

# OSPAR CEMP Guideline

## Common indicator: Condition of benthic habitat communities (BH2) – common approach

(OSPAR Agreement 2018-06)<sup>1</sup>

*This OSPAR biodiversity indicator is still in the early stages of implementation and as a result of iteration and learning, it is anticipated that there will be evolution of the methods and approaches documented in the CEMP guidelines. Version updates will be clearly indicated and be managed in a phased approach via ICG-COBAM through its expert groups and with the oversight and steer of BDC.*

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<sup>1</sup> This document exists in English only

# 1 Introduction

These guidelines outline the monitoring and assessment requirements for the OSPAR common approach: “condition of benthic habitat communities (BH2)”.

More detailed technical specifications for this indicator are in **Annex 1**. As a conceptual “umbrella” (see below), it is recommended that, in the future, a set of guidelines (according to each habitat and pressure types to be assessed) should be developed for this common approach to operationalise it at its full potential (all MSFD/OSPAR issues for benthic habitats) and update OSPAR CEMP to ensure coherence and comparability at (sub)-regional scale.

Specific applications of the indicator to date are described in **Annex 2** and **Annex 3**. These applications contributed to the OSPAR Intermediate Assessment (BH2-A and BH2-B).

## 1.1. Context and summary description

Depending on habitat and pressure-type to be assessed (according to specific assessment methods and scales), this BH2 common approach can be adapted to enable the analyses of impacts from each human pressure type on the condition of each benthic habitat type (see Table 1). The indicator should thus inform management measures for human activities that generate pressures, notably the maximum acceptable level of pressure for sustainable use.

Regional assessments on benthic habitats are at an early stage of development and this common approach will be further elaborated on in subsequent assessment cycle(s).

Preliminary testing demonstrated that BH2 is conceptually applicable to several habitat types and is sensitive to various pressure types. Several case studies (per habitat and pressure type) have been realised through Southern North Sea Project and BenthVAL associated research programmes. Nevertheless, more data (geographical coverage and habitat and pressure type) and further testing is required to conclude on relevance and performances of each Multi metric index (MMI) types according to each habitat and pressure types, at (sub)-regional scale, to operationalise BH2 common concept for each specific application (table 1).

Table 1: Relationships between habitat and pressure types, and how / if the relationships are currently assessed or considered. Relationships based on the revised Marine Strategy Framework Directive (Commission Decision 2017/848/UE and MSFD Annex III 2017/845/UE). Broad pressure and habitat types (EUNIS<sup>2</sup> L3) are described at high levels, however assessment of state-pressure relationship should be undertaken on a finer scales at habitat community (EUNIS L5) and pressure subtypes (Annex 1, table 2). Monitoring, assessment and reporting should be completed per pressure and habitat type. Effects of cumulative (different types) pressures are currently not assessed (gap of knowledge). In the future, this could potentially be completed and/or combined to give an overall understanding of the condition of benthic habitats in the North-East Atlantic.

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<sup>2</sup> The European Nature Information System habitat classification is a system to classify types of habitats on several nested levels. The higher the level, the more details and sub-types of habitats are included. Level numbering used here is from EUNIS version 10/2016. <http://eunis.eea.europa.eu/>

Benthic Broad Habitat Type, including their associated biological communities	Broad Pressure Type							
	Physical disturbance	Extraction/Injury of species	Hydrological changes	Eutrophication (nutrients or organic enrichment)	Non-indigenous, pathogens, cultivated and genetically modified species	Contaminants	Litter	Energy, including under water noise
Littoral rock and biogenic reef				A				
Littoral sediment				A				
Infralittoral rock and biogenic reef				A				
Infralittoral sediment	P			A				
Circalittoral rock and biogenic reef				A				
Circalittoral sediment	P			A				
Offshore circalittoral rock and biogenic reef								
Offshore circalittoral sediment	P			P		P		
Upper bathyal rock and biogenic reef								
Upper bathyal sediment								
Lower bathyal rock and biogenic reef								
Lower bathyal sediment								
Abyssal								

**Key:**

<b>A</b>	Assessed and reported under OSPAR and the European Union Water Framework Directive (WFD)
	Considered under OSPAR and the European Union Marine Strategy Framework Directive (MSFD)
<b>P</b>	Partially assessed in the OSPAR Intermediate Assessment 2017
	Main risks (potentially widespread across the OSPAR maritime area)
	Relationship identified but not currently assessed

The principle of the common approach “Condition of benthic habitat communities, BH2” is to detect and quantify impact of a pressure by a deviation (of values of the index) compared to (simultaneously assessed) baseline condition (defined as undisturbed or least disturbed), per habitat type.

BH2 has been endorsed as a common regional indicator for the North East Atlantic OSPAR (2013) and is part of a common set of indicators. This is expected to quantify pressure-state relationships (i.e. impacts) and to give, in combination with other benthic indicators, a useful integrated quality score of the condition of the benthic community, for each assessed habitat, calibrated by occurring pressure(s).

This common approach (BH2) will build upon two types of information

- Biological (species composition and relative abundances) and environmental support data (substrate and water metrics) of the sampling station;
- Disturbance (pressure) characteristics: type, intensity and frequency of occurring pressure(s) that potentially causes damage in the sampled area.

The way to combine these basic parameters and metrics in indices (e.g. diversity index, pressure index, etc.) and/or multivariate analysis to compute BH2, depends of the various combinations of habitat and pressure types, and sub-regional specificities. Alternative combinations and proposed options to build MMIs are generally based on the same core datasets (ecological parameters and metrics) and could thus be tested alternatively or simultaneously in the case studies. Various approaches to calculate and test MMI,

depending on habitat, pressure types or national approaches are presented in Annexes 1, 2 and 3. The “BENMMI” tool was developed in the Southern North Sea project and could be used to facilitate these calculations and testing (Walvoort and Van Loon, 2016).

Environmental support data (abiotic data, e.g. salinity, depth classes, sand grain size, etc.) are used to define different benthic habitat types. However, the condition of benthic habitats, as defined in MSFD and implied by BH2, needs to be assessed at community level (EUNIS L5). The ICG-COBAM benthic expert group stated during the Hamburg workshop (July 2012, See Annex 1), that the quality assessment of the habitat should be based on its community level (EUNIS level 5) to take into account and reduces a factor of the natural variability of communities, when assessing effects of pressure. However, in specific local context (depending of the area to be assessed), where natural variability between communities is lower than effects of pressures, a slightly higher EUNIS level (e.g. L4 or 3) could be tested and considered (See BH2-B, Annex 3). Both biological and physico-chemical data (e.g. oxygen, flow and organic matter rate) may be influenced by human and/or natural pressures, and could be simultaneously considered as state variables and a proxy for the level of disturbance (validated by pressure data). The collection of (semi-)quantitative pressure data, at relevant and compatible temporal and spatial scales, is a key step to integrate this metric and to quantify the pressure-state relationship (i.e. impacts).

Lack of adequate data at (sub)-regional scale compromises the establishment of clear and accurate pressure-state relationships, and thus possibility to define accurate assessment values for each habitat versus pressure pair. This is due to both lack of adapted monitoring and data flows barriers. Even if promising, this indicator requires more development and testing to be fully operational for all OSPAR and MSFD issues. Issues and action plans to further progress were developed through EcApRHA<sup>3</sup> research programme and OSPAR process. For an OSPAR indicator to be operational, the methodological specifications need to be completed and agreed by the expert group, as well as having in place the monitoring and communication arrangements (CEMP).

The development of this common approach is closely linked to those of BH1 (typical species composition – candidate indicator), BH3 (physical damage of predominant and special habitats – common indicator) and BH4 (area of habitat loss – candidate) development, to ensure complementarity and avoid redundancies. There has been no further development for BH5 (size-frequency distribution of bivalve or other sensitive/indicator species), however this indicator, with a specific parameter (size), should also be considered in future development and gap filling. It is anticipated that the overall assessment of benthic habitat requires combining information provided by these indicators (at least BH3 and BH2 in a first step, to combine complementary and respectively wide scale spatial approach to fine scale ground-truthing. See EcApRHA deliverables 2.3 and 4.1).

For a sub-regional scale integrated assessment (See EcApRHA), the common approach has to be used in combination with the indicator “Extent of Physical damage to predominant and special habitats” (BH3). As a positive feedback, the results from BH3 could help optimise and design monitoring assessment areas to assess condition of a habitat type against a pressure gradient. To report GES at the (sub)-regional scale, the method to scale up assessment/monitoring areas/stations results should be discussed in a second step. This scaling up of assessment at sub-regions requires the development of a method to extrapolate data from assessment areas at a community level (EUNIS 5) to sub-regions, via broad habitat type (EUNIS 3).

