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Report of the Study Group on Ecological Quality Objectives for Sensitive and for Opportunistic Benthos Species

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Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark
Telephone + 45 33 15 42 25 · Telefax +45 33 93 42 15
www.ices.dk · info@ices.dk

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1 Opening and Local Organisation

K. Essink welcomed the participants and shortly explained the reason for establishing the SGSOBS. Ms. D. Lindemann explained safety regulations in force in the ICES building. The participants are listed in Annex 1.

2 Appointment of Rapporteur

Alison Miles was appointed as Rapporteur.

3 Terms of Reference (TOR)

According to Council Resolution 2ACE02 the Terms of Reference for SGSOBS are:

a) in continuation of the development of EcoQ element (o) Density of sensitive (e.g., fragile) species and EcoQ element (p) Density of opportunistic species to [OSPAR 2004/1]:
    i) identify possible species, taking into account developments in implementing the Water Framework Directive;
    ii) commence development, for the species identified, and on the basis of the criteria for sound EcoQOs established by ICES in 2001, of related metrics, objectives and reference levels for this EcoQO;
b) for these EcoQ elements, to consider further the spatial scale requirements of sampling and the adequacy of existing monitoring activities to determine their status and trends, and provide further advice based on scenario considerations on the applications of possible EcoQOs;
c) where possible and appropriate, reconstruct the historic trajectory of the metric and determine its historic performance (hit, miss or false alarm) relative to the objective being measured, as a basis for deciding the relationship to management. This requires the collection of the relevant available historic data/information;
d) taking into account all potential sources of relevant information, determine what information it will be possible to collect in future to assess whether the EcoQO is being met (taking into account practicability and costs);
e) develop draft guidelines, including monitoring protocols and assessment methods, for evaluating the status of, and compliance with, the EcoQO.

SGSOBS will report by 1 April 2004 for the attention of ACE and the Marine Habitat Committee.

4 Adoption of Agenda

The draft-agenda was accepted without amendment (Annex 2).

K. Essink indicated that two subgroups would be formed to deal with the agenda items regarding (a) sensitive and (b) opportunistic species. At regular times progress of the subgroups would be discussed in plenary and agreed upon.

5 Review of previous work (OSPAR, BEWG, WGECO, etc.)

5.1 EcoQO concept (OSPAR)

K. Essink gave a short introduction to the EcoQO concept as developed by OSPAR. OSPAR has proposed the following set of issues for EcoQOs for the North Sea:

1. Reference points for commercial fish species
2. Threatened or declining species
3. Sea mammals
4. Sea birds
5. Fish communities
6. ***Benthic communities***
7. Plankton communities
8. Habitats
9. Nutrient budgets and production
10. Oxygen consumption

With respect to benthic communities the following EcoQ elements have been selected:

b. presence and extent of threatened and declining species [also non-benthos]
m. changes/kills in zoobenthos in relation to eutrophication
n. imposex in dogwhelk *Nucella lapillus*
o. density of sensitive (e.g., fragile) species
p. density of opportunistic species

When determining the metrics to be developed for the EcoQO elements (o) and (p), OSPAR suggests considering the following possibilities:

1. an index for opportunists or sensitivity
2. a metric based on the proportion of species that are opportunistic or sensitive
3. the density of selected indicator (sentinel) species

During development of EcoQOs, careful definition of notions is necessary. On OSPAR's request this was given a great deal of attention by the ICES WGECO (see under 5.3).

5.2 Relation to EU Water Framework Directive (WFD)

K. Essink referred to the contents of a document dealt with at the OSPAR BDC Meeting, Bruges, February 2004 (BDC 04/2/3-E(L)). This document presents a draft conceptual description of the system of ecological quality objectives. BDC is invited to agree a conceptual description based upon this document as part of the report on the North Sea pilot project of ecological quality objectives. The document contains the following relevant sections.

5.2.1 Background

BDC 2003 agreed that the Secretariat should develop a draft description of the conceptual framework for EcoQOs which sets out the way in which EcoQOs are intended to be applied, taking into account, *inter alia*, the advice provided by ICES and the background document on the development of EcoQOs.

5.2.2 Links to the EC Water Framework Directive (WFD)

The EC WFD establishes links to the ecosystem approach by adopting targets (subject to various qualifications) for coastal waters in terms of achieving "good surface water status" within 15 years. "Good surface water status" is defined in terms of "good ecological status", coupled with "good surface water chemical status". These in turn are to be defined in relation to a number of factors, which are to be assessed in relation to reference conditions representing the conditions to be expected in undisturbed water bodies, which in consequence are to be regarded as having "high ecological quality". The "ecological quality ratio", in which this assessment is summarised, is to reflect conditions representing only limited or slight anthropogenic disturbance.

The factors to be assessed for **coastal waters** cover:

biological quality elements:	phytoplankton, macroalgae and angiosperms, **benthic invertebrate fauna**
hydromorphological elements:	tidal regime, morphological conditions
physico-chemical elements:	general conditions (temperature, oxygenation, transparency, nutrient concentrations), specific synthetic pollutants, specific non-synthetic pollutants.

There is an obvious relationship between this approach and the EcoQO system. Many of the factors to be assessed for ecological quality are those covered by the EcoQO system. The most notable differences are:

a. the EcoQO system covers the higher levels of the ecosystem (top predators, in particular) much more than the EC WFD;

b. the EC WFD (being focused much more on waters linked closely to land, and therefore subject to human intervention in the physical shape of the environment) covers hydromorphological elements in a way that the EcoQO system does not.

5.2.3 Handling these linkages

How can the various approaches be fitted together?

In the first place, we need to recognise that the open sea will be different from coastal waters as defined for the EC WFD.

Secondly, it is probably possible to interpret the ultimate aims of the OSPAR strategies as seeking effectively the same state as that defined by the WFD as "high ecological status" – in other words, the ecological quality that can be recognised in areas undisturbed by human activities.

Thirdly, it is probably possible to interpret the ecological quality that would result from achieving the EcoQOs as being in line with the "good ecological status" which the WFD sets as the goal for coastal waters in general. In other words, the status that the EcoQOs seek is one where human interference has been reduced to levels consistent with a healthy ecosystem which shows the distinguishing structures and functions of the ecosystems historically present before, say, 1850.

This equation of EcoQOs and "good ecological status" is not beyond argument, but some such equation is needed if the two systems are to be operated in parallel.

In Appendix 1 of the BDC document the following is stated with respect to sensitive (e.g., fragile) and to opportunistic species:

Within benthic communities, the density of sensitive and of opportunistic species is considered relevant to the human activity "Placement of cables and pipelines". This is because low density of the former (i.e. sensitive species), or high density of the latter (i.e. opportunistic species), would suggest that the balance between location and protection policy is not correct.

K. Essink commented that the Study Group should consider also pressures other than the "Placement of cables and pipelines", e.g., sediment disturbance by bottom trawling, extraction of sand and gravel, and not forget the importance of natural disturbances for which no protection policy seems to be appropriate.

5.3 Work done by ICES

K. Essink provided the following overview of earlier work done within ICES.

5.3.1 BEWG and WGECO

The matter of development of EcoQOs for the EcoQ elements (o) density of sensitive (e.g., fragile) benthos species, and (p) density of opportunistic benthos species was taken up by the Benthos Ecology Working Group [BEWG] in their meetings in 2002 (Tromsø, Norway) and 2003 (Fort Pearce, FL, USA) as well as by the Working Group on Ecosystem Effects of Fishing Activities [WGECO] in their meetings in 2002 and 2003.

5.3.2. Advisory Committee on Ecosystems (ACE)

All work done within ICES is summarised in the 2003 ACE Report (pp. 40–50). With respect to the EcoQ elements (o) and (p)

- A total of 180 taxa were identified as meeting the criteria for sensitive species. This includes biogenic structure-forming species as well as species with fragile morphological features;

- A total of 69 taxa were identified as meeting the criteria for opportunists. This includes opportunistic scavengers.

These lists are inevitably incomplete. (See for provisional lists: 2003 WGECO Report.)

It was concluded by ACE that monitoring of changes in abundance of these taxa presents many practical constraints. Moreover, the present benthos sampling schemes in the North Sea are largely inadequate to detect species-specific trends in abundance on the spatial scale required.

ICES considered five alternative approaches for developing the EcoQ elements (see WGECO Report 2003), ranging from (i) direct measurement of the absolute abundance of each sensitive (fragile) and opportunistic species, to (iv) an assessment of the density of a selection of indicator (sentinel) species. The latter option may be the most promising, i.e., to effectively monitor the abundance of a few indicator (sentinel) species. This may provide a warning system to trigger further action. However, the monitoring and cost implications of this approach still need to be considered in detail. There is also a need to develop robust and objective criteria for the selection of the sentinel species.

ICES believes that further development of EcoQOs for benthic systems should be done in two ways:

- through a focus on habitat quality;
- through the development of EcoQOs targeted at specific issues.

5.3.3 Definitions

For the sake of quality of ICES advice, it is important to start working from well-formulated definitions. These were already developed at an early stage (TemaNord, 1999):

Ecological Quality (EcoQ):

The EcoQ of surface water is an overall expression of the structure and function of the aquatic systems, taking into account the biological community and natural physiographic and climatic factors as well as physical and chemical conditions including those resulting from human activities.

Ecological Quality Objective (EcoQO):

EcoQO is the desired level of EcoQ relative to the EcoQ reference level.

Ecological Quality Reference Level:

EcoQ reference level is the level of EcoQ where anthropogenic influence on the ecological system is minimal.

K. Essink recommended that the Study Group keep these definitions well in mind, and, if necessary, provide further refinement of the definitions.

5.4 References

ICES, 2002 - 2002 BEWG Report
ICES, 2002a - 2002 WGECO Report
ICES, 2003 - 2003 BEWG Report
ICES, 2003a - 2003 WGECO Report
OSPAR, 2004 - BDC Meeting, Bruges, February 2004 (document BDC 04/2/3-E(L)
TemaNord, 1999 – Workshop on Ecological Quality Objectives (EcoQOs) for the North Sea, Scheveningen, The Netherlands, 1–3 September 1999. Nordic Council Of Ministers, TemaNord 1999: 591, 75 pp.

6 Reports on related (Inter)national work

6.1 Marine quality assessment by use of benthic species-abundance distributions

M. Blomqvist and H. Cederwall gave a Power Point presentation of results of a project on assessment of the ecological status in Swedish coastal waters using soft-bottom macrofauna. Diversity indices ES50 (ES50 = expected number of species among 50 individuals) were calculated according to Hurlbert (1971). Sensitive species were found to occur mainly in undisturbed environments, i.e., at stations with high ES50 values. Low ES50 values indicate disturbed environments, inhabited by tolerant species.

Application of ES50 along the west coast of Sweden gave good results. Application on the east coast, however, is not without problems due to the natural low macrozoobenthos diversity in the brackish Baltic Sea.

For the assessment of the environmental quality ,a new benthic quality index (BQI) is proposed, using tolerance values for individual species and abundance data within the community. An extended summary is given in Annex 3.

