different locations: Belgium (132), Germany (64), Ireland (14), Spain (45), Denmark (72), United Kingdom (250), Norway (12), France, Portugal and Netherlands. We tested four methods: UK (and RoI), Denmark (both multimetric), Spain (factorial analysis: M-AMBI) and Norway (multimetric). Then, we have added methods from France, Portugal and Netherlands. Each country used their own reference conditions and ecological status boundaries. We made pairwise comparison, by linear regression; then four-by-four comparison and kappa analysis to determine agreement (all the methodologies and results can be seen in Borja *et al.*, 2007).

In general, the correlations between the methods are high and highly significant. After adjusting the previous boundaries for each of the ecological status, for each of the countries (see Table 2), the final agreement was very high (kappa >0.86). The final result shows an almost perfect agreement between the four studied methods (Table 3). Only between 3 and 12% of the sampling stations show disagreement between methods (this is when a method classifies a sample as High or Good status and the other as Moderate, Poor or Bad (Table 3).

Table A18.2. Final boundaries agreed between the member states, for NEA-1.

	DK	NL	UK/IR	SP/FR/PT	N
Moderate/Good	0.53	0.6	0.64	0.53	0.81
Good/High	0.67	0.8	0.75	0.77	0.92

Table A18.3. Final agreement, in terms of Kappa analysis and percentage of disagreement.

	DENMARK	UK	SPAIN	NORWAY
DENMARK		8.47%	5.51%	7.91%
UK	0.91 (almost perfect)		12.53%	3.11%
SPAIN	0.93 (almost perfect)	0.86 (almost perfect)		11.72%
NORWAY	0.91 (almost perfect)	0.96 (almost perfect)	0.87 (almost perfect)	

Monitoring in the Basque Country (North of Spain): an example

Although officially the monitoring for the WFD must start in 2006, in the case of the Basque Country it started in 1995. We sample annually, in winter, in 18 water bodies (14 transitional, and 4 coastal). In total we have 32 estuarine sampling stations and 19 coastal sampling stations.

Sampling is made by Box corer (0.06 m2) or Van Veen (0.07 m^2) grabs, both stainless steel. We take three replicates for benthos and one for sediment. The penetration must be at least 5 cm (depending on sediment) to consider it as correct. Then the sediment is sieved with 1 mm mesh size sieve. Biological samples are fixed in a buffered 4% formaldehyde solution (1 part 40 % formaldehyde solution and 9 parts sea water). For buffering we use sodium tetraborate (= Borax) in excess. Samples are stained with Rose Bengal.

In the laboratory, samples are sorted under a magnification lamp and stereomicroscope. After identification and counting, biomass (dry weight) is determined at 60ºC until constant weight (at least 24-48 h).

For sediments, grain size (φ-scale: silt/clay fraction < 63 µm, 125 µm, 250 µm, 500 µm, 1000 µm, 2000 µm) is determined by combining the Beckman-Coulter LS 13320 (laser diffraction) with aquatic suspension processing module (resolution 0.04–2,000 µm) (for small particle size) and sieving column (0.5 phi resolution) for higher grain size.

Organic matter is determined by weight loss on ignition (450 ºC, 24 h). Redox potential is measured in situ, using a ORION 977800 platinum electrode, connected to a digital pH-meter/milivoltimeter CRISON 501 (resolution ± 1 mV).

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Annex 19: Sieving comparison

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ORIGINAL ARTICLE

Sieving alive or after fixation: effects of sieving procedure on macrobenthic diversity, density and community structure

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Abstract Although combining datasets is often needed to unravel large-scale or long-term patterns in benthos ecology, this is frequently hampered by differences in technical design of the individual studies. One element that often vary among macrobenthic studies is the sieving procedure: sieving alive versus sieving after fixation. This study therefore aimed at the qualification and quantification of the impact of sieving procedure, using a 1 mm mesh sized sieve, at three levels of ecological organisation: (1) diversity, (2) species and taxon density, and (3) community structure. To include a maximum suite of macrobenthic species and to evaluate the community-specific effects, the impact of sieving procedure was investigated within four widely spread macrobenthos communities in the Belgian part of the North Sea. Sieving alive negatively impacted all tested diversity measures (S, N_1, N_2, N_∞, H′, ES_{100} and J′): community-dependent relative losses of up to 35% were observed. However, most trends were ambiguous and statistically non-significant. Community- and taxon-dependent impacts were detected at the level of density. Mainly polychaetes were found to be negatively impacted by sieving alive (relative losses maximum 81%): especially small, interstitial polychaetes (e.g. *Hesionura elongata* and *Spio filicornis*) tend to actively escape from the sieve (relative loss up to 100%). Next to size, also behaviour, the presence of head appendages, the depth of the sampling stations and sampling season are believed to influence the sieving procedure impact. While detailed community composition was impacted (ANOSIM dissimilarity: maximum 85%), no major impact on the differentiation between the investigated communities was detected. The present study thus demonstrated that combining data, retrieved with a different sieving procedure can be useful, but its reliability will mainly depend on the type of questions one wants to answer. In all cases caution at all levels of ecological organisation is advised.

Keywords Sieving procedure · Fixation · Macrozoobenthos

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Introduction

The technical design of soft-sediment macrozoobenthos studies can vary substantially, depending on study-specific objectives (Bilyard et al. 1987). Variations in the elements that constitute such a study design can influence the comparability of different data sets. Some elements that vary among studies and that have already been studied intensively are the sampling devices (Thorson 1957; Eleftheriou and Holme 1984; Bilyard et al. 1987; Long and Wang 1994), sample replication (McIntyre et al. 1984; Bilyard et al. 1987), sieve mesh size (Eleftheriou and Holme 1984; Bilyard et al. 1987; Ohwada 1988; Bachelet 1990; James et al. 1995; Gage et al. 2002; Thompson et al. 2003) and level of

Annex 20: NSBP CRR

Draft structure for Cooperative Research Report

1. Summary (H. Rees)

2. Introduction (H. Rees)

3. NSBP 2000 Data Management (E. Vanden Berghe)

3.1 Taxonomic problems

3.2. Sources of data

3.3 Database structure

3.4 Access to NSBP 2000 data

4. The North Sea environment

4.1 Synopsis and human influences (H. Rees)

4.2 Sediment particle size (H. Hillewaert)

4.3 Heavy metals in sediments (G. Irion)

5. Patterns and changes in the benthos (1986–2000)

5.1 Structure and characterising species of macro-zoobenthos communities in 2000 (E. Rachor, S. Degraer, G. Duineveld , H. Reiss)

5.2 Changes in community structure (1986–2000) and causal influences (I. Kröncke, H. Reiss)

5.3 Species distributions (R. Smith, J. Eggleton)

5.4 (Role of) biotic/diversity indices (G. Van Hoey, H. Rees, H. Reiss, J. Craeymeersch)

5.5 Predictive modelling (W. Willems, S. Degraer)

5.6 Parallel studies (M. Schratzberger, G. Duineveld)

5.7 Structuring species: a case study. (G. Van Hoey)

6. Ecosystem interactions (1986 – 2000)

6.1 Links between infauna, epifauna and fish distributions (H. Reiss)

6.2 Functional diversity (M. Lavaleye)

6.3 Fishing practices (J. Craeymeersch, M. Lavaleye, G. Duineveld, M. Bergman)

6.4 Benthic community studies over relevant time-scales (GD, JC, HeR, ER, SG/HH, HR)

7. Conclusions (H. Rees)

8. Recommendations (H. Rees)

9. Acknowledgements

10. References

Annex 1 Collaborative projects relevant to the assessment of benthic communities of the North Sea