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<sup>3</sup> Applying an Ecosystem Approach to (sub) Regional Habitat Assessments (EcApRHA): Addressing gaps in biodiversity indicator development for the OSPAR Region from data to ecosystem assessment. This project is co-financed by the European Union’s DG ENV/MSFD/Action Plans 2014, agreement no. 11.0661/2015/712630/SUB/ENVC.2 OSPAR. [www.ospar.org/work-areas/bdc/ecaprho](http://www.ospar.org/work-areas/bdc/ecaprho)

## 2 Monitoring

Regional assessments on benthic habitats are at an early stage of development and this common approach will be further elaborated in subsequent assessment cycle(s).

More details on monitoring and assessment principles of the common approach are described in BH2 technical specification in **Annex 1**, which aims to contribute to the further updating of the CEMP guideline when agreed both at expert and policy levels. Details on already agreed and implemented monitoring and assessment in the context of the European Union Water Framework Directive are described in **Annex 2**. Details on the partial OSPAR intermediate assessment for the Southern North Sea are described in **Annex 3**.

It is anticipated that current monitoring, and pressure data, have gaps to fully assess all habitats, against all pressure type (See Table 1) in all OSPAR maritime area, notably for offshore habitats.

### 2.1 Purpose and quantitative objectives

Depending on habitat and pressure type to be assessed (according to specific assessment methods and scales), this common approach can be adapted to enable the analyses of impacts from each human pressure type on the condition of each benthic habitat type (see Table 1). It should thus inform of management measures for human activities generating pressures, notably the maximum acceptable level of pressure, for sustainable use (See also paragraph 3.3 on assessment criteria).

This common approach was explicit in the MSFD Commission Decision on GES (2010/477/EU), for the indicator 6.2.2, partly explicit in indicators 1.6.1, 1.6.2 and 6.2.1, and implicit in Criteria (applied to benthic habitats):

- 2.2. Environmental impact of invasive non-indigenous species
- 4.3. Abundance/distribution of key trophic groups/species
- 5.2. Direct effects of nutrient enrichment
- 5.3. Indirect effects of nutrient enrichment
- 6.1. Physical damage, having regard to substrate characteristics
- 7.2. Impact of permanent hydrographical changes
- 8.2. Effects of contaminants
- 10.2. Impacts of litter on marine life

According to the recently revised Marine Strategy Framework Directive (MSFD) Guidance - COMMISSION DECISION (EU) 2017/848, this common approach could be applied, notably through integration with other indicators (to be further discussed, work in progress), to assess Criteria (applied to benthic habitats):

- D6C1: Physical loss (permanent change) of the natural seabed [*at community level*]
- D6C3: each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions [...], by physical disturbance
- D6C5: The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions
- D4C1: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures

- D2C3: Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species
- D5C6: The abundance of opportunistic macroalgae is not at levels that indicate adverse effects of nutrient enrichment
- D5C7: The species composition and relative abundance or depth distribution of macrophyte communities achieve values that indicate there is no adverse effect due to nutrient enrichment including via a decrease in water transparency
- D5C8: The species composition and relative abundance of macrofaunal communities, achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment
- D7C2: Spatial extent of each benthic habitat type adversely affected (physical and hydrographical characteristics and associated biological communities) due to permanent alteration of hydrographical conditions
- D8C2: The health of species and the condition of habitats (such as their species composition and relative abundance at locations of chronic pollution) are not adversely affected due to contaminants including cumulative and synergetic effects
- D8C4: The adverse effects of significant acute pollution events on the health of species and on the condition of habitats (such as their species composition and relative abundance)

Further framework development (monitoring and assessment methods, detailed protocols and data flows) is however needed to address all potential MSFD/OSPAR purposes. It should also include the necessary flexibility (both for relevant metrics and indices to be used) to take into account the wide range of applications to different habitat types, to target offshore habitats and to assess sensitivity/tolerance to various pressure types. These further works should be made according to the detailed technical specification (Annex 1), which is a living archiving document, to be updated by BH2 lead, describing all already agreed principles made by contributing experts.

## 2.2 Monitoring Strategy

Relevant assessment scales for BH2 should be at the benthic habitat community scale (EUNIS level 4 to 6) to take into consideration and reduce a factor of the natural variability of communities, which could be higher than effects of pressure. Corresponding geographical scale depends both on habitat type and pressure type to be assessed. To be comparable at (sub)regional level, a proposal of 3 nested scales for monitoring was discussed in the expert group. The three scales include:

- Network of stations at the (sub)-regional scale (common monitoring and inter-calibration for EU reporting)
- Network of stations at the national scale (national funding, specific pressure or habitats, and inter-calibration for national and EU reporting)
- Network of assessment areas, at a site scale, adapted to specific local pressure and habitat types (and according to a risk based approach; fig.1). It is to note that these assessment areas are conditioned by a prioritised habitat-pressure pair and aim to quantify specific state-pressure relationships, and should be adaptive and adapted, depending on the specific habitat and pressure type (both for specific relevant spatial and temporal resolution). Coordinated national and sub-regional networks of assessment area would be more cost-efficient, to share habitat/pressure pairs to be quantified. If no or low impacts are measured at a location during the monitoring, or if another habitat/pressure is prioritised (e.g. appearance of a new pressure), the network should be updated ((re)moving or adding specific assessment areas). This update requires a close link and

high reactivity with local management (policy-makers) and should enable, in the case of newly planned activities, to start monitoring pressures before, during and after potential impact by the occurring activity.

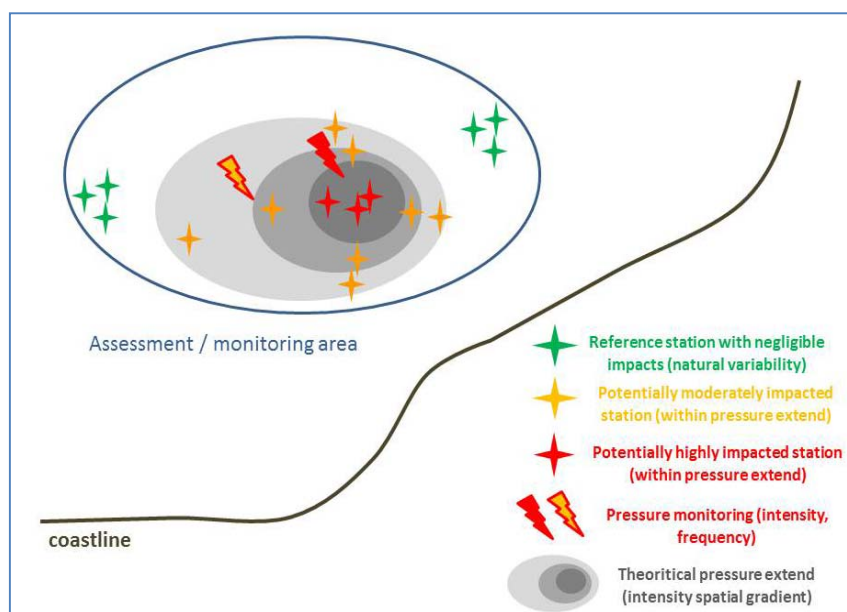


Figure 1: Theoretical principle of an assessment/monitoring area, for specific pressure and habitat types. Scale and spatial pattern may vary from meters to kilometres, depending of the type of pressure and habitat distribution and pattern. Monitoring design (scale, frequencies, etc) must be adapted to the ecological and disturbance (pressure) characteristics (Elliott et al., in press).

### 2.3 Sampling Strategy and Quality assurance/ Quality Control

The required methods and effort for ecological characteristics strongly depend on the habitat type. Epibenthic species on hard substrates are generally monitored using quadrats counts or optical, non-destructive methods. Endobenthic communities are generally sampled using standardized grabs or corers. To avoid spurious evaluations, minimum sample estimation (replications of samples) is strongly recommended. It will be a task of the working group to advice on the most relevant method for each habitat, according to the pressure type. Lots of standards already exist for many types of habitats, but still need harmonization at the EU level. For example, it is recommended to use the ISO norms for benthic communities sampling:

- EN ISO 16665. Edition: 2014-08-01. Water quality — Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna.
- EN ISO 19493. Edition: 2007-09-01. Water quality — Guidance on marine biological surveys of hard-substrate communities.

Ultimately, a guidance of detailed recommended methods for each pair of habitat per pressure types, including sub-regional specificities, should be produce to ensure comparability at the European or (sub)-regional scale.

The spatial planning of the monitoring (for each nested assessment scale, spatial resolution of sampling locations, etc.) depends of BH2 metrics, habitat type, pressure type, exposure to pressure (scale and intensity) and (sub)-regional potential specificities. These specificities should be further discussed and detailed by expert groups. Furthermore, monitoring budget constraints often play a role. Optimisation with other indicators monitoring requirements (notably BH1 and BH3) and with existing or future monitoring programmes (both on ecological and disturbance parameters) should be investigated.