6.2 Identification of Marine Indicator Species from time series and other studies

K. Hiscock reported on a study undertaken together with O. Langmead and R. Warwick for the Joint Nature Conservation Committee (JNCC) in 2003 that was initiated following a recommendation in a review of time-series studies in Britain and near-Europe (Hiscock and Kimmance , 2003 – see url below). That recommendation indicated that some of the species that had shown change in abundance or presence in relation to change in environmental conditions might be identified as indicator species and that key references should be re-inspected to identify those species. In discussion with potential collaborators and with JNCC and Environment Agency (EA) staff, it was determined that much potential information in the literature would be likely to come from other sources as well as time-series studies. A programme of work was identified and is currently (late March 2004) being undertaken:

Phase 1: Identification of data sources

The following sources of information were used:

- JNCC Time-series study (http://www.marlin.ac.uk/time_series_metadata)
- Pollution studies (accessed through the National Marine Biological Library)
- Marine Life Information Network (*MarLIN*) sensitivity reviews (http://www.marlin.ac.uk)
- Expert opinion

Phase 2: Data logging and interpretation

The following records were made:

- Species identified in reports as indicators
- Species demonstrated to change significantly in relation to an activity

Information was recorded in a spreadsheet according to:

- Human activity (from *MarLIN*)
- Habitat (EUNIS classification – see: (http://mrw.wallonie.be/cgi/dgrne/sibw/eunis.des.X1X.pl?CODE=A)

Species were evaluated according to "*indicator criteria*" and confidence was assigned (depending on number of publications featuring that species).

Results

Work is in progress and examples only are shown below.

Review of library information - an example:

Activity: Commercial fishing – trawling (beam and otter)

Habitat: Sublittoral sand and muddy sand (EUNIS A4.2)

Table 6.2.1**.** Species that decrease in abundance

Species	Phylum: Class	Conf.	Sources
Echinocardium cordatum	Echinodermata: Echinoidea	3	Bergman & Hup (1992); Lindeboom & de Groot (1998); MacDonald et al. (1996)
Amphiura filiformis	Echinodermata: Ophiuroidea	2	Rumohr & Kujawski (2000); Lindeboom & de Groot (1998)
Arctica islandica	Mollusca: Pelecypoda	2	Rumohr & Kujawski (2000); Craeymeersch et al. (2000)
Aphrodita aculeata	Annelida: Polychaeta	1	Kaiser et al. (1998)
Nephtys spp.	Annelida: Polychaeta	1	Kaiser et al. (1998)
Lanice conchilega	Annelida: Polychaeta	1	Bergman & Hup (1992)
Spiophanes bombyx	Annelida: Polychaeta	1	Bergman & Hup (1992)
Magelona pappillicornis	Annelida: Polychaeta	1	Bergman & Hup (1992)
Pectinaria spp.	Annelida: Polychaeta	1	Lindeboom & de Groot (1998)
Enipo kinbergi	Annelida: Polychaeta	1	Lindeboom & de Groot (1998)
Lagis Koreni	Annelida: Polychaeta	1	Kaiser & Spencer (1996)
Urothoe spp.	Crustacea: Eumalacostraca	1	Kaiser & Spencer (1996)
Ampelisca brevicornis	Crustacea: Eumalacostraca	1	Craemeersch et al. (2000)
Ampelisca spp.	Crustacea: Eumalacostraca	1	Kaiser & Spencer (1996)
Callianassa subterranea	Crustacea: Eumalacostraca	1	Lindeboom & de Groot (1998)
Upogebia spp.	Crustacea: Eumalacostraca	1	Lindeboom & de Groot (1998)
Corystes cassivelaunus	Crustacea: Eumalacostraca	1	MacDonald et al. (1996)
Asterias rubens	Echinodermata: Asteroidea	1	Bergman & Hup (1992)
Echinocyamus pusillus	Echinodermata: Echinoidea	1	Rumohr & Kujawski (2000)
Trachythyone elongata	Echinodermata: Holothuriodae	1	Lindeboom & de Groot (1998)
Leptosynapta inhaerens	Echinodermata: Holothuriodae	1	Lindeboom & de Groot (1998)
Ophiura ophiura	Echinodermata: Ophiuroidea	1	Rumohr & Kujawski (2000)
Cylichna cylindracea	Mollusca: Gastropoda	1	Lindeboom & de Groot (1998)
Cingula vitrea	Mollusca: Gastropoda	1	Lindeboom & de Groot (1998)
Ensis spp.	Mollusca: Gastropoda	1	MacDonald et al. (1996)
Spisula solida	Mollusca: Pelecypoda	1	Rumohr & Kujawski (2000)
Nucula tenuis	Mollusca: Pelecypoda	1	Rumohr & Kujawski (2000)
Phaxas pellucidus	Mollusca: Pelecypoda	1	Rumohr & Kujawski (2000)
Nucula nitidosa	Mollusca: Pelecypoda	1	Rumohr & Kujawski (2000)
Fabulina (Tellina) fabula	Mollusca: Pelecypoda	1	Bergman & Hup (1992)
Telimya ferruginosa	Mollusca: Pelecypoda	1	Lindeboom & de Groot (1998)
Mysella bidentata	Mollusca: Pelecypoda	1	Lindeboom & de Groot (1998)
Thyasira flexuosa	Mollusca: Pelecypoda	1	Lindeboom & de Groot (1998)

Table 6.2.2. Species that increase in abundance

Species	Phylum: Class	Conf.	Sources
Ophelina accuminata	Annalida: Polychaeta	1	Lindeboom & de Groot (1998)
Spiophanes bombyx	Annalida: Polychaeta	1	Lindeboom & de Groot (1998)
Spio filicornis	Annalida: Polychaeta	1	Lindeboom & de Groot (1998)
Urothoe brevicornis	Crustacea: Amphipoda	1	Craeymeersch et al. (2000)
Urothoe poseidonis	Crustacea: Amphipoda	1	Craeymeersch et al. (2000)
Liocarcinus holsatus	Crustacea: Eumalacostraca	1	Rumohr & Kujawski (2000)
Hyas coarctus	Crustacea: Eumalacostraca	1	Rumohr & Kujawski (2000)
Corystes cassivelaunus	Crustacea: Eumalacostraca	1	Rumohr & Kujawski (2000)
Atylus swammerdami	Crustacea: Eumalacostraca	1	Craeymeersch et al. (2000)
Pagurus bernhardus	Crustacea: Eumalacostraca	1	Kaiser et al. (1998)
Pseudocuma longicornis	Crustacea: Malacostraca	1	Craeymeersch et al. (2000)
Psammechinus miliaris	Echinodermata: Echinoidea	1	Rumohr & Kujawski (2000)
Echinocardium cordatum	Echinodermata: Echinoidea	1	Rumohr & Kujawski (2000)
Ophiura albida	Echinodermata: Ophiuroidea	1	Rumohr & Kujawski (2000)
Ophiura spp. Juveniles	Echinodermata: Ophiuroidea	1	Lindeboom & de Groot (1998)
Buccinum undatum	Mollusca: Gastropoda	1	Rumohr & Kujawski (2000)
Phoronis spp.	Pseudocoelomata: Phoronida	1	Lindeboom & de Groot (1998)

Shading indicates ambiguous taxa that appear on both lists. “Confidence” is the number of references naming that species.

Interrogation of the MarLIN database

The *MarLIN* Microsoft Access database was queried to identify species that had a High (H) or Intermediate (I) intolerance to different factors (stressors). An example of output is shown below:

Table XX

	EA 'Exposure pressure'													
	[None]	Suspended sediment		Increased turbidity	[None]	Priority substances			Nitrate / Phosphate	Salinity		Oxygen concentrati	Thermal range/heat	
	Equivalent *MarLIN* environmental factor													
Species	Smothering	Increased suspended sediment	Decreased suspended sediment	Increased turbidity	Physical disturbance	Synthetic chemicals	Heavy metals	Hydrocarbons	Changes in nutrients	Increased salinity	Decreased Salinity	Deoxygenation	Increased temperature	Decreased temperature
Abra alba					I	H	I				I			I
Ahnfeltia plicata	I	I		I	I	H		H	I					
Alaria esculenta	I	I			I	I	I		I	H			H	
Alcyonium digitatum	I				I	I				I		H		
Alkmaria romijni	I				I									
Amphianthus dohrnii					H					I		I	I	
Amphiura chiajei								H			H			I
Amphiura filiformis						H	I	H		H				
Antedon bifida	H				H	H	I	H		H	H	I	I	
Aphelochaeta marioni					I	H			I					
Aphrodita aculeata					I					H	H			
Arctica islandica	I				I	H	I	I			I			
Arenicola marina					I	H		I	I				I	
Armandia cirrhosa					I					H				
Ascidiella scabra					H	I					I			
Ascophyllum nodosum	H				H	I			I					
Asterias rubens					I	I	I	H		H		H	H	
Atrina fragilis	I				H								I	
Axinella dissimilis	I	I			I					H		I	I	
Balanus crenatus	H				I	H	I		I			H	H	

The *MarLIN* approach to assessing intolerance, recoverability and sensitivity together with glossaries and scales is on: http://www.marlin.ac.uk/glossaries/combi_sens_ass_rat.htm.

There are difficulties in using the literature review approach:

- Requirement to know a lot about species distribution patterns (i.e., rare or common, clumped or evenly dispersed, boreal or Lusitanian) to ensure they comply with characteristics of a good indicator.
- Highly sensitive species rapidly disappear and thus do not indicate LEVELS of an activity (e.g., *Ampelisca* and hydrocarbon contamination).
- Opportunistic species can occur at high abundance levels in response to many different activities. These are symptomatic of community disruption but cannot be classified as a response to any particular activity (e.g., *Capitella capitata* complex).
- Multiple interacting stressors may complicate patterns of benthic responses; causal agents are difficult to attribute to community change in many long-term studies, e.g., estuaries with long histories of waste disposal.

Overall, the project is identifying intolerance and sensitivity for a wide range of species. The project will report by the end of April 2004.

6.3 Sensitive and opportunistic species relationships and the AZTI Marine Biotic Index (AMBI)

A. Borja explained that there are several advantages in using soft-bottom benthic communities as disturbance indicators, such as: (i) they represent the real effect on the biota (from species to the community level); (ii) they are a global indicator of pollution or disturbance; (iii) they offer integrated information throughout time; (iv) they have short life-cycle species and fast recovery after disturbance (hence, they are good change indicators); and (v) they are easily-worked elements.

In recent years, several benthic biotic indices have been proposed for use in estuarine and coastal waters in order to determine the natural and man-induced impacts. One of them, named AMBI (AZTI Marine Biotic Index), was created by Borja *et al.* (2000) and has been applied to different European geographical areas, experiencing various human impacts (Borja *et al.*, 2003a). The AMBI offers a "pollution classification" of a particular site, representing the benthic community "health" (*sensu* Grall and Glémarec, 1997). The theoretical basis of AMBI is that of the ecological adaptive strategies of the *r*-, *k*-, and *T*-selected species (McArthur and Wilson, 1967; Pianka, 1970; Gray, 1979) and the progressive steps in stressed environments (Bellan, 1967; Pearson and Rosenberg, 1978).

Species should be classified into five ecological groups, based upon sensitivity/tolerance to pollution (or disturbance): (i) Group I: very sensitive; (ii) Group II: indifferent; (iii) Group III: tolerant; (iv) Group IV: Second order opportunistic; and (v) Group V: First order opportunistic. A formula (see Borja *et al.*, 2000) permits the derivation of a series of continuous values, based upon the proportions of the five ecological groups amongst the species composing the benthic community.

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

The most recent impacts checked were (Muxika *et al.*, submitted): (i) relationships with anoxic processes in Sweden; (ii) a good gradient shown in oil-based mud drilling impact, in the North Sea (with a high significant correlation with total hydrocarbons); and (iii) harbour dredging impact.

The AMBI is very easy to use, having freely-available software, including a continuously updated species list, incorporating more than 2,700 taxa (http://www.azti.es/ingles). Even with these advantages, some problems have been identified by users of the AMBI as a "tool" for detecting and evaluating impacts (see Borja *et al.*, 2004b).

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

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6.4 Using indicator species to assess the state of macrobenthic communities

S. Birchenough reported on work done together with C. Frid at the Dove Marine Laboratory, University of Newcastle-upon-Tyne (Bustos-Báez and Frid, 2003). She stated that environmental impact assessments are often followed by the continuous monitoring needed to determine community change. This long-term monitoring can be time-consuming and expensive. The concept of indicator species attempts to use their presence in a sample or area to characterise a certain degree of community change or pollution effects. This approach has been widely applied to benthic monitoring studies. However, many studies develop their own list of "indicators" in cases without having a prior knowledge of the area or any long-term data. This can result in the production of circular arguments.

A meta-analysis was carried out on data sets from five of the twenty designated United Kingdom sewage sludge dumping grounds and the data set from the classic study of Pearson and Rosenberg (1978). A number of indices were constructed to examine the robustness of the latter study across these UK studies. After having refined criteria for "indicator taxa", the spatial and temporal changes in macrobenthic communities occurring at the Tyne sewage sludge dumpsite were examined to test the utility of this approach. Of the total pool of 123 taxa, 81 taxa responded in one study only, while *Spio filicornis* (O. F. Müller), *Spiophanes bombyx* (Claparède), *Lagis koreni* (Malmgren) and *Nephtys cirrosa* (Ehlers) showed directly contradictory patterns in different locations. The Spearman's rank correlation test showed a significant negative relationship between the density of macro-litter per station found at the Tyne dumping ground and the abundance of *Abra alba* (Wood) (r_S=0.462, n= 6, P=0.1) and *Amphiura filiformis* (O. F. Müller) (r_S=0.493, n= 6, P=0.1). These were the only indicator taxa, which showed a strong relationship to sewage contamination. It was therefore concluded that while the concept of indicators may be widely applicable, the actual indicator taxa are not. This demonstrates that the use of indicators must be continually developed providing prior information of the study area.

References

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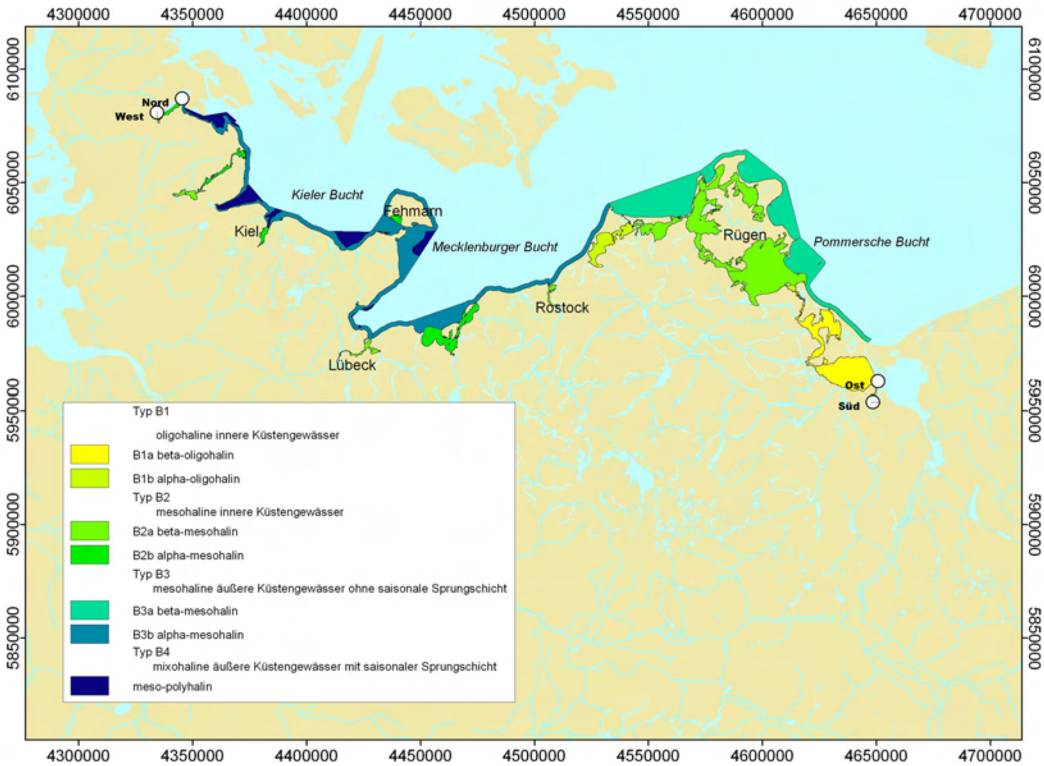
6.5 Valuation of marine habitats and species in the southern Baltic Sea

F. Gosselck gave a short account of experiences in the German part of the Baltic Sea. The waters in this area are characterised by a high temporal and spatial variation in salinity. This variability results from the geographical position of the Baltic, an area of exchange between the brackish water of the Baltic, inflowing saltwater of the North Sea, and the runoff of freshwater from land, which all depend on weather conditions.

The gradient of salinity decreases from west to east, dividing the German part of the Baltic in the western Belt Sea (<15 PSU) and the Baltic Proper east of the Darss sill (<8 PSU). In the deeper parts of the Baltic Sea (> 10m), the water column is stratified. In the implementation of the Water Framework Directive and the Habitat Directive of the EC, we have to concentrate on the shallow coastal areas.

In the Baltic Sea, the composition of fauna and flora is determined mainly by salinity. Because of the high variability of salinity, the habitats of the Baltic Sea are dominated by marine-euryhaline, typical brackish or freshwater species.

Using Multi Dimensional Scaling (PRIMER package), we can show that the benthic communities in the German part of the Baltic can be distinguished by the salinity of the overlying water body (see figure). Salinity is the main natural stressor. Since the salinity depends on weather conditions, it is highly variable and the benthic species occurring there are adapted to changing abiotic conditions. The species are mainly euryoecous (opportunistic) with rapid growth and a short life time. There are no sensitive species (k-strategists) in the shallow coastal waters. Therefore, the common metrics which are based on the proportion of "k"- and "r"-strategists cannot be used. As a consequence, a special assessment method for the brackish water conditions has to be developed. If there are no effects on the composition of species as the result of the eutrophication, we have to calculate the changes of the abundance and biomass.



In the German part of the Baltic coast, anthropogenic stressors are mainly related to eutrophication and to deepening of some river mouths. Heavy metal contamination is restricted to a few points near shipyards (see table below).

Man-made changes since 1900	**Environmental changes**	**Effects on benthos in the coastal waters of the Baltic Sea**
Building of channels, increasing of shipping traffic		Migration of alien species
Deepening and straightening of estuaries	Increased salinity, Increased exposition	Migration of marine-euryhaline species to the inner coastal waters
Increasing nutrients (agriculture, communal, industrial) Other contaminants	Eutrophication	Increasing productivity: decreasing belt of submersed plants, increasing biomass of zoobenthos, fishes, waterbirds, oxygen depletion, drifting algae...
Coastal protection, Other buildings on the shoreline	Loss of shallow water areas, increase of terrigenous particles, sedimentation	Decreasing belt of submersed plants, effects on filter feeders

6.6 Evaluation of the effects of dredging disposal on the macrobenthos of the Belgian Continental Shelf

I. Moulaert reported on studies done together with H. Hillewaert.

For the different dredging disposal sites as well as for some reference points on the Belgian Continental Shelf, long-term data series are available (1980–2003). To determine which reference points would be best to compare with the main disposal sites, sediment composition was considered. The sediment composition of the main disposal areas and the reference areas has been relatively stable in the last 15–20 years. The sediment composition of the main disposal areas S1 and S2 is comparable with the sediment composition of reference station Westdiep (median grain size: ± 200 µm; silt fraction: ± 5 %).

Although the long-term data series have to be interpreted with caution, no trends in number of taxa, abundance or diversity could be detected that are directly related to any disposal, as changes and trends that were found for the disposal areas can also be found in reference stations on the Belgian Continental Shelf. Because no data are available from before the start of disposal, it is difficult to (1) distinguish the effects of disposal from the natural variation and other disturbances, (2) identify species that are sensitive or species that are opportunistic to the direct effect of disposal.

6.7 Effects of sand extraction on the macrobenthos in extraction-zone II of the Belgian Continental Shelf

I. Moulaert reported on work done together with B. Maertens and H. Hillewaert.

Two specific zones on the Belgian Continental Shelf are reserved for sand extraction. Black-box data, showing the exact location of the sand hoppers during actual extraction, indicate that the bulk of the sand extraction activity in zone II is located on the Kwintebank. A study was undertaken to evaluate the overall condition in zone II, with emphasis on the peculiar situation on the Kwintebank (station Zg1) based on macrobenthos and sediment composition data. In 1996 a monitoring programme, with four sampling stations, was set up in extraction zone II based on black-box data. The number of species, density, and Shannon-Wiener diversity of the macrobenthos are calculated as well as the proportion of the different sediment fractions, the median grain size, and the amount of interstitial water.

Station Zg2 (where sand extraction is at a low level) and station Zg1 have the lowest number of ind/m². The reference area and the station Zg3 and Zg4, located on the Kwintebank, have a substantially higher abundance (up to 3500 ind/m²). The coarser sand locations, Zg1 and Zg2, also have a lower number of species: respectively, 12 to 20 and 2 to 13. At the other stations, up to 40 different species are found. Data are subjected to a cluster analysis and ordination and every time, the same stations grouped together: Zg1-Zg2 and Zg3-Zg4. The two-way indicator species analysis also splits the samples up in the same groups.

Station Zg1 is located in a zone of intensive extraction activity. When looking at the major taxa of this station, the macrobenthic composition shows no temporal trends. For this station, a significant decrease in the amount of species is found, whereas the decreases in abundance and diversity are not significant at a confidence level of 95%. To try to explain the decrease in number of species, the different sediment fractions have also been analysed. A significant increase of the 500–1000 µm fraction and an almost significant increase of the 250–500 µm fraction has been found, whereas the 125–250 µm fraction shows a significant decrease. This increase of the coarser sediment fractions may be an effect of the sand extraction. No significant temporal trends were detected for any of the other stations.