Monitoring frequencies should also be discussed, depending on habitat and pressure types (See table 1). It will be determined, case by case, by the natural variability of biological and environmental parameters, at



the scale of habitat, and by the variability of anthropic disturbances (intensity and frequency). A cost-benefit analysis should also be conducted, including optimised monitoring (both between indicators, and with other biodiversity and pressure/activities monitoring programmes).

Monitoring requirement for BH2 needs further consideration within OSPAR (specifically ICG-COBAM and the relevant expert groups, in close interactions with ICG-C and ICG-MSFD). Ideally, a guidance document, or more probably a set of guidance documents (according to each habitat and/or pressure types), should be produced as a supplement to this guideline to advise on detailed and specific BH2 monitoring requirements and facilitate its implementation. These documents should include potential (sub)-regional specificities. It will be a step by step work, which habitat/pressure pairs will need to be prioritised.

## 2.4 Data reporting, handling and management

Currently, all datasets are produced and managed by each Contracting Parties, including for Water Framework Directive (200/60/CE<sup>4</sup>) elements of the common approach. Thus, monitoring and data flow at (sub)-regional scale still need to be defined and coordinated for most of habitat and pressure types.

- *Reporting format (Available via a link in the CEMP Appendices)*  
*[To be completed, according to each habitat and pressure types to be assessed...]*
- *Data metadata schema (Link to ODIMS<sup>5</sup>, INSPIRE<sup>6</sup> compliant)*  
*[To be completed, according to each habitat and pressure types to be assessed...]*
- *Confidence levels in data*  
Biological data: The quality of the biological data depends largely on the sample collection and taxonomic expertise of the analysts and of the quality control for each of the monitoring networks. Hence, caution should be taken when compiling data from different sources. Spatial and temporal resolutions have to be compatible with other dataset (environmental, pressure; See Annex 1).  
Environmental data: spatial and temporal resolutions have to be compatible with other datasets (biological, pressure).  
Pressure data: spatial and temporal resolutions have to be compatible with other datasets (biological, environmental).  
*[To be completed, according to each habitat and pressure types to be assessed...]*
- *Data flows described (Additional to information in CEMP Appendix)*  
Once the common assessment method is defined, and specific ones (per habitat and pressure type), compatible monitoring programmes need to be in place to produce relevant data (figure 2). There are currently many gaps, both in the methods, ongoing relevant monitoring and data availability, to assess or even test BH2 for all habitats and pressure types (table 1). BH2 thus requires further work to be fully operational at (sub)-regional scale to address all MSFD/OSPAR issues. Nevertheless, previous and ongoing work summarised here has enabled the potential of this

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<sup>4</sup> DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L327, 22/12/2000).

<sup>5</sup> ODIMS: OSPAR Data and Information Management System. <http://odims.ospar.org/>

<sup>6</sup> The INSPIRE Directive aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. <http://inspire.ec.europa.eu/>

common approach, and contribution to a partial assessment. Figure 2 highlights data flows will have to be established according to the policy on data sharing of each network and institution.  
 [To be completed, according to each habitat and pressure types to be assessed...]

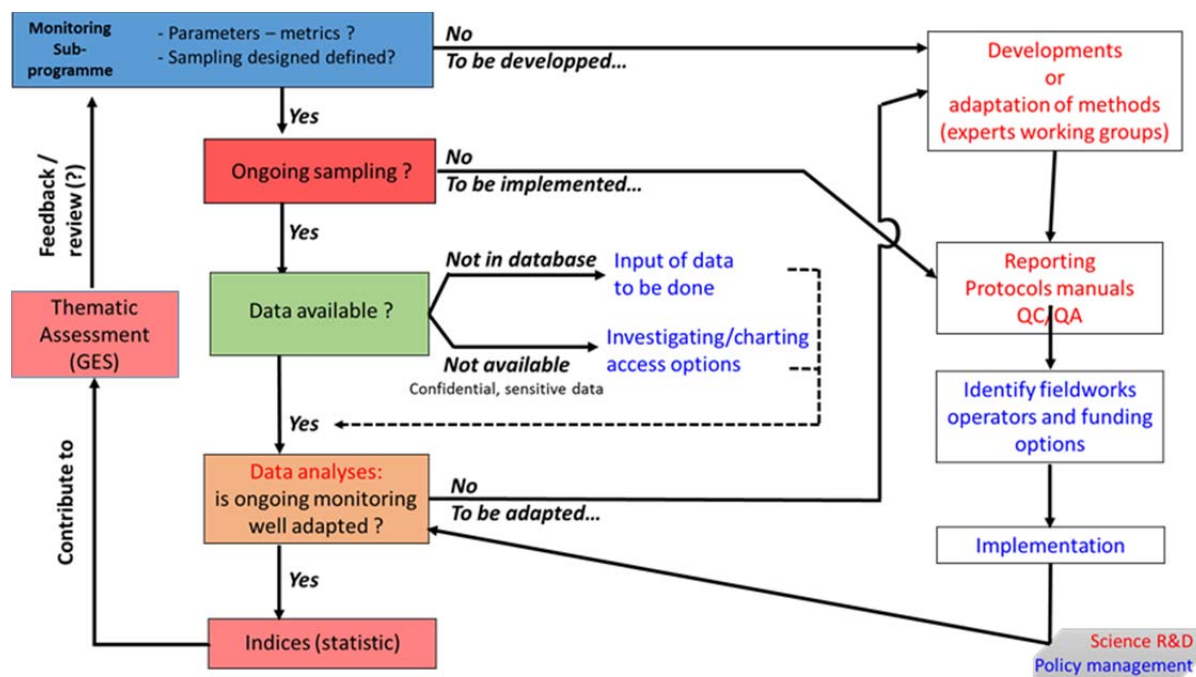


Figure 2: Technical process to implement an operational thematic assessment, at indicator or more integrated levels.

### 3 Assessment

Regional assessments on benthic habitats are at an early stage of development and this common approach will be further elaborated in subsequent assessment cycle(s).

More details on monitoring and assessment principles of the common approach are described in BH2 technical specification (Annex 1). Details on already agreed and implemented monitoring and assessment in the context of the European Union Water Framework Directive are described in Annex 2. Details on the partial OSPAR intermediate assessment for the Southern North Sea are described in Annex 3.

Results for the OSPAR intermediate assessment (2017) are available at <https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/habitats/condition-of-benthic-habitat-defining-communities/>

#### 3.1 Data acquisition

- How you extract the data specifically for your assessment question  
 [To be completed and detailed, according to each habitat and pressure types to be assessed...]

#### 3.2 Preparation of data

- Normalisation of data (If it has come from different monitoring methods)  
 [To be completed and detailed, according to each habitat and pressure types to be assessed...]

- *Aggregation and integration of data acquired*  
[To be completed and detailed, according to each habitat and pressure types to be assessed...]

### 3.3 Assessment criteria

- *Defining assessment unit/scale (temporal and spatial)*  
The assessment unit is the benthic habitat community, defined at corresponding EUNIS level (4 to 6).  
Assessment scale should be adapted, depending on pressure type to be assessed. For example, assessment units in Water Framework Directive are “waterbodies”, as defined by each Member State to report on them ecological quality status. Benthic assessments contribute then as a “quality element”, in addition to other quality elements such as pelagic (plankton) assessment and fish assessment (estuaries), to assess the biological status of the water body. Within the WFD, which by definition aims to assess ecological status of water bodies through quality elements, integration rules (often “one out all out”) are applied between biological, chemical and hydrological status to assess each waterbody quality status, against eutrophication (effects of nutrients and organic enrichments). So, even if the benthic habitat is assessed at community level, waterbodies are the relevant assessment scale for management of eutrophication, as it enables to identify source of pressure, mainly from terrestrial or coastal inputs. Thus, results of benthic habitat assessment contribute as one of the quality element, to conclude on the ecological quality status of the wider waterbody.

For the specific partial assessment of the Southern North Sea against abrasion by bottom trawling fisheries (Annex 3), and according to the generally lower alpha (local species richness) and beta (habitats) diversities in this sub-region, it was tested and agreed that this partial assessment could be conducted on EUNIS level 3, subdivided by two depth ranges, for each area assessed (See Annex 3). It was recognized that in most of other OSPAR area, where diversity of habitats at community level are greater, the common approach recommendation to undertake sampling and assessment at community level (EUNIS L4 to 6) would be required. For other pressure types, no integration rules have been yet developed, however this needs to be further discussed. The combination with other benthic indicators (e.g. for physical disturbance by bottom-trawling fisheries, according to the proposed method developed through EcApRHA research programme, for integrated assessment), would enable a wider scale (spatially) and more complete (improved confidence) assessment, adapted to the management of each pressure type (See EcApRHA deliverable 5.6 – Action plan and OBHEG work plan).