Effects strongly depend on the volume and the intensity of extraction. Stations that are not located near any zone of disturbance or are located in a zone with low dredging intensity do not show any effects. Stations in a zone of intensive activity show changes in sediment and also in the macrobenthos. The relationship between sand extraction activity and changes in sediment composition and macrobenthos is unclear because (1) there are no data available from these sampling points from before the extraction activities started, (2) the exact fractions that are extracted are unknown, and (3) the area is subjected to many different influences.

6.8 Thermal pollution and benthos

K. Mo gave a short review of results from benthos monitoring in relation to the impact from cooling water discharge from a nuclear power plant in the southern Bothnian Bay, Sweden.

The water from the power plant is discharged into a shallow semi-enclosed basin, with an area of about 1 km^2 and a depth of 5 m, before it flows out to the open sea. The water in the basin is about 10 degrees C warmer than the intake-water.

Before the power plant started, the benthic fauna in the basin was dominated by *Macoma balthica* and *Gammarus* spp. After the power-plant started in 1980, *Macoma balthica* and *Gammarus* spp. decreased, while *Potamopyrgus antipodarum* and *Corophium volutator* increased in abundance. The fauna was characterised by large variations between sampling occasions.

The decrease in *M. balthica* was probably a direct effect of the heated water. For about ten years, small individuals (spat) of *M. balthica* were found in every late autumn, but they never grew to become adults. These young individuals have not appeared at all in the period 1990–2003.

During 1980–1990 *C. volutator* was benefiting from the heated water, showing increased abundances. Probably they could reproduce more often in a season than before. In the last five years, however, *C. volutator* had disappeared completely from the samples, due to unclear reasons. The fauna in the basin is now poor, with no crustaceans, and consists almost only of the gastropod *P. antipodarum* (>90 %). This gastropod can reproduce very rapidly and at any time of the year, since it is a viviparous autogamous hermaphrodite. Only in the summer, are some specimens of *Chironomidae* and *Oligochaeta* also present.

The investigation shows the importance of long time series. Effects or secondary effects of an impact can appear after a long time.

7 EcoQ element (o): Density of sensitive (e.g., fragile) benthos species [ToR: a]

After some discussion and clarification, the definition of sensitivity provided as a part of the "Texel/Faial criteria for the identification of species and habitats in need of protection" (developed by OSPAR) was adopted.

> *Sensitive species – A species easily depleted by human activity and when affected is expected to recover over a long period or not at all.*

As such the term "sensitivity" takes into account both the tolerance to and the time needed for recovery (largely species dependent) from the stressor. Fragile species are considered to be especially susceptible to physical/mechanical disturbance.

Sensitive species will usually be k-strategists, with a long life-cycle (> 1 year), large size, slow growth, and late sexual maturity. Sensitive species may act as key structural species for the community, with their loss creating cascading effects on the community. Providing that no natural stress acts on the area (e.g., salinity), sensitive species, representing the full range of age classes, may be present in the benthic community. These species will be those that are initially "lost" as a result of a stressor acting on the community. The species will remain absent for as long as the stressor remains, or for the time required for the recovery of the species.

The decrease of sensitive species, within an area, is an initial "signal" of the negative influence of a stressor. The precise nature of the acting stressor should be identified before proper management actions can be decided upon.

7.1 Identification of species sensitive to stressors [ToR: a]

The provisional list of 22 sensitive species included in the 2003 report of the WG on Ecosystem Effects of Fishing Activities (WGECO) was considered to inadequately reflect the range of species that could be identified as sensitive according to the Texel/Faial definition. Several of the initiatives drawn attention to during the current meeting provided a more promising list of sensitive species in relation to a range of factors (stressors). The initiatives are:

- AZTI Marine Biotic Index (AMBI) which identifies sensitive, indifferent, tolerant, second order, and first order opportunistic species from analysis of a wide range of survey data in areas affected by different stressors.
- Swedish Tolerance values ($ESO_{0.05}$) which are derived from survey data from the whole Swedish coast indicate the richness of the communities in which a species is found (only non-rare species included).
- *MarLIN* database which includes indices of tolerance and recoverability from which sensitivity is identified. The indices are assigned following review of literature sources.
- Marine Biological Association of the UK review of literature identifying species that respond to stressors.

An exercise was undertaken during the meeting to combine information from the first three of the above listed sources to identify intolerance and sensitivity of species to a range of stressors. The exercise was a potentially large one and only species with names beginning with "A" were included (242 species). Annex 4 shows the results of the exercise and the recommendations below result in part from the exercise.

Recommendations:

1. The above information resources and any others readily available should be combined to identify intolerant, sensitive, and opportunistic species.
2. Sensitive taxa should be related to the EcoRegion and habitat type (e.g., EUNIS habitat type) in which they occur.
3. Lists of species from analysis of survey data should be presented so that rare or uncommon species are not included (may be EcoRegion dependent). Rare species cannot be used reliably to identify the presence of adverse effects.

4. The identification of key structural and functional sensitive species that are intolerant and/or sensitive to stressors needs to be given priority because of their high ecological significance. (For example, the loss of *Modiolus* (a key structural species with rich associated fauna) due to lowered salinity results in the disappearance of the mussels and the associated community. *Modiolus* has "high" sensitivity: once lost, it will only return over a long period of time and beds will probably not re-establish for 10+ years.)
5. Sensitive species that are normally in high abundance in a biotope are preferred over low density species as potential indicators.
6. Sensitive species that are conspicuous, easily identified, and readily observed or surveyed should be identified as "Sentinel species".

Stress

It is expected that many species will be sensitive to a wide range of stressors and therefore indicative of "stress". The ideal objective is to identify stressor-specific species; however, this is considered as unrealistic as it will seldom be encountered in the real world. Stress needs to be identified as natural or anthropogenic in order to separate one from the other. Anthropogenic stress can be defined as any man-made change produced in benthic habitats or within marine environments.

The following categories of stressors were identified during the workshop and should be used to data analysis and to structure reviews:

Chemical stressors- nitrates/phosphates (eutrophication)
organic matter compounds
oxygen concentration
heavy metals
synthetic compounds (hormones, industrial products)
hydrocarbons (oil)
salinity

Physical stressors – mechanical disturbance (e.g. fishing)
removal of substratum (e.g. aggregate dredging)
changes in grain size
changes in temperature
suspended sediment
water flow rate
thermal
sediment deposition (smothering)

Biological stressors- parasites/diseases
removal of a species
non-natives

7.2 Development of metrics, objectives and reference levels [ToR: a]

Metrics

EcoQOs can be used for:

1. Management of an area to maintain favourable conservation status (including for the protection of marine natural heritage, for the maintenance of nursery habitats, for the maintenance of scenic appeal). EcoQ expected to be at or close to 'pristine' EcoQO.
2. Identification of the allowable quality limits in relation to exploitation of a area (fishing, dredging etc). EcoQO will be set at lower level than for maintenance of condition at undisturbed levels.
3. Identification of levels of improvement (towards an expected status of unpolluted) in polluted areas (city sewage, dumping sites, oil exploration and extraction etc). EcoQ expected to differ markedly from EcoQO.

Ad 1) For the conservation of a marine benthic community a full community analysis has to be done. Species richness and species lists are important, and focusing at sensitive species might be given priority.

Ad 2) For exploitation areas (e.g. fishing), a balance between demersal fish species and their benthic food source (benthic production) might be in focus. Here, conservation of species is not important, but "high nutrition" benthic food organisms (=biomass) are in focus. The community oscillations need to be followed and benthic community switching to low production may be prevented by managing the fisheries.

Ad 3) For polluted areas, alterations in the balance between opportunistic and sensitive species might be in focus. However, of the various measures (metrics) that have been developed, many are not relevant to identification of sensitive or opportunistic species (e.g., Shannon-Wiener and other diversity indices). Many other ways of illustrating the separation of different assemblages (e.g., Multi-Dimensional Scaling) do not directly indicate what is driving that change. The indices, however, developed at AZTI (the AZTI Marine Benthos Index) and the Swedish BQI (Benthic Quality Index) are valuable because they identify the species that are causing the change in the index. Those species may in-turn give clues of what environmental factors are causing change and, importantly for environmental management, whether those species are key structural, key functional, or dominant species that will result in long-term change. Information resources are becoming more-and-more available to identify why species might have changed in abundance or been lost or gained in a community (for instance, the *MarLIN* Web site).

Assuming that the sensitive taxa are identified, possible metrics for the use in practice are:

- Presence/absence of identified sensitive taxa
- Average abundance of identified sensitive taxa
- Proportion of abundance/biomass against habitat-specific reference for appropriate geographical area
- Age class composition against age class composition from undisturbed reference conditions (e.g., on the Dutch coast – *Spisula* decreased after shoreline nourishment)
- Area coverage (for instance, maerl beds, scallop beds, cold water coral reefs)

Reference levels

Habitat-specific reference conditions (of sensitive species) are required for the appropriate geographical area.

The EU Water Framework Directive (WFD) has defined four methods of establishing such reference conditions. Following the approach of the WFD reference conditions for sensitive species can be established using:

1. an existing undisturbed site or a site with only very minor disturbance
2. historical data and information
3. predictive models (statistical and/or experimental)
4. expert judgement (well documented).

The reference conditions must summarize the range of possibilities and values for the biological quality elements over periods of time and across the geographical extent of the type (CIS COAST Guidance 2.4, Vincent *et al*. 2002).

Creating habitat-specific reference conditions requires a ‘common currency’ for describing the habitats. For instance, the EUNIS (European Union Nature Information System) classification has been adopted by the UK & ROI WFD benthic invertebrate project for creating WFD habitat-specific reference conditions.

Whilst the EUNIS classification would not identify sensitive or opportunistic species that occur within biotope groupings, there may be a link to information on ‘Biology and sensitivity of this biotope’ (the *MarLIN* Web pages). A ‘Sensitive and opportunist species present in this biotope’ field could be added to the *MarLIN* database although significant work would be required.

Objectives

The desired level of the EcoQ relative to the EcoQ reference level is defined by the management objectives of the area (e.g. to achieve ‘good status’ as defined by the WFD, to prevent ecological deterioration of the area). Different mixes of stakeholders and technical advisors may develop the ecological and the social/economic operational objectives.

Reference levels and common standards

In order to identify reference levels for benthic EcoQ, it is necessary to have available or develop:

1. A meta-data catalogue of benthic survey data. This should be the European Marine Environmental Database but that needs development to adopt meta-data fields relevant to marine biological survey data.
2. a common data base or network of databases of survey information for management use (per area, depth, substrate = ecozones). Such a resource is being developed as a part of the Marine Biodiversity and Ecosystem Function (MARBEF) programme (see: http://www.marbef.org) by the Flanders Marine Data Institute (VLIZ). There is a need for databases that have marked lists for species distribution, sensitivity, opportunistic live mode, and classic fish food organisms (ecosensitivities). Common standards, language, common taxa database. Common meta-data fields.
3. A species dictionary that includes recent synonyms. The European Register of Marine Species is being developed as a part of the MARBEF programme.

7.3 Spatial scale requirements of sampling [ToR: b]

This section relates to sensitive as well as to opportunistic benthos species.