*[To be completed and detailed, according to each habitat and pressure types to be assessed...]*

- *Baseline/ reference level*  
According to ICG-COBAM (2012) and previous experts meetings, the following baseline and assessment value methods are strongly recommended for BH2:  
\* Baseline setting: “reference” state, with negligible impacts. An existing “reference” state, simultaneous monitored with assessed observations units, for each habitat type, is the most scientifically robust, transparent and comprehensible method. Furthermore in the context of climate and global changes, past (historical data) or modelling of “reference” states are less robust and relevant, and should be avoided for condition assessment, except for some extreme cases (no actual “references” existing at all assessment scales). As BH2 is conceptually calibrated along a pressure gradient, the reference may accommodate some impacts as long as the

assessed gradient of resulting state cover the GES/no GES range (expected shift of the community at this boundary) (Elliott et al., in press). As Marine Protected Areas (MPAs) begin to recover to a less impacted state (if adequately managed, enforced and appropriately designated), the number and quality of “reference” areas will increase. Experts’ judgement is recommended as an integral part of the baseline setting approach for benthic habitats. However, in specific local context (depending of the area to be assessed) pristine (or least damaged) benthic habitats communities may not be present any more due to widespread and long term chronic fishing pressure. In this case, an alternative reference setting principles could include the use of a high percentile value of a set of index values from a least disturbed area and period (of 6 years for reporting). The precise percentile value used can be adjusted to the degree of chronic fishing pressure, or any other chronic human pressure, using a well-defined expert judgement rule, in the specific assessed area. If sufficient reference values of good quality are available, the construction of a depth-reference value model is recommended, because it enables the estimation of reference values for assessment areas with insufficient benthos data. See Van Loon et al. (in press) and Annex 3 (BH2-B) for more details and specific application.

- \* Assessment value setting: assessment value set as a deviation from the baseline. The specific state assessment values which are set should account for the natural variability in space and time of the habitat type and its potential for recovery (resilience). The complementary use of experts’ judgements is recommended.

In addition to these well-defined principles, the setting of baselines and assessment values requires testing/validating by case studies (See Annex 1, II.1) and calibrated by the implementation of BH2 at (sub-)regional scale (See Annex 1, III.2).

*[To be detailed, according to each habitat and pressure types to be assessed...]*

- *Assessment value*

According to BH2 definition and stage of development, a qualitative assessment value has actually been discussed in experts group (See Annex 1) and defined as: “Anthropic pressures are at a level (both intensities and frequencies) that does not adversely compromise recovery (resilience) of benthic habitat communities, both in its diversity, structure and functions”.

The progressive operationalisation of BH2 would enable to quantify and estimate this assessment value and current quality status compared to available baselines, for each habitat and pressure type prioritised. Development of future integrated assessment, by combining other indicators (specifically area-related ones for wider scales) would enable to produce spatial distribution of assessment values, for each assessed habitat and pressure type prioritised (See EcApRHA deliverables 2.3 , 4.1 and 5.6, and Elliott et al, in press).

*[To be further discussed and completed, both by scientist and policy makers, according to each habitat and pressure types to be assessed. Risk-based approach and precautionary principle<sup>7</sup> are strongly recommended in case of lack of knowledge and notably for multiple co-occurring pressures...]*

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<sup>7</sup> Refer to <http://www.ospar.org/about/principles/precautionary-principle>

### 3.4 Spatial Analysis and / or trend analysis

- *Statistical analysis (e.g. Method for trend analysis, Establishment of confidence limits)*  
*[To be completed and detailed, according to each habitat and pressure types to be assessed...]*

### 3.5 Presentation of assessment results

- *Consideration of target audience and appropriate communication style*
- *Assessment metadata schema (link to ODIMS)*
- *Confidence in assessment (data and method, including spatial and temporal coverage)*  
*[Work and document (assessment sheets) in progress, to be finalised for OSPAR intermediate assessment 2017]*

## 4. Change Management

- *Responsibility for follow up of the assessment is the Biodiversity Committee via the ICG-COBAM expert group for Benthic Habitats;*
- *Links and coherence with ICG-MSFD, EIHA and ICG-C for (cumulative) pressures should be further strengthened. Links and coherence with other relevant European expert groups to be maintained (HELCOM, BARCON, ICES/BEWG, JRC);*
- *This indicator, and links with other benthic, and potentially pelagic and trophic indicators (integrated assessments) was developed with the assistance of the EU-Cofinanced EcAprHA project 2015-2017.*

## 5. List of Annexes

Annex 1 – Detailed technical specifications of BH2

Annex 2 - Condition of benthic habitat communities (BH2-A): Some coastal habitats in relation to nutrients and/or organic enrichment. CEMP specific guidelines

Annex 3 - Condition of benthic habitat communities (BH2-B): Subtidal Habitats of the Southern North Sea. CEMP specific guidelines

## 6. References:

*Elliott S., Guérin L. and Grall J., in press. Assessment of marine benthos pressure-state relationships in the absence of pristine benthic habitats. In Springer series ‘Humanity and the Seas’: Multipurpose Marine Protected Areas: A New Approach for Managing the Seas.*

*ICG-COBAM, 2012. “OSPAR’s MSFD advice manual on biodiversity. Approaches to determining good environmental status, setting of environmental targets and selecting indicators for MSFD descriptors 1, 2, 4 and 6”. Version 05/03/2012. 114p. + annexes. <http://www.ospar.org/work-areas/cross-cutting-issues/msfd/msfd-advice-manuals>*

*Van Loon W.M.G.M., Walvoort D.J.J., Van Hoey G., Vina-Herbon C., Blandon A., Pesch R., Schmitt P., Scholle J., Heyer K., Lavaleye M., Phillips G., Duineveld G.C.A., Blomqvist M. A regional benthic fauna assessment method for the Southern North Sea using Margalef diversity and reference value modelling. Ecological Indicators, in press, 2017.*

Walvoort D.W.W. and Van Loon W.M.G.M., 2016. BENMMI user manual. <http://publicaties.minienm.nl/documenten/user-manual-benmmi-3-0>

*More references included in Annexes 1, 2 and 3 (living documents of the OSPAR Benthic Habitat Expert Group)*

## OSPAR CEMP guidelines

Common Biodiversity Indicators: Condition of benthic habitat communities (BH2)

Technical Specifications

Annex 1: Technical specifications – method development

# ANNEX 1

## OSPAR – Common Biodiversity Indicators Condition of benthic habitat communities (BH2)

### Technical specifications (method development) Version 2018/01/12

*This document is an updated “technical specifications” of the “condition of benthic habitat communities” OSPAR indicator (BH2), as a “living” document (first drafted in ICG-COBAM, 2013b), presented and adopted at BDC 2013 and which has been regularly updated, according to work progressed. These technical specifications summarises main work conducted since 2011 and conclusions agreed by experts, including contributions of other relevant working groups (e.g. ICES, JRC, EIHA and ICG-C) and associated research projects. This work in progress is part of the Term of Reference of ICG-COBAM and is made in the continuity of its previous works on indicators, of which terminology, principles and results are described in reference documents<sup>8</sup>. Drafted by Laurent Guérin (BH2 lead, FR), integrating experts feedback, from dedicated workshops: Hamburg (10-11/07/2012), Madrid (29-30/10/2013), Dinard (8-10/07/2014), Aberdeen (16-17/06/2015), Warnemünde (29-30/10/2015); Dinard (16-17/03/2016), London (20-22/06/2017), ICES (28/04-02/05/2014, 16-20/02/2015, 04-08/05/2015, 9-13/05/2016); JRC (7-9/09/2015, 20-21/04/2016) and associated research programmes: Southern North Sea Project (2014-2016, coord. Willem Van Loon, NL), ANR BenthovAl (2014-2017, coord. Olivier Gauthier, FR) and EcApRHA<sup>9</sup> (2015-2017, coord. OSPAR Secretariat).*

#### I.1. Summary description of the indicator (principles and development process)

**Name:** Condition of benthic habitat communities

**OSPAR Code:** BH2

**Status:** Adopted at BDC and OSPAR 2013 as **OSPAR-wide (sub-regions II, III and IV) common indicator**

**State of methodological development:**

Development step	State
Ecosystem components attributed (species/habitat types)	Defined. Intertidal, shallow and shelf benthic habitats. Applicability/adaptability to bathyal and abyssal benthic habitats (deep sea) is less obvious and would need further discussion
Applicability to sub-regions	Yes for all, with possible specificities (e.g. for baseline / GES)
Biological and environmental parameters and metrics	Defined for parameters. Metrics may be adapted, according to sampling protocols to be applied

<sup>8</sup>ICG-COBAM, 2011. “OSPAR’s MSFD advice manual on biodiversity. Approaches to determining good environmental status, setting of environmental targets and selecting indicators for MSFD descriptors 1, 2, 4 and 6”. Version 05/03/2012. 114p. + annexes.