The spatial scale of survey and monitoring programmes needs to be appropriate for the species to be focussed upon and the area to be assessed (habitat, geographical area, management unit). Therefore, in a designated water body, there is a requirement for

- Identification of the habitats present
- Identification of the sensitive species related to habitats
- Identification of magnitude of the potential stress acting in the area

The list presented in Annex 5 contains most of the opportunistic species having a worldwide distribution. Hence, for opportunistic species the spatial scale requirements of sampling are not as relevant as in sensitive species, and may be habitat specific. Likewise, it is vital to possess proper prior knowledge of the area of study, which can be obtained via historic records (e.g. time series data), baseline studies, reference (undisturbed or pristine) areas and laboratory experiments.

7.4 Adequacy of existing monitoring activities [ToR: b]

This section relates to sensitive as well as to opportunistic benthos species.

The group wants to stress the importance of adequate taxonomic determination in the current monitoring networks, especially of the most important opportunistic taxonomic groups (e.g. Polychaeta, Oligochaeta, Chironomidae, etc.). The importance of taxonomic knowledge within these groups, allowing to the identification of the lowest taxonomic level, was also stressed. Further, it was noted that in some cases not all the species included in such taxa respond to stress in the same way, its importance as indicators being under- or over-estimated when identified and used as a whole group.

Hence, the group recommends the revision of existing national monitoring networks in such a way that better taxonomy is included and that neighbouring countries identify down to the same taxonomic levels. Revision of existing monitoring programme is also necessary to respond to the new European requirements (e.g., Water Framework Directive).

There is a continued need for further harmonisation/standardization of monitoring programmes, quality assurance (QA) of data, and collation of datasets for common use. The latter issues are in the work package of the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the North-east Atlantic (SGQAE),and will be treated in a document that is under preparation "General guidelines on quality assurance for biological monitoring in the OSPAR area".

7.5 Further advice based on scenario considerations [ToR: b]

This section relates to sensitive as well as to opportunistic benthos species.

The group considered the 5 scenarios for development of EcoQO elements, as presented in the ICES 2003 WGECO Report, and advised as follows:

Scenarios 1 and 2 require a substantial amount of resources to be practical and realistic. Hence, they should be considered on an exceptional basis (cf. Kuenitzer *et al.*, 1992), for an assessment of wider areas.

At present, the limited availability of sentinel species means that there is no realistic basis for the implementation of Scenario 5. Maurer and Nguyen (1996) and Bustos-Báez and Frid (2003) have highlighted that it is unrealistic and naïve to expect a single taxon to be the sentinel of community/ecosystem without extensive qualification. However, K. Hiscock brought forward that the coral *Leptopsammia pruvoti* might be used as a sentinel species indicating degradation elsewhere in the benthic community (based on observations at the island of Lundy (UK)

It was concluded that at present, Scenarios 3 and 4 are the most promising due to the development of different approaches through Europe (see Section 8.2). The differences between both Scenarios relate to the use of opportunistic and sensitive species only (in Scenario 4) or all of the identified species in samples (in Scenario 3). The group stressed its preference for using all the identified species in samples, in order to avoid loss of valuable information provided by the species excluded as in Scenario 4.

References

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7.6 Historic trajectory of metrics and relationship to management [ToR: c]

This section relates to sensitive as well as to opportunistic benthos species.

Studies along disturbance gradients, e.g. from point source discharge, have allowed for the identification of those species as being sensitive to the defined disturbance or showing an opportunistic response. Under such conditions, species provided water system managers with the opportunity to ask "is the environmental health getting better or worse?" In absence of point source disturbance, the use of species has been much less put in practice. However, in the case of fishing effects on fragile and long-lived species that are key structural such as horse mussels *Modiolus modiolus* (and therefore are potential sentinel species), observed changes have been used to regulate human activities.

The application of the concept of sentinel species has been little used in the past, except that charismatic species such as deep water corals provide an 'icon' for the public to be concerned about and to encourage politicians to take action. Now, it is needed to move to a situation where a 'catalogue' of sensitive and opportunistic species can be used to assess the quality of a location in relation to expected presence of species in the type(s) of biotope or biotope groupings present. Such an 'expectation' of the character of an area in terms of species present and of their abundance can become an Ecological Quality Objective.

The group also discussed the consistency of methodologies over time. Such consistency is vital in order to allow comparisons of data sets for the application of the metrics mentioned (see Annex 6) and to provide strong advise for managers.

The first historic step in the development of metrics was the application of univariate methods (see Annex 6), starting with the diversity approach. A further step included the multimetric indices and all the associated biotic indices. The third step was the multivariate approach, with the most novel method including modelling.

The group assessed the utility of these approaches from an ecological point of view, stressing the power of the multivariate approach. This is due to the incorporation of a vast amount of information, such as biological and physico-chemical variables, in the analysis. The potential of the modelling approach in ecological studies, in order to simulate different scenarios and to provide advise for non-specialists and politicians, was also discussed. At this moment this approach is considered of limited value for real application.

The recent development of several multimetric methods can help when the knowledge of the area or the availability of a large amount of information is scarce. The group highlighted the necessity of combining several metrics (univariate, multimetric and/or multivariate – only if adding explanatory value) in order to provide an adequate, robust ecological assessment. This holds for opportunistic and sensitive species alone, and in combination.

7.7 Future potential to assess EcoQO being met [ToR: d]

This section relates to sensitive as well as to opportunistic benthos species.

Much of the future success is dependent on the quality of data collected. It is considered advisable, in order to provide an adequate ecological assessment, to collect physical, chemical and biological information synchronously. This will help pinpointing to the stressor(s) active. An appropriate characterisation of the substrate should be undertaken, for this purpose a multidisciplinary approach should be considered (e.g. surveys conducted with sedimentologists).

In the case of biological data, the lowest level of taxonomic identification should be aimed for. Moreover, abundance and biomass data should be also used. Biomass data will help to gain insight in the productivity of the system. In relevant areas, the appropriate methodology should be chosen to obtain the necessary data. Biomass data should be standardized to allow for comparisons between data sets.

7.8 Development of draft guidelines for status evaluation [ToR: e]

Guidelines for status evaluation, using sensitive and/or opportunistic benthos species, should at least include the following:

1) An evaluation of previous sampling programmes in order to provide baseline information. This should also include physico-chemical data.

2) A quality assurance programme, including regular training of taxonomic expertise, allowing for species identification at the lowest taxonomic level, and adoption of ISO/CEN standards for survey design, sampling equipment and laboratory analysis in order to facilitate consistency among benthic studies.

3) A catalogue of the interpretation 'tools' available to environmental managers. These tools will include:
   a) An electronic species dictionary to ensure a common species terminology (ITIS or ERMS).
   b) An electronic biotope dictionary having a 'matching programme' so that survey data can be identified to biotopes or biotope groups (EUNIS).
   c) A means to identify where survey information has been collected and the metadata from those surveys (EDMED).
   d) Information on the biology and sensitivity of species and biotopes (*MarLIN*) for interpretation of survey and monitoring results.
   e) A 'catalogue' of intolerant, sensitive and opportunistic species that can be targeted for rapid survey or that can be used in interpreting survey results (work in progress).

4) A review of 'case studies' that illustrate how intolerant, sensitive and opportunistic species respond to environmental change including from both from natural and human stressors.

5) A description of the survey analysis tools that provide indices based on the presence of intolerant, sensitive and opportunistic species. The description should indicate the advantages as well as the disadvantages.

6) A glossary of terms.

8 EcoQ element (p): Density of opportunistic species [ToR: a]

The group reviewed the concept of 'opportunistic species'. It was concluded that opportunistic species (second-and first-order, based in Borja *et al.,* 2000, ecological groups IV and V) follow the reproductive (*r*) strategy (*sensu* Pianka, 1970), with short life-cycle (<1 year), small size, fast growth, early sexual maturity, planktonic larvae through the year and direct development. These species dominate in pronounced unbalanced situations, proliferating after intense disturbance or pollution episodes, occupying the space previously occupied by sensitive or tolerant species. They are often associated with disturbed (e.g. reduced) sediments. The trophic pattern is mainly dominated by surface or subsurface deposit-feeders.

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Pianka, E.R. (1970) On r- and K- selection. *American Naturalist*, 104(940), 592-597.

8.1 Identification of species and their response to stressors [ToR: a]

The group reviewed and compared the provisional list of 24 opportunistic benthic species provided by ICES WGECO (2003) with the list composed by Borja *et al.* (2000, 2003), (available at www.azti.es). The latter list includes 54 taxa as first-order opportunistic species and 119 as second-order opportunistic species. Only 4 species are common in both classifications (*Capitella capitata, Cirratulus cirratus, Chaetozone setosa* and *Polydora ciliata*). Five taxa (*Pomatoceros triqueter, Scolelepis bonnieri, Spio filicornis, Spiophanes bombyx* and *Streblospio shrubsolii*) should be considered as tolerant to the organic matter increase, but not as opportunistic, as defined above. The remainder of 24 species should not be considered as opportunistic.

The group discussed the responses of the opportunistic species to several stressors. It was pointed out that in cases species' responses might differ depending on the nature of stressors. It was also noted, however, that in some circumstances these species might respond differently to several kinds of disturbance and/or impacts.

Pearson & Rosenberg (1978, 1987) highlighted the importance of food sources as a central factor structuring benthic communities. This is necessary to consider when addressing the response of opportunistic species.

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

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

Annex 5 contains the lists of first-order and second-order opportunistic taxa/species with an indication of their known response to chemical and physical stressors. No response is known of these species to biological stressors.

References

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 (12), 1100 - 1114.

Borja, A., I. Muxika and J. Franco, 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.

Pearson. T.H. & R. Rosenberg (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review,* 16, 229-311.

Pearson, T.H. & R. Rosenberg (1987) Feast and Famine: structuring factors in marine benthic communities. In: *Organisation of communities: past and present* edited by P. Giller and J. Gee, *British Ecological Society Symposium 1986*. Blackwell Scientific Publications, Oxford, pp. 373-395.

8.2 Development of metrics, objectives and reference levels [ToR: a]

In the last years several metrics or approaches have been developed in order to explain and reveal the impact of stressors on benthic communities. These metrics have been named biotic or benthic indices, and can be grouped into three classes: (i) univariate individual-species data or community structure measures, such as species diversity, richness, abundance/biomass ratios, etc.; (ii) multimetric indices combining several measures of community response to stress into a single index; and (iii) multivariate methods describing the assemblages pattern, including modelling (see details in the Annex 6).

The metrics listed in Annex 6, which include as a determination criterion the presence of opportunistic species, can be grouped into four 'families':

(i) Benthic Pollution Index (BPI)/Biotic Index/AMBI/ Bentix

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

(ii) Coefficient of Pollution (CoP)

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

(iii) Benthic Index of Estuarine Condition/Benthic condition Index (BCI)/Benthic Index of biotic integrity (B-IBI)

These indices consider species diversity, total abundance, total biomass, percentage of abundance pollution-indicative taxa, percentage of abundance pollution-sensitive taxa, percentage of biomass of pollution-sensitive taxa, percentage of biomass >5 cm below sediment-water interface. These metrics combine structural parameters from the community and physico-chemical substrate conditions.

(iv) Indicator Species Index/Benthic Quality Index

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

8.3 Spatial scale requirements of sampling [ToR: b]

(See under 7.3)

8.4 Adequacy of existing monitoring activities [ToR: b]

(See under 7.4)

8.5 Further advice based on scenario considerations [ToR: b]

(See under 7.5)

8.6 Historic trajectory of metrics and relationship to management [ToR: c]

(See under 7.6)

8.7 Future potential to assess EcoQO being met [ToR: d]

(See under 7.7)

8.8 Development of draft guidelines for status evaluation [ToR: e]

(See under 7.8)

9 Gaps in knowledge & Future work to be done

In this section a summary is given of the most important issues dealt with in the sections 7 and 8 of this report. Some recommendations are formulated.

9.1 Sensitive species

It is recognized that the decrease of one or more sensitive species within an area (habitat type or EcoRegion) is an initial signal of a negative influence of a stressor. The precise nature of the stress, however, that is exerted on the benthic community concerned, has to be identified because among the sensitive species listed there are hardly any that do react to only one specific kind of stress. This means that additional work needs to be done before proper management action can be considered and decided upon.

It is strongly recommended that in addition to overall sensitive species within the group of sensitive species priority is given to monitoring of species playing a key role in the structure and functioning of structural habitats, e.g., *Modiolus* beds, *Lophelia* reefs and *Sabellaria* reefs. This is especially relevant for protection purposes because any impact on these kinds of structural habitats may have cascading effects which may be irreversible.

With respect to metrics for sensitive species a few possibilities were presented. Which metric would be the best to apply will, however, be dependent of the specific habitat or community. For instance, absence of sensitive species "X" in habitat " A" may be indicative for disturbance of the seabed by e.g. bottom trawling, whereas absence of the same species "X" in habitat "B" may be a normal phenomenon, being related to the nature of that habitat (e.g., a quite different sediment type).

As a consequence, reference conditions need to be defined for each habitat or larger seabed management unit.

It is the opinion of the group that for use in soft substrates the potential of using sensitive species only is relatively low. On rocky bottoms, with epifauna, the potential is considered higher. Therefore, in soft substrates it is recommended to use sensitive species in combination with opportunistic species; even whole community analysis is advocated.

It is recommended that effort is made to complement and improve on the information on the MarLIN website with respect to sensitivity and opportunistic character of benthic species. This will increase the importance of the MarLIN data for users.

9.2 Opportunistic species

It is concluded that there is a serious gap in detailed taxonomic knowledge of different groups of opportunistic benthic species, such as Polychaeta, Oligochaeta and Chironomidae.

Of existing lists of opportunistic species, only a limited number were considered to be indicative for disturbance of the seabed or pollution episodes, in such a way that these species become dominant at the expense of other (sensitive and intolerant) species. Many species are considered being tolerant to increased organic loading rather than showing a real opportunistic response to disturbance of a community or habitat.

Furthermore, opportunist species may respond to any disturbance, natural or man-induced. So, in cases that an increase of opportunistic species is observed, it is necessary to define whether the disturbance is natural or induced by anthropogenic stressor(s).

With respect to metrics it is recommended to make use of one or more of biotic indices. More indices should be used only if these provide added information. These indices may be selected out of a limited number of index 'families' which include opportunistic species.

These biotic indices do also include information on the occurrence of other and of sensitive species in benthic communities. They, therefore, can be applied in a wider sense.

9.3 Scenario considerations

With respect to the 5 scenario's presented in the 2003 WGECO Report the scenario's 1 and 2 are considered not well feasible because of the enormous effort required. On the other hand, scenario 5 on using indicator (sentinel) species is considered too simple an approach because of the virtual absence of stressor specific indicator species/taxa among the sensitive and opportunistic species. This leaves the scenario's 3 and 4 as being the more promising.

10 Report of the Meeting

Successive drafts of the Study Group report were discussed and commented on. The collated final draft report was discussed and revisions agreed upon.

11 Date and Place of next meeting

Not applicable. The Study Group will await further requests, depending on considerations in ICES (BEWG, WGECO, ACE) and OSPAR.

12 Closing of the meeting

K. Essink closed the meeting on Wednesday 24 March at 15:45.

List of Annexes

Annex 1:List of participants

Name	Address	Telephone no.	Fax no.	E-mail
Silvana Birchenough	CEFAS Burnham Laboratory Remembrance Avenue Burnham-on-Crouch Essex CMO 8HA United Kingdom	+44 1621 787211	+44 1621 784989	s.n.r.birchenough@ cefas.co.uk
Mats Blomqvist	Hafok AB SE-17961 Stenhamra Sweden	+46 8 56046462		mb@hafok.se
Ángel Borja	AZTI Herrera kaia, Portualde z/g 20110 Pasaia (Gipuzkoa) Spain	+34 943 004800	+34 943 004801	aborja@pas.azti.es
Hans Cederwall	Dept. of Systems Ecology Stockholm University SE-10691 Stockholm Sweden	+46 8 164243	+46 815 8417	hlc@systems.ecology. su.se
Karel Essink (chair)	Nat. Inst. for Coastal and Marine Mangement/RIKZ P.O. Box 207 9750 AE Haren Netherlands	+31 50 5331373	+31 50 5340772	k.essink@rikz.rws.min venw.nl
Fritz Gosselck	Institut für Angewandte Oekologie Alte Dorfstrasse 11 18184 Neu Brodersdorf Germany	+38 204 6180	+38 204 61810	gosselck@ifaoe.de
Karin Heyer	Inst. f. Biogeochemie und Meereschemie Bundestr. 55 Hamburg Germany	+49 40 865387	+49 40 8666258	heyerkarin@t-online.de
Keith Hiscock	Marine Biological Assoc. Citadel Hill Plymouth PL1 2PB UK	+44 1752 633 352	+44 1752 633 102	k.hiscock@mba.ac.uk
Lis Lindal Jørgensen	Havforskningsinstituttet / Institute of Marine Research Avdeling Troms / Troms branch Sykehusveien 23 N-9091 Troms, Norway	+ 47 77 60 97 58	+ 47 77 60 97 01	lis.lindal.joergensen@i mr.no
Alison Miles	National Marine Service Environment Agency Kingfisher House Goldhay Way, Orton Goldhay Peterborough PE2 5ZR United Kingdom	+44 1733 464138	+44 1733 464634	alison.miles@environm ent-agency.gov.uk

Name	Address	Telephone no.	Fax no.	E-mail
Ine Moulaert	CLO Sea Fisheries Department Ankerstraat 1 B-8400 Ostende Belgium	+32 5934 2250	+32 5933 0629	ine.moulaert@dvz.be
Kerstin Mo	Institute of Coastal Research National Board of Fisheries Gamla Slipvägen 19 S-74071 Öregrund SWEDEN	+46 173 46 474		kerstin.mo@ fiskeriverket.se

Annex 2:Agenda

STUDY GROUP ON ECOLOGICAL QUALITY OBJECTIVES
FOR SENSITIVE AND FOR OPPORTUNISTIC BENTHOS SPECIES
[SGSOBS]
COPENHAGEN, DENMARK
March 22-24, 2004

ANNOTATED-AGENDA (DRAFT)

1. **Opening & Local Organisation**
   Introduction by Chair

2. **Appointment of Rapporteur**

3. **Terms of Reference**
   Reference: Council Resolution 2ACE02

4. **Adoption of Agenda**

5. **Review of previous work (OSPAR, BEWG, WGECO, etc.)**
   5.1. EcoQO concept (OSPAR)
   5.2. Relation to EU Water Framework Directive
   5.3. Work done by ICES

6. **Reports on related (inter)national work**
   Oral presentations by participants. Written accounts to be annexed to SG Report

7. **EcoQ element (o): Density of sensitive (e.g., fragile) benthos species**
   7.1. Identification of species sensitive to stressors [ToR: a]
   7.2. Development of metrics, objectives and reference levels [ToR: a]
   7.3. Spatial scale requirements of sampling [ToR: b]
   7.4. Adequacy of existing monitoring activities [ToR: b]
   7.5. Further advice based on scenario considerations [ToR: b]
   7.6. Historic trajectory of metrics and relationship to management [ToR: c]
   7.7. Future potential to assess EcoQO being met [ToR: d]
   7.8. Development of draft guidelines for status evaluation [ToR: e]

8. **EcoQ element (p): Density of opportunistic species species [ToR: a]**
   8.1. Identification of species and their response to stressors [ToR: a]
   8.2. Development of metrics, objectives and reference levels [ToR: a]
   8.3. Spatial scale requirements of sampling [ToR: b]
   8.4. Adequacy of existing monitoring activities [ToR: b]
   8.5. Further advice based on scenario considerations [ToR: b]
   8.6. Historic trajectory of metrics and relationship to management [ToR: c]
   8.7. Future potential to assess EcoQO being met [ToR: d]
   8.8. Development of draft guidelines for status evaluation [ToR: e]

9. **Gaps in knowledge & Future work to be done**

10. **Report of the Meeting**

11. **Date and Place of next meeting**

12. **Closing of the meeting**

Annex 3:Marine quality assessment by use of benthic species-abundance distributions

Mats Blomqvist
Hafok AB, SE-179 61 Stenhamra, Sweden

Hans Cederwall
Dept. of Systems Ecology, Stockholm University, SE-106 91 Stockholm, Sweden

Hans Nilsson
Marine Monitoring at Kristineberg, SE-450 34 Fiskebäckskil, Sweden

Rutger Rosenberg, Kristineberg Marine Research Station, University of Gothenburg, SE-450 34 Fiskebäckskil, Sweden

1. Introduction

During 2003 the Swedish Environment Protection Agency financed several projects to establish a system for assessing the ecological status in Swedish coastal waters in accordance with the EC Water Framework Directive (WFD). Here is summarized the results of the project dealing with soft-bottom macrofauna.

A comprehensive database was set up within the project. Data from nearly 6 500 stations were used out of which 2 500 were situated in the coastal area covered by the WFD. The total number of grab samples from the coastal area was 16629. The data originated from national, regional and lokal monitoring programmes as well as from research projects covering a timeperiod from 1920 to 2002 and depths between 5 and 600 m. Altogether 1 595 taxa were found in the material. Use of names of species and genera may change between taxonomists and over time. Synonyms have been checked and nomenclature used by ICES has been applied.

2. West Coast of Sweden (Skagerrak, Kattegat and the Sound)

Diversity index

In pollution gradients in marine waters the diversity increases with distance from the pollution outfall (Pearson and Rosenberg 1978). Consequently, for the marine areas along the west coast of Sweden, calculation of the expected number of species (ES) was made among 50 individuals according to Hurlbert's (1971) formula, which is used in the computer software PRIMER (Clark and Warwick 1994):

$$ES50 = \sum_{i=1}^{s} \frac{(N-N_i)!(N-50)!}{(N-N_i-50)!N!}$$

where *N* is total number of individuals in a sample and "*Ni*" is the number of the "*i*-th" species. The validation of the index is based on the individuals of each species being randomly distributed, which is not always the case. In order to not include species occurring in few samples only, the number of sample occasions where a species must be recorded was limited to ≥20. We use ES50 instead of ES100 to include samples with abundances between 50 and 100 in the analysis, which could be useful in disturbed areas with abundances in this interval. A high correlation ($r^2 = 0.957$, n =382) was found between ES50 and ES100. Thus, samples with <50 individuals were not included in the analysis.

Tolerant and sensitive species

Tolerant species are by definition predominantly found in disturbed environments. That means that they mainly occur at stations with low ES50. In contrast, sensitive species occur in areas with no or minor disturbance and would then be associated with high ES50. In an abundance frequency distribution of a particular species in relation to ES50 values at the stations where it has been recorded, the most tolerant individuals of a species are likely to be associated with the lowest ES50 values. We selected that 5 % of the population will be associated to this category, and define this value as the species tolerance value: $ES50_{0.05}$. The rest of the population may, for various reasons, have greater ES50 values and have been present in less disturbed environments.

3. East Coast of Sweden (Baltic Sea)

Diversity

The brackish-water Baltic Sea is a sea with low species diversity (ca 10 % of the number of taxa generally found along the Swedish West Coast). You could say that the whole Baltic Sea is disturbed, salinity disturbed. We also found when looking at areas with pollution source, that the number of taxa often was as high in the area close to the pollution source as it was in the area furthermost from the pollution source. In fact there were cases where the number of taxa was actually higher close to the pollution source. The species dominating in the two areas were however different. This indicated that the use of a diversity index for establishing the sensitivity of different Baltic Sea taxa would not be very successful. Nevertheless we calculated ES50-values also for the Baltic Sea areas.

Tolerant and sensitive species

Trying to use Hurlberts index to establish tolerance/sensitivity for Baltic Sea species gave results deviating strongly from what was already known about different species. For example: A well known sensitive species, *Monoporeia affinis*, received the next lowest value, stating that it should be one of the most tolerant species. A well known tolerant species, *Chironomus plumosus*, received a rather high value, stating that it should be a sensitive species. For the Baltic Sea we had to use what was already published about the sensitivity of different taxa together with our own expertise and what was found in the data material. For the southern Baltic Proper also the ES50-values for the Swedish West Coast was used. In several cases two or more publications had classified the same species. Generally they were put in the same sensitivity class, in a few cases in the bordering class.

All taxa, except the very rare ones (found on less than 10 stations in each basin) were classified into four classes. To be able to use the same formula for assessing the benthic quality, each taxon in a class the same sensitivity value, corresponding to the ES50-values for the Swedish West Coast:

Class	**Sensitivity value**
Very tolerant	1
Tolerant	5
Sensitive	10
Very sensitive	15

4. Benthic quality assessment

For the assessment of the environmental quality at a particular station, a new benthic quality index (BHQ) is proposed:

$$BQI = \left(\sum_{i=1}^{n}\left(\frac{A_i}{totA} \times ES50_{0.05i}\right)\right) \times {}^{10}\log(S+1)$$

The tolerance value ($ES50_{0.05}$ for the West Coast or the corresponding value for the East Coast) of each species found at a station is multiplied with the mean relative abundance (*A*) of this species (”*i*”) to put weight on common species in relation to rare species. Further, the sum is multiplied with ^{10}logaritm for the mean number of species (*S*) at the station, as high species diversity is related to high environmental quality. All information related to number of species and abundance at a station is used for this quality assessment.

5. References

Clark, K.R. and R.M. Warwick (1994). Change in marine communities: An approach of statistical analysis and interpretation. Plymouth Marine Laboratory.

Hurlbert, S.H. (1971). The nonconcept of species diversity: A critique and alternative parameters. *Ecology* 52: 577-586.

Pearson, T.H. and R. Rosenberg (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanogr. Mar. Biol. Ann. Rev.* 16: 229-311.

Annex 4:Species identified as Intolerant of, and Sensitive to stressors (an example)

Four sources of information have been used:

- AZTI Marine Biotic Index. Group I (‘Sensitive’ species) are listed and are sensitive for a range of stressors.
- *MarLIN* database: Lower case is species intolerance, uppercase is species sensitivity. VH = Very High; H/h = High; i = Intermediate; M = Moderate
- ICES 2003 ACE report. F = Fragile (=Intolerant); S = Sensitive in relation to mechanical disturbance from fisheries.
- Swedish Tolerance Values (ES0 $_{0.05}$). Species included are those with an index above 10 or species listed in other sources.

Only species beginning with ‘A’ are listed here to provide a demonstation.

SPECIES	AMBI ecological group	Nitrates/ Phosphates	Organic matter	Oxygen	Heavy metals	Synthetic chemicals	Hydrocrabons	Salinity	Mechanical disturbance	Removal of substratum	Smothering	Swedish tolerance values ES0 0.05
Abarenicola claparedei	I											
Abarenicola sp.	I											
Abra alba					i	M, h		i	F, i			4
Abyssoninoe scopa	I											
Abyssoninoe scopa aequilobata	I											
Acanthocardia aculeata	I											
Acanthocardia echinata	I								F, S			
Acanthocardia paucicostata	I											
Acanthocardia sp.	I											
Acanthocardia tuberculata	I											
Acanthochitona crinita	I											
Acanthochitona fascicularis	I											
Achelia echinata	I											
Achelia hispida	I											
Achelia longipes	I											
Achelia simplex	I											
Achelia sp.	I											
Acidostoma obesum	I											13.20
Acidostoma sp.	I											
Aclis gulsonae	I											
Acmaea sp.	I											
Acmaeidae	I											
Acmira simplex	I											
Acrocnida brachiata	I								F			
Acteon sp.	I											
Acteon tornatalis									F			
Acteon tornatilis	I											

Acteonidae	I											
Actinia equina	I											
Actinia sp.	I											
Actiniaria	I											
ACTINIIDAE	I											
Aeolidia papillosa	I											
Aeolidia sp.	I											
Aequipecten opercularis	I											
Aequipecten sp.	I											
Aglaophamus malmgreni												11.5
Ahnfeltia plicata		i				M, h	M, h		i		i	
Akera bullata	I											
Akera sp.	I											
Akeridae	I											
Alaria esculenta		i			i	i		M, h	i		i	
Alcyonidium diaphanum									F			
Alcyonium digitatum	I			M, h		i		i	F, i		i	
Alcyonium sp.	I											
Alderia modesta	I											
Alkmaria romijni									H, i		H, i	
Alvania abyssicola	I											14.40
Alvania beanii	I											
Alvania crassa	I											
Alvania punctura	I											
Alvania semistriata	I											
Alvania sp.	I											
Amaea trilobata	I											
Amaeana sp.	I											
Amaeana trilobata	I											15.40
Amage adspersa	I											
Amage auricula	I											
Amathia pruvoti	I											
Amhipholis brachiata									F			
Ammotrypane aulogaster	I											
Ammotrypane cylindricaudatus	I											
Amparete lindstroemi												11.6
Ampelisca abdita	I											
Ampelisca aequicornis	I											
Ampelisca anomala	I											
Ampelisca armoricana	I											
Ampelisca brevicornis	I											12.50
Ampelisca diadema	I											10.70
Ampelisca gibba	I											
Ampelisca heterodactyla	I											
Ampelisca macrocephala	I											11.60
Ampelisca multispinosa	I											
Ampelisca sarsi	I											
Ampelisca sp.	I											
Ampelisca spinifer	I											
Ampelisca spinimana	I											
Ampelisca spinipes	I											
Ampelisca spooneri	I											
Ampelisca tenuicornis	I											13.00
Ampelisca toulemonti	I											
Ampelisca typica	I											
Ampeliscidae	I											
Ampharete acutifrons	I								F			6.80
Ampharete falcate												12.3
Ampharete finmarchica	I											

Ampharete goesi	I											
Ampharete grubei	I											
Ampharete lindstroemi	I											
Ampharete sp.	I											
Amphianthus dohrnii				I				i	H, h			
Amphictene auricoma	I											11.50
Amphictene capensis	I											
Amphictene sp.	I											
Amphidesma lucinale	I											
Amphilepis norvegica	I											14.70
Amphipolis squamata	I											
Amphitrite auricoma	I											
Amphitrite cirrata	I											
Amphitrite johnstoni	I											
Amphitrite sp.	I											
Amphiura brachiata	I											
Amphiura chiajei	I						M, h	M, h	F			10.60
Amphiura filiformis	I				i	M, h	M, h	M, h				9.50
Amphiura sp.	I											
AMPHIURIDAE	I											
Ampicteus gunneri									F			12
Ampithoe rubricata	I											
Ampithoe sp.	I											
Ampithoe valida	I											
Amythasides macroglossus	I								F			11.00
Anadara diluvii	I											
Anadara polii	I											
Anapagurus bicorniger	I											
Anapagurus breviaculeatus	I											
Anapagurus hyndmanni	I											
Anapagurus laevis	I											
Anapagurus sp.	I											
Angulus tenuis	I											
Anobothrus gracilis	I											
Anobothrus sp.	I											
Anodontia fragilis	I											
Anomia ephippium	I								F			
Anomia sp.	I											
ANOMIIDAE	I											
Anoplodactilus sp.	I											
Anoplodactylus petiolatus	I											
Anoplodactylus pygmaeus	I											
Ansates pellucida	I											
Antalis entale	I											
Antalis sp.	I											
Antedon bifida				I	i	M, h	M, h	M, h	F, M, h		M, h	
Antennella sp.	I											
ANTHOZOA	I											
Anthura gracilis	I											
Antinoella finmarchica	I											
Antinoella sarsi	I											
Aora gracilis	I											13.70
Aora sp.	I											
Aora spinicornis	I											
Aora typica	I											
AORIDAE	I											
Aphelochaeta marioni		i				M, h			i			
Apherusa bispinosa	I											
Apherusa cirrus	I											

Apherusa ovalipes	I											
Apherusa sarsi	I											
Apherusa sp.	I											
Aphrodita aculeata	I							M, h	F, i			10.6
Aphrodita sp.	I											
APHRODITIDAE	I											
Apicularia guerinii	I											
Apistobranchus sp.	I											
Apistobranchus tenuis	I											14.40
Apistobranchus tullbergi	I								F			
Aplysia punctata	I											
Aponuphis grubii	I											
Aporrhais pespelicani	I								F			8.9
Aporrhais serresianus	I											
Aporrhais sp.	I											
Apseudes spinosus												12.6
Arca diluvii	I											
Arca fragilis	I											
Arca pectunculoides	I											
Arcopagia balaustina	I											
Arctica islandica						M, h	i	i	F, S, M, i		M, i	7.5
Arenicola marina	I	i				M, h	i		i			5.80
Arenicola sp.	I											
Argissa hamatipes												12.5
Aricia cuvieri	I											
Aricia foetida	I											
Aricia latreillii	I											
Aricia sp.	I											
Aricidea albatrossae	I											
Aricidea annae	I											
Aricidea assimilis	I											
Aricidea capensis bansei	I											
Aricidea catherinae	I											
Aricidea cerrutii	I											
Aricidea claudiae	I											
Aricidea curviseta	I											
Aricidea fauveli	I											
Aricidea fragilis	I											
Aricidea fragilis mediterranea	I											
Aricidea jeffreysi	I											
Aricidea laubieri	I											
Aricidea minuta	I											
Aricidea monicae	I											
Aricidea quadrilobata	I											
Aricidea roberti	I											
Aricidea simonae	I											
Aricidea simplex	I											
Aricidea sp.	I											
Aricidea suecica	I											
Aricidea suecica meridionalis	I											
Aricidea suecica simplex	I											
Aricidea wassi	I											
Armandia cirrhosa	I						VH	h	M, i			10.40
Armandia polyophthalma	I											
Armandia sp.	I											
Armina loveni	I								S			
Arrhis phyllonyx												
Artacama proboscidea												11.6
Ascidiella scabra						i		i	h			