ICG-COBAM, 2013a. “Report by ICG-COBAM on the development of an OSPAR common set of biodiversity indicators. Part A: process for selecting indicators ; Part B: abstracts of proposed common biodiversity indicators”. Version 18/02/2013. 40p.

ICG-COBAM, 2013b. “Report by ICG-COBAM on the development of an OSPAR common set of biodiversity indicators. Part C : technical specifications”. Version 18/02/2013. 156 p.

<sup>9</sup> Applying an Ecosystem Approach to (sub) Regional Habitat Assessments (EcApRHA): Addressing gaps in biodiversity indicator development for the OSPAR Region from data to ecosystem assessment. This project is co-financed by the European Union’s DG ENV/MSFD/Action Plans 2014, agreement no. 11.0661/2015/712630/SUB/ENVC.2 OSPAR. [www.ospar.org/work-areas/bdc/ecapra](http://www.ospar.org/work-areas/bdc/ecapra)

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Disturbance/pressure parameters and metrics	Defined for parameters. Metrics depends of pressure types, and data availabilities
Monitoring requirements	Partly defined (to be further discussed and agreed, depending of habitat and pressure types)
Assessment scales	Defined. Habitat at community level
Baseline / GES	Principles: defined Case studies: several realised in 2014-2017 Calibration: no (operationalisation needed)

### *State of operationalisation:*

<b>Operationalisation phase</b>	<b>State</b>
Work plan	Initial (2013-2015) + COBAM/EcApRHA (2015-2017) + OBHEG multi-year Work plan (submitted to COBAM (2) 2017)
Methodological development	Partly defined, still on-going for full potential. Living document regularly updated from experts meeting (e.g. workshops), for submission to COBAM and BDC
Case studies / data flows	Partly. Several made on existing data. Case studies realised in 2014-2017. Sub-regions coverage and representativeness depends on data availabilities and CP's involvement. Data flows and policy to be further discussed and agreed
Status assessments (baseline and GES setting, reporting)	Requires an updated <u>Joint Assessment and Monitoring Programme (JAMP)</u> , according to technical specifications and monitoring requirements. Discussion and agreement with policy-makers needed

### **Context and description of BH2**

Given the complexity of biodiversity, both in its range of character and the number of aspects that contribute to an assessment of state, it is common practice to use a set of indices to assist in monitoring and assessment programmes and to help simplify this complexity. There are a variety of different types of indices: state (including impact), pressure and response. These help limit the number of parameters that need to be monitored to those which can most effectively represent wider functional and structural aspects of the ecosystem. Where possible, state indices should closely respond (in space and time) to a particular anthropogenic pressure (by responding to the impact of the pressure) and hence be linked to associated management requirements.

The assessment of environmental state provided by one or more indices should allow inferences to be made on the wider state of biodiversity components in that ecosystem. State means the actual (measured or otherwise assessed) benthic condition (e.g. of a species, species functional group, community or habitat) in a given geographical area. The assessment of state can be derived by taking direct measurements of the particular biodiversity component ('state indices') or indirectly by measuring the prevailing anthropogenic pressures ('pressure indices'). The best assessment and way to link state changes to pressure would be to measure simultaneously the particular biodiversity component and the prevailing pressure (both human and natural). Additionally, it is usually necessary to consider the cost of implementing the indicator.



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Species composition and relative abundances are used to study or assess the biodiversity and state of benthic habitat communities (EUNIS<sup>10</sup> level 4 to 6). A plethora of Benthic Indices (BI) exists, but their use depends on (1) objective of the assessment/study (e.g. pressure or habitat types), (2) geographical/spatial resolution scale and (3) ecological and statistical relevancies. The development of BI, combining various metrics, indices and sensitivity/tolerance classifications, was made mandatory by the EU Water Framework Directive (WFD) for its implementation and assessments. Multi-metric BI (See appendix) classically contains diversity indices (e.g. Shannon or Simpson), species richness indices (e.g. the number of species, Margalef D) and/or classification of sensitive/tolerant species (e.g. AMBI or ITI). This sensitivity of species is a proxy used as disturbance quantification for some pressures on benthic community. This requires a good knowledge, both for community and species taken into account, of its natural spatial and temporal scales of variation and its sensitivity to a specific pressure gradient.

Multidimensional scaling in community structure from a reference condition, aims to link pressure (for management issues) and pressure-impact calibration of state indices (level of disturbance/resilience), with various pressures types at the community level. The latter eliminates the need for species sensitivity classification given community composition changes can be quantified. In the wider regional context for OSPAR or MSFD requirements, there are actually many knowledge gaps regarding the effect of pressures on different habitats types (Kaiser et al. 2006).

The collection of (semi-)quantitative pressure data and the construction of a suitable pressure index (HELCOM 2010) is a key step to integrate this metric and to validate the pressure-impact evaluation. This common approach is explicit in the indicator 6.2.2 of the Commission Decision on GES (2010/477/UE), partly explicit in indicators 1.6.1, 1.6.2 and 6.2.1, and implicit in Criteria (applied to benthic habitats):

- 2.2. Environmental impact of invasive non-indigenous species
- 4.3. Abundance/distribution of key trophic groups/species
- 5.2. Direct effects of nutrient enrichment
- 5.3. Indirect effects of nutrient enrichment
- 6.1. Physical damage, having regard to substrate characteristics
- 7.2. Impact of permanent hydrographical changes
- 8.2. Effects of contaminants
- 10.2. Impacts of litter on marine life.

According to the recently revised Marine Strategy Framework Directive (MSFD) Guidance - COMMISSION DECISION (EU) 2017/848, this common approach could be applied, notably through integration with other indicators (to be further discussed, work in progress), to assess Criteria (applied to benthic habitats):

- D6C1: Physical loss (permanent change) of the natural seabed [*at community level*]
- D6C3: each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions [...], by physical disturbance
- D6C5: The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions
- D4C1: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures

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<sup>10</sup> The European Nature Information System habitat classification is a system to classify types of habitats on several nested levels. The higher the level, the more details and sub-types of habitats are included. Level numbering used here is from EUNIS version 10/2016. <http://eunis.eea.europa.eu/>

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- D2C3: Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species
- D5C6: The abundance of opportunistic macroalgae is not at levels that indicate adverse effects of nutrient enrichment
- D5C7: The species composition and relative abundance or depth distribution of macrophyte communities achieve values that indicate there is no adverse effect due to nutrient enrichment including via a decrease in water transparency
- D5C8: The species composition and relative abundance of macrofaunal communities, achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment
- D7C2: Spatial extent of each benthic habitat type adversely affected (physical and hydrographical characteristics and associated biological communities) due to permanent alteration of hydrographical conditions
- D8C2: The health of species and the condition of habitats (such as their species composition and relative abundance at locations of chronic pollution) are not adversely affected due to contaminants including cumulative and synergetic effects
- D8C4: The adverse effects of significant acute pollution events on the health of species and on the condition of habitats (such as their species composition and relative abundance)

Further framework development (monitoring and assessment methods, detailed protocols and data flows) is however needed to address all potential MSFD/OSPAR purposes. It should also include the necessary flexibility (both for relevant metrics and indices to be used) to take into account the wide range of applications to different habitat types, to target offshore habitats and to assess sensitivity/tolerance to various pressure types. These further works should be made according to these detailed technical specifications, which are a living archiving document, to be updated by BH2 lead, describing already agreed principles made by contributing experts.

Depending on habitat and pressure type to be assessed (according to specific assessment methods and scales), this BH2 common approach can be adapted to enable the analyses of impacts from each human pressure type on the condition of each benthic habitat type (see tables 1 and 2). It should thus inform of management measures for human activities generating pressures, notably the maximum acceptable level of pressure, for sustainable use. Regional assessments on benthic habitats are at an early stage of development and this common approach will be further elaborated in subsequent assessment cycle(s).

Lack of adequate data compromises the establishment of clear and accurate pressure-state relationships, and thus possibility to define accurate assessment values for each habitat versus pressure pair. This is due to both lack of adapted monitoring and data flows barriers. Even if promising, this indicator requires more development and testing to be fully operational for all OSPAR and MSFD issues. Issues and action plans to further progress are defined and available through EcApRHA action plan and OBHEG multi-year work plan. For an OSPAR indicator to be operational, the methodological specifications need to be completed, detailed and agreed by the expert group, as well as having in place the monitoring and communication arrangements (CEMP).

The development of this common approach is closely made according to those of BH1 (typical species composition), BH3 (physical damage of predominant and special habitats) and BH4 (area of habitat loss) development, to ensure complementarity and avoid redundancies. There is actually no further development for BH5 (size-frequency distribution of bivalve or other sensitive/indicator species), however this indicator, with a specific parameter (size), should also be considered. It is anticipated that the overall

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assessment of benthic habitat requires combining information provided by these indicators (at least BH3 and BH2 in a first step, to combine complementary and respectively wide scale spatial approach to fine scale ground-truthing).

For a sub-regional scale integrated assessment (See EcApRHA), this common approach has to be used in combination with the indicator “Extent of Physical damage to predominant and special habitats” (BH3). As a positive feedback, the results from BH3 could help optimise and design monitoring assessment areas to assess condition of a habitat type against a pressure gradient. To report GES at the (sub)-regional scale, the method to scale up assessment/monitoring areas/stations results should be discussed in a second step. This scaling up to assessment at sub-regions require to develop method to extrapolate from assessment areas of a community level defined habitat (EUNIS 5) to sub-region, via predominant habitat level (EUNIS 3) and ecological subdivision of the sub-region (biogeographic area).

Table 1: Relationships between habitat and pressure types, and how / if the relationships are currently assessed or considered. Relationships based on the revised Marine Strategy Framework Directive (Commission Decision 2017/848/UE and MSFD Annex III 2017/845/UE). Broad pressure and habitat types (EUNIS L3) are described at high levels, however assessment of state-pressure relationship should be undertaken on a finer scales at habitat community (EUNIS L5) and pressure subtypes (See table 2, below). Monitoring, assessment and reporting should be completed per pressure and habitat type. Effects of cumulative (different types) pressures are currently not assessed (gap of knowledge). In the future, this could potentially be completed and/or combined to give an overall understanding of the condition of benthic habitats in the North-East Atlantic.

Benthic Broad Habitat Type, including their associated biological communities	Broad Pressure Type							
	Physical disturbance	Extraction/injury of species	Hydrological changes	Eutrophication (nutrients or organic enrichment)	Non-indigenous, pathogens, cultivated and genetically modified species	Contaminants	Litter	Energy, including under water noise
Littoral rock and biogenic reef				A				
Littoral sediment				A				
Infralittoral rock and biogenic reef				A				
Infralittoral sediment	P			A				
Circalittoral rock and biogenic reef				A				
Circalittoral sediment	P			A				
Offshore circalittoral rock and biogenic reef								
Offshore circalittoral sediment	P			P		P		
Upper bathyal rock and biogenic reef								
Upper bathyal sediment								
Lower bathyal rock and biogenic reef								
Lower bathyal sediment								
Abyssal								

Key:

A	Assessed and reported under OSPAR and the European Union Water Framework Directive (WFD)
	Considered under OSPAR and the European Union Marine Strategy Framework Directive (MSFD)
P	Partially assessed in the OSPAR Intermediate Assessment 2017
	Main risks (potentially widespread across the OSPAR maritime area)
	Relationship identified but not currently assessed

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Table 2: theoretical example of assessment result of condition of a habitat subtype (EUNIS level 5) against sub-types of ‘physical damage’ pressure. This should be used in combination with ‘physical damage to predominant and special habitat’ indicator for an integrated assessment of benthic habitats (where and how much impacted?). <sup>1</sup>Maximum acceptable level of pressure: from state-pressure relationship, level of pressure corresponding to the assessment value of the statistical index of condition, considered as unacceptable impact (no resilience, not recoverable, not sustainable). Depending on pressure sub-type, pressure unit could be expressed as intensity, frequency or both

### Broad habitat type (EUNIS L3 e.g. offshore circalittoral) sand versus physical damages

\* Habitat sub-type (EUNIS L5): e.g. *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment

Physical pressures sub-types	Condition of benthic habitat community
Permanent change of habitat characteristics (biotic or abiotic) e.g. infrastructure	Habitat loss
Removal of substratum (extraction) with possible recovery of same benthic community	Condition index value / maximum acceptable <sup>1</sup> level of pressure
Surface abrasion (e.g. by bottom trawling fisheries: )	Condition index value / maximum acceptable <sup>1</sup> level of pressure
Sub-surface abrasion (e.g. by bottom trawling fisheries: dredging)	Condition index value / maximum acceptable <sup>1</sup> level of pressure
Changes in suspended solids	Condition index value / maximum acceptable <sup>1</sup> level of pressure
Siltation rate changes	Condition index value / maximum acceptable <sup>1</sup> level of pressure

### 1.2. Ecosystem components attributed (species/habitat types)

Ecosystem components (fig. 1) relevant for BH2 are intertidal (mediolittoral), shallow and shelf benthic habitats, both special (including OSPAR list of threatened and/or declining habitats, except deep sea habitats; table 3) and MSFD broad habitats types (See tables 1 and 2), but at biological community level (e.g. EUNIS 4 or 5). For the purpose of MSFD, the term habitat addresses both the abiotic characteristics and the associated biological community. Traditionally applied to macro-endofauna (from 1 mm mesh size) of soft bottom sediments, the BH2 could conceptually apply to any community defining a habitat (e.g. including macro-epifauna and macro-flora like macroalgae for rocky habitats, or seagrass beds for angiosperms).

This indicator is thus conceptually applicable to rocky, biogenic reefs and coarse sediments habitats, but some adaptations could be required due to specific monitoring requirements (e.g. % recovery or densities for biological metrics).

Applicability/adaptability to bathyal and abyssal habitats is less obvious and would need further discussion.

Applicability/adaptability to microbenthos (up to 1 mm mesh size) and foraminifera (Schönfeld *et al.*, 2012) would also need further discussion.

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**MSFD Biodiv. Components : vertical vs pressure & coastal-deep sea gradient**

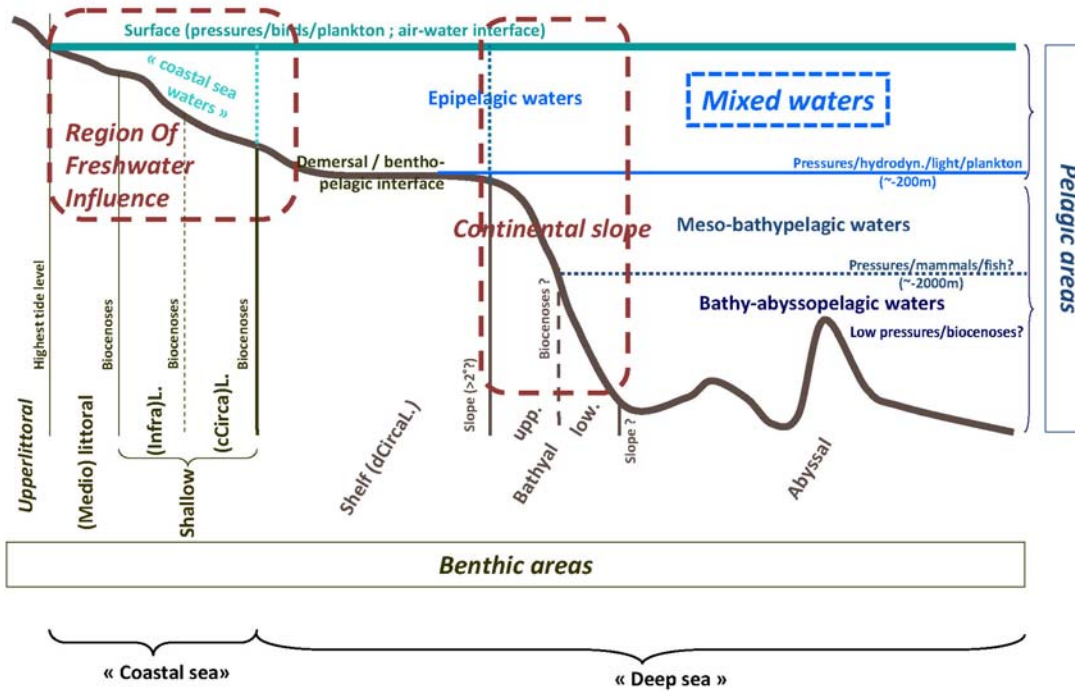


Figure 1: Biodiversity components (benthic and pelagic habitats). This scheme has been developed and adapted from ICG-COBAM works, by the interpretation of common ecological characteristics and MSFD requirements at Regional Sea scale.

Table 3: OSPAR List of threatened and/or declining habitats (Ref. 2008-6) and their theoretical applicability of BH2.