Ascophyllum nodosum		i				H, i			H, h		H, h	
Aspidosiphon kowalevskii	I											
Aspidosiphon muelleri	I											
Astacilla gorgonophila	I											
Astacilla longicornis	I											
Astacilla sp.	I											
Astarte borealis	I											
Astarte elliptica	I											
Astarte montagui	I											
Astarte sp.	I											
Astarte sulcata	I											
Astarte triangularis	I											
ASTARTIDAE	I											
Asterias rubens	I			M, h	i	i	M, h	M, h	F, i			7.90
Asterias sp.	I											
Asterina gibbosa	I											
Astropecten aranciacus	I											
Astropecten filiformis	I											
Astropecten irregularis	I								F			10.30
Astropecten irregularis typicus	I											
Astropecten pentacanthux	I											
Astropecten sp.	I											
Astropectinidae	I											
Atelecyclus rotundatus	I											
Atelecyclus sp.	I											
Atelecyclus undecindentatus	I											
Athanas nitescens	I											
Athanas sp.	I											
ATHECATA	I											
Atrina fragilis		M			M				VH, h		H, i	
Atylus falcatus	I											
Atylus guttatus	I											
Atylus sp.	I											
Atylus swammerdami	I											
Atylus vedlomensis	I											14.00
Autonoe longipes	I											
Axinella dissimilis				H, i				H, h	F, H, i		H, i	
Azorinus chamasolen	I											

Annex 5:First-order opportunistic taxa/species to become dominant in response to stress

Taxa/Species	Chemical	Physical	Biological
Amphichaeta sannio			
Capitella capitata	X	x	
Capitella sp.	X	x	
CAPITELLIDAE	X	x	
Capitellides giardi	X	x	
Clitellio arenarius	X		
Clitellio sp.	X		
ENCHYTRAEIDAE	x		
Ficopomatus enigmaticus			
Grania sp.			
Heterochaeta costata	x		
Heterochaeta sp.	x		
Jassa falcata		x	
Jassa marmorata		x	
Jassa sp.		x	
Leiocapitella dollfusi	x	x	
Leiochrides sp.	x		
Limnodrilus hoffmeisteri	x		
Limnodrilus sp.	x		
Malacoceros fuliginosus	x	x	
Maldanella robusta			
Mastobranchus trinchesii			
Monopylephorus irroratus			
NAIDIDAE	x		
Nais elinguis	x		
Nais sp.	x		
Nebalia bipes			
Nebalia sp.			
OLIGOCHAETA	x		
Paraleiocapitella mosambica	x	x	
Paranais frici	x		
Paranais litoralis	x		
Paraprionospio pinnata	x		
Peloscolex benedeni	x		
Peloscolex heterochaetus	x		
Peloscolex sp.	x		
Pseudocapitella incerta	x	x	
Pseudoleiocapitella fauveli	x	x	
Pseudomastus deltaicus			
Scolelepis fuliginosa	x	x	
Stylaria lacustris	x		
Tubifex costatus	x		
Tubifex tubifex	x		
TUBIFICIDAE	x		
Tubificoides amplivasatus	x		
Tubificoides brownae	x		
Tubificoides crenacoleus	x		
Tubificoides galiciensis	x		
Tubificoides insularis	x		
Tubificoides pseudogaster	x		
Tubificoides sp.	x		
Tubificoides swirencoides	x		

Second-order opportunistic taxa/species to become dominant in response to stress:

Taxa/Species	Chemical	Physical	Biological
Anadara demiri		x	
Aphelochaeta multibranchiata	x		
Aphelochaeta vivípara	x		
Branchiura sowerbyi			
Branchiura sp.			
Capitomastus minimus	x	x	
Capitomastus sp.	x	x	
Caulleriella alata			
Caulleriella bioculata			
Caulleriella caputesocis			
Caulleriella sp.			
Caulleriella zetlandica			
Chaetozone gibber	x	x	
Chaetozone setosa	x	x	
Chaetozone sp.	x	x	
CHIRONOMIDAE	x		
Chloeia venusta			
CIRRATULIDAE			
Cirratulus caudatus			
Cirratulus chrysoderma			
Cirratulus cirratus			
Cirratulus filiformis			
Cirratulus incertus			
Cirratulus sp.			
Cirriformia sp.			
Cirriformia tentaculata			
Corbula giba	x	x	
DIPTERA			
Dodecaceria concharum			
Glycera alba			
Heterocirrus sp.			
Heteromastus filiformis	x		
Heteromastus sp.	x		
HIRUDINEA			
Iphinoe rhodaniensis			
Laeonereis glauca			
Leitoscoloplos mammosus			
Monticellina heterochaeta			
Nereis caudata	x	x	
Nereis irrorata	x	x	
Ophryotrocha bacci	x		
Ophryotrocha dubia	x		
Ophryotrocha gracilis	x		
Ophryotrocha grayonicola	x		
Ophryotrocha hartmanni	x		
Ophryotrocha labronica	x		
Ophryotrocha longidentata	x		
Ophryotrocha puerilis	x		
Ophryotrocha sp.	x		
Pagastiella orophila			
Pagastiella sp.			
Pholoe inornata			
Piscicola geometra			
Piscicola sp.			
Polycirrus appendiculatus			
Polycirrus aurantiacus			
Polycirrus medusa			
Polycirrus norvegicus			
Polycirrus pallidus			
Polycirrus plumosus			
Polycirrus sp.			

Polycirrus tenuisetis			
Polydora caeca	x	x	
Polydora caulleryi	x	x	
Polydora ciliata	x	x	
Polydora cornuta	x	x	
Polydora flava	x	x	
Polydora giardi	x	x	
Polydora ligerica	x	x	
Polydora ligni	x	x	
Polydora polybranchia	x	x	
Polydora pulcra	x	x	
Polydora quadrilobata	x	x	
Polydora socialis	x	x	
Polydora sp.	x	x	
Polypedilum convictum			
Polypedilum sp.			
Prionospio banyulensis	x	x	
Prionospio caspersi	x	x	
Prionospio cirrifera	x	x	
Prionospio dubia	x	x	
Prionospio ehlersi	x	x	
Prionospio fallax	x	x	
Prionospio malmgreni	x	x	
Prionospio multibranchiata	x	x	
Prionospio pinnata	x	x	
Prionospio pulchra	x	x	
Prionospio sp.	x	x	
Prionospio steenstrupi	x	x	
Protocirrineris chrysoderma			
Pseudomalacoceros tridentata			
Pseudopolydora antennata	x	x	
Pseudopolydora caulleryi	x	x	
Pseudopolydora kempi	x	x	
Pseudopolydora paucibranchiata	x	x	
Pseudopolydora pulchra	x	x	
Pseudopolydora sp.	x	x	
Rhaphidrilus nemasoma			
Schistomeringos rudolphi			
Sigambra parva			
Sigambra tentaculata			
Staurocephalus rudolphii			
Stauronereis caecus			
Tharyx acutus	x	x	
Tharyx annulosus	x	x	
Tharyx dorsobranchialis	x	x	
Tharyx heterochaeta	x	x	
Tharyx killariensis	x	x	
Tharyx marioni	x	x	
Tharyx mcintoshi	x	x	
Tharyx multibranchis	x	x	
Tharyx sp.	x	x	
Tharyx tesselata	x	x	

Annex 6:List of metrics

(i) 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. Wat. Res. Proj. Annu. Rep.*, 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*. SCCWRP, Long Beach, California, USA, pp 103-121.

- ABC curves

  Warwick, R. and K.R. Clarke, 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., P. Panayotidis and N. Stamatis, 2001. Ecological evaluation of transitional and coastal waters: a marine benthic macrophytes-based model. *Mediterranean Marine Science,* 2: 45-65.

(ii) 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., J.G. Wilson, C.R. Harris and D.L. Tomlinson, 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 M. Glémarec, 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., J.K. Summers and G.R. Gaston, 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. *Estuaries,* 17: 372-384.
Engle, V.D. and J.K. Summers, 1999. Refinement, validation and application of a benthic condition index for Northern Gulf of Mexico estuaries. *Estuaries*, 22: 624-635.
Paul, J.F., K.J. Scott, D.E. Campbell, J.H. Gentile, C.S. Strobel, R.M. Valente, S.B. Weisberg, A.F. Holland and J.A. Ranasinghe, 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., J. A. Ranasinghe, 1997. An estuarine benthic index of biotic integrity (B-BY) for Chesapeake Bay. *Estuaries,* **20**: 149-158;
Van Dolah, R. F., J. L. Hyland, A. F. Holland, J. S. Rosen, T. R. Snoots, 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., L. C. Scott, D. M. Dauer, J. L. Hyland, D. E. Russell, 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., L. C. Scott, J. L. Hyland, D. M. Dauer, D. E. Russell, F. W. Kutz, 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., J. Franco and V. Pérez, 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., I. Muxika and J. Franco, 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.
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Simboura, N. and A. Zenetos, 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., M. Mistri and R. Rossi, 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 Nº 40114: 1-32.

- Benthic Quality Index

Rosenberg, R., M. Blomqvist, H. Nilsson, H. Cederwall and A. Dimming (submitted). Marine quality assessment by use of benthic species-abundance distribution; a proposed new protocol within the EC Water Framework Directive. *Marine Pollution Bulletin*.

(iii) Multivariate and modelling approaches:

- 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., J.G. Ferreira and T. Simas, 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.

- Mult—Dimensional Scaling (MDS)

    Warwick, R.M. & Clarke, K.R. 1991. A comparison of some methods for analysing changes in benthic community structure. *J. Mar. Biol. Ass*. 71, 225-244.

- Canoco

    ter Braak, C. J. F. and Šmilauer, P. (1998). *CANOCO Reference Manual and User's Guide to Canoco for Windows. Software for Canonical Community Ordination (version 4)*. Centre for Biometry Wageningen (Wageningen, NL) and Microcomputer Power (Ithaca NY, USA), 352 pp.

- PRIMER

    Clarke, K.R. & Ainsworth, M. 1993. A method of linking multivariate community structure to environmental variables. *Mar. Ecol. Prog. Ser.* 92, 205-219

    Clarke, K.R. & Gorley, R.N. 2001. *PRIMER v5: User Manual/Tutorial*. Plymouth.