DESCRIPTION	OSPAR Regions where the habitat occurs	BH2 applicability
<b>HABITATS</b>		
Carbonate mounds	I, V	?
Coral Gardens	I, II, III, IV, V	?
<i>Cymodocea</i> meadows	IV	Yes
Deep-sea sponge aggregations	I, III, IV, V	?
Intertidal <i>Mytilus edulis</i> beds on mixed and sandy sediments	II, III	Yes
Intertidal mudflats	I, II, III, IV	Yes, but at biological community level (e.g. EUNIS 4 or 5) for all subtypes
Littoral chalk communities	II	?
<i>Lophelia pertusa</i> reefs	All	?
Maerl beds	All	Yes

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<i>Modiolus modiolus</i> beds	All	Yes
Oceanic ridges with hydrothermal vents/fields	I, V	?
<i>Ostrea edulis</i> beds	II, III, IV	Yes
<i>Sabellaria spinulosa</i> reefs	All	Yes
Seamounts	I, IV, V	?
Sea-pen and burrowing megafauna communities	I, II, III, IV	Yes
<i>Zostera</i> beds	I, II, III, IV	Yes

Habitats defined at biological community level, including invertebrates species listed by OSPAR (*Arctica islandica*, *Megabalanus azoricus*, *Nucella lapillus*, *Ostrea edulis*, *Patella ulyssiponensis aspera*) and habitat subtypes of Habitats Directive<sup>11</sup> list, should be considered. BH2 would potentially be applicable to all of these habitats, if defined at biological community level.

“Species habitats”<sup>12</sup> for OSPAR list and Habitats Directive lists for mammals, seabirds, turtles and fish should also be considered, where links with benthic habitats exist (e.g. to rest, feed, reproduce, etc). Depending on its characteristics, BH2 could be applied to assess these specific habitats status, and consequently, links with these species conservation status.

### 1.3. Indicator parameters and metrics

The common approach BH2 implies two types of information (parameters):

- (i) **ecological (state) characteristics: biological** (species composition and relative abundances) and **environmental** (substrate and water abiotic characteristics) variables of the sampling station;
- (ii) **disturbance characteristics**: type (e.g. nutrients or organic enrichments, mobile bottom gear fisheries, sediment extraction, contaminants, non-indigenous species, etc.), intensity (e.g. concentration of contaminants, abundances of NIS) and frequency (e.g. continuous, dates and periods of year, only one initial, etc.) of occurring pressure(s) that potentially cause damage.

The typical ecological metrics and dataset are composed of several data matrices related to the same observation units (sampling station):

- the community matrix: a biological matrix specifying the abundance (density, biomass), %coverage or presence/absence of all species<sup>13</sup>(recommended, but may be accommodated at lower level taxonomic groups) in different samples, pertaining to different positions in space and/or time;

<sup>11</sup>Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 22.7.1992. Directive as last amended by Directive 2006/105/EC (OJ L 363, 20.12.2006, p. 368).

<sup>12</sup>habitats related to mobile species by their functions, e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals

<sup>13</sup>It has to be taken into account that species communities may differ locally even if the habitat is similar (e.g. sandbanks). Attention has to be paid to the fact that species lists depend on the expertness of taxonomists in the monitoring teams. Different results could be caused by uneven taxonomic expertise in the teams that could mask the real differences in environmental status. The set-up of the relevant metric also has to be habitat specific and might be (further) developed by each Member State with respect to their (sub)-

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- the spatial and temporal matrices: specifying the position of observations in space and time (e.g. Global Positioning System coordinate(s) and date(s) of sampling);
- the environmental matrices: any number of matrices describing environmental conditions, as support parameters (e.g. grain size and/or profile imagery of sediment, organic matter rate, rock structure, water temperature, salinity, depth, hydrodynamics, etc.).

The disturbance characteristics may be indirectly estimate by the ecological ones (sensitivity classification of species or habitats, sediment profile imagery, etc.). But recent approaches recommend estimating the disturbance directly by pressure data. For policy and management issue (e.g. OSPAR, MSFD), this imply that BH2 has to be calculated and validated on ecological **and** pressure data (See above for parameters of disturbance characteristics) to estimate and calibrate impacts. The disturbance metrics and dataset should be acquired as much as possible at coherent and compatible spatial and temporal scales, with the ecological data. Ideally, the sampling strategy (observations units) should be collected along a disturbance gradient (both spatial and temporal) of a specific main pressure, in an area selected by a risk-based approach (pressure gradient within its extent, and close reference locations with negligible impacts; See I.5. fig.2 and Elliott et al., in press). Anthropogenic pressure data should be related to variation in benthic community structure. Ideally, disturbance data should be of a quantitative nature, but semi-quantitative can be accommodated in statistical models. In whole, the joint analysis of disturbance and community data should allow to adequately describe the EcoQ (Ecological Quality status) of habitats submitted to different anthropogenic pressures.

Besides, some biotic indices (BI) have been developed, including **alternative component** (e.g. foraminifera, Schönfeld *et al.*, 2012) **or parameters**. For example, Sediment Profile Images (SPI) provides exclusive in situ views of the sediment-water interface and subsurface sediments (Diaz and Treffy, 2006; Rhoads and Cande 1971). Acquired parameters are both relevant for ecological and disturbance characteristics. This technique can constitute a useful tool to assess sediment features and the activity of benthic organisms (Nilsson and Rosenberg, 1997), optimized for offshore cohesive sediments. SPI has been successfully used to detect benthic habitat changes (Rumohr and Schomann, 1992), including: organic enrichment (Karakassis et al., 2002; Labruno et al., 2012), benthic hypoxia (Nilsson and Rosenberg, 2000), and physical disturbance (Rosenberg et al., 2003). Other analysis like testing sensitivity of BI to fishing impacts have been recently published (Juan and Demestre, 2012). The SPI method could be usefully tested for the pressure monitoring of fisheries and other human pressures on the sea floor. Pressure data are necessary to validate the results.

### **Multi-metric approach and multivariate analysis**

Numerical ecology generally aims to statistically model the variance of the community matrix by way of the environmental matrices, while taking the spatial and/or temporal components into account. In the context of assessing EcoQ (Ecological Quality status), the community matrix is traditionally first summarised to a few or a single metrics that are used in further computations. This step can involve some form of multivariate analysis.

Notwithstanding their inherent differences in terms of elaboration, assumptions, and practical application, all EcoQ indices rely on a fundamental three-step process in establishing the status in a given location:

1. Computation of a Biotic Index (BI) using the community matrix;

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regional reference values. Incoherence with metrics used in the indicator BH1 "Typical species composition" should be avoided, and an optimization should be made for monitoring data (common parameters).

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2. Computation of an Ecological Quality Ratio (EQR), by comparing the observed BI to that of an undisturbed or least disturbed location (“reference”);
3. Transformation of observed EQR (standardized quantitative variation of the BI) to an EcoQ (target value = deviation from the baseline, limit between GES & non-GES) by relying on any number of conversion scales.

A number of scientific problems still plague each of these steps. This limits our ability to routinely interpret such results in the context of European Framework Directives. Generally, each used index and EcoQ have been developed for a specific issue, and specific assessment scale. Development, testing and implementation has thus to be made carefully, according to each assessment and scale requirements (specific to each Directives).

Experts recognised that many alternative algorithms exists to compute BI, but than most of BI actually used corresponds to one or a combination of these four following alternatives:

- Diversity indices (e.g. Shannon, Margalef d);
- Species sensitivity indices (based on species sensitivity/rarity classification, e.g. AMBI);
- Species biological traits indices (based on species biological traits classification, e.g. ITI);
- Multivariate analyses (on metrics and/or intermediate indices, e.g. Bray-Curtis similarity, BRI).

Thus, the way to combine these basic parameters and metrics in intermediate indices (e.g. diversity index, pressure index, etc.) or global multivariate analysis to build multi-metric indices (MMI), depend on the issue (pressure type), habitat types or sub-regional specificities, has still to be further discussed and agreed, depending on habitat and pressure types assessed. Nevertheless, alternative combinations and proposed options to build alternative BI or MMI are generally based on the same core datasets (ecological parameters and metrics) and could thus be tested alternatively or simultaneously in the case studies.

The “BENMMI” tool was developed in the Southern North Sea project and could be used to facilitate these calculations and testing (Walvoort and Van Loon, 2016).

### I.4. Spatial scope: applicability to sub-regions

BH2 is conceptually applicable in all sub-regions, for all relevant type of habitats (See I.2), with possible specificities (e.g. for baseline or GES). It is potentially more sensitive and more specifically linked, by definition, to anthropogenic pressure than the “typical species composition” indicator (BH1). Nevertheless, BH1 is complementary and a necessary preliminary step to characterize ecological state of habitats (natural variation, both at spatial and temporal scales) and high impacts (changes of habitats characteristics). BH3 and BH4, as wider scale area-related indicators, are also complementary and a necessary preliminary step to select prioritized assessment areas for BH2, according to a risk based approach.

Since same habitat may be dwelled by different species in different sub-regions, a specific set of habitats by sub-regions (OSPAR & MSFD) is expected. This work has to be linked (and avoid redundancies) with EUNIS, which update is in progress. Coordinated works with BH1 development and operationalisation should provide **a cross-table of main habitats ecological characteristics** (using a common typology, e.g. EUNIS), with ‘potential biological communities’ specificities within main biogeographic zones of the OSPAR region and sub-regions. The ultimate complementarity would be to complete BH1 monitoring (which spatial resolution can be higher, as frequency and costs may be lower) with additional monitoring requirements for BH2 (parameters, frequencies), by focussing on prioritized habitat X pressure pairs (with a spatial



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analyse (risk-based approach) provided by BH3) to calibrate the pressure/impacts relationship (See EcApRHA and OBHEG work plan).

The effect of pressures and relevant associated assessment scales depends of type of pressure (e.g. eutrophication impacts occurs generally at a wider scale than sediment extraction). Thus, some technical aspects of BH2 should vary and be specified for each category of pressure. A **classification of pressure types** have been discussed by the experts groups to test BH2 technical aspects according to each pressure type. As a first step, some pressure types have been prioritized, as mainly occurring at OSPAR (sub-)regional scale, notably physical pressures as noticed for BH3. Coordinated works with BH3 development and operationalisation should provide a **cross-table of main disturbance characteristics** (at least for physical pressures) and spatial analyses to conduct a risk-based approach, with potential vulnerabilities and specific impacts for each habitat type. The ultimate complementarity would be to calibrate the pressure/impacts relationship, by BH2 ground truthing, to fit BH3 vulnerability classification and impacts models (See EcApRHA and OBHEG work plan).

Further works and discussions in the OSPAR benthic habitat expert group and through associated research projects are on-going to progress on the testing of ecologically relevant habitats and pressure types for BH2 case studies. However, the (often limited) data availability often restrict the number of habitats/pressure pairs which can actually be assessed with sufficient statistical confidence and/or geographical coverage.

### 1.5. Assessment scales

#### Defining Assessment Scale (from ICG-COBAM, 2011)

Following the ecosystem-based approach required for implementation of the MSFD, the assessment of biodiversity components should be undertaken at ecologically relevant scales, taking into account the cumulative pressures and their impacts from human activities (Art 8.1b, Annex III Table 2) and based on the criteria provided for assessment in the COM Decision (e.g. habitat/species distribution, species population size, habitat extent and habitat/population condition). [...]

Defining scale can be confusing because this term is relevant in different ways depending on several different aspects of the MSFD. Thus scale should be considered in relation to:

- i. **Assessment of state (in relation to the definition of GES and associated state targets)** of one or several biodiversity components, as GES is determined at the level of the region/subregion (Art. 3(5)). These may be linked, by trophic relation for example in Descriptor 4 or functional relation such as between species and habitats (refer Habitats Directive). This aspect could be expressed as an 'ecological assessment area' (or aggregated sub-areas) for reporting purposes
- ii **Management measures**, which can be considered at either a local scale, to avoid missing or masking cumulative local impacts that could affect the overall quality status at larger scales, or at a broad scale to manage efficiently biodiversity components or pressures that operate over large areas of a region/subregion (as required by MSFD);
- iii **Monitoring** to assess state, expressed as the spatial and temporal resolution of data. These resolutions (number of sampling stations, accuracy of remote detection, sampling frequencies, etc.) are likely to be a compromise between "high resolution", which enable a very accurate, but expensive assessment and a more pragmatic approach, identifying a resolution in accordance with available resources which can then be used to define assessment scale and data needs. [...]

There are many different aspects of assessment scale (e.g. habitats occur at a different scale to many of the pressures acting upon them), with respect to the scale required to determine GES, this would depend on the scale of the habitat

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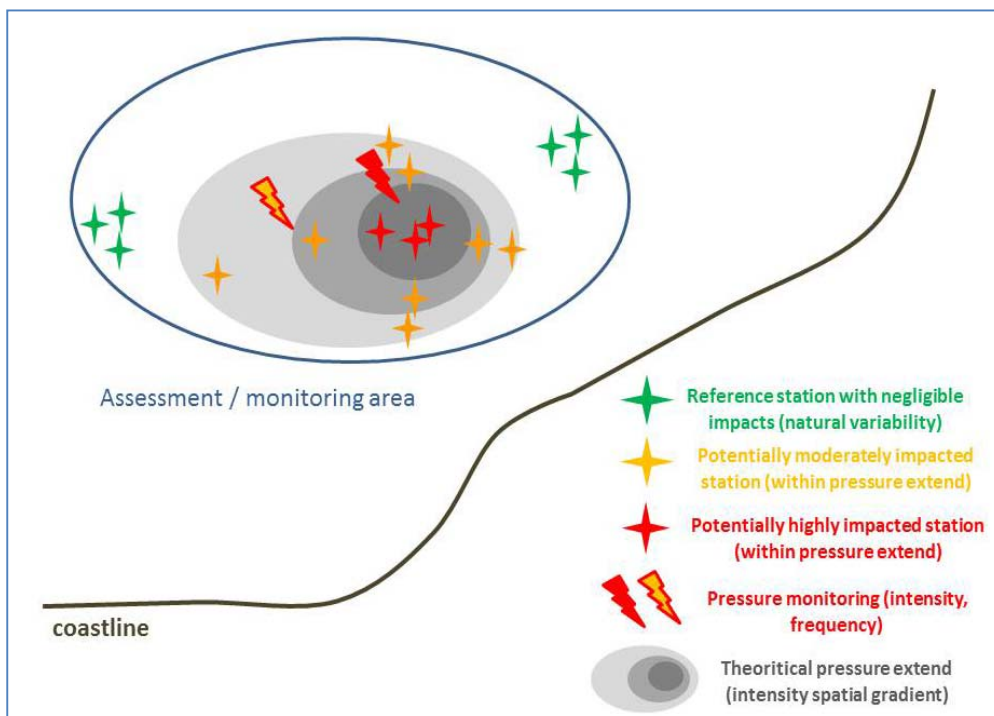
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within a particular assessment area. In practice this would require **consideration on a case by case basis**. [...] Assessment scales for habitats **are smaller than, and nested within**, sub-regions.

Relevant assessment scales for BH2 should be at the benthic habitat community scale (EUNIS level 4 to 6) to take into consideration and reduce a factor of the natural variability of communities, which could be higher than effects of pressure. Corresponding geographical scale depends both on habitat type and pressure type to be assessed. To be comparable at (sub-)regional level, a proposal of 3 nested scales for monitoring was discussed in the expert group. The three scales include:

- Network of stations at the (sub-)regional scale (common monitoring and inter-calibration for EU reporting)
- Network of stations at the national scale (national funding, specific pressure or habitats, and inter-calibration for national and EU reporting)
- Network of assessment areas, at a site scale, adapted to specific local pressure and habitat types (and according to a risk based approach; fig.1). It is to note that these assessment areas are conditioned by a prioritised habitat/pressure pair and aim to quantify specific state/pressure relationships, and should be adaptive and adapted, depending on the specific habitat and pressure type (both for specific relevant spatial and temporal resolution). Coordinated national and sub-regional networks of assessment area would be more cost-efficient, to share habitat/pressure pairs to be quantified. If no or low impacts are measured at a location during the monitoring, or if another habitat/pressure is prioritised (e.g. appearance of a new pressure), the network should be updated ((re)moving or adding specific assessment areas). This update requires a close link and high reactivity with local management (policy-makers) and should enable as much as possible, for the case of new planned pressure, to start monitoring before, during and after the pressure duration to have a complete understanding of the impacts.



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Figure 2: Theoretical principle of an assessment/monitoring area, for specific pressure and habitat types. Scale and spatial pattern may vary from meters to kilometres, depending of the type of pressure and habitat distribution and pattern. Monitoring design (scale, frequencies, etc) must be adapted to the ecological and disturbance (pressure) characteristics (Elliott et al., in press).

### 1.6. Monitoring requirements (parameters, frequency, material & methods): guidelines/specificities

The required methods and effort for ecological characteristics strongly depend on the habitat type to be addressed. Epibenthic species on hard substrates are generally monitored using quadrats counts or optical, non-destructive methods. Endobenthic communities are generally sampled using standardized grabs or corers. To avoid spurious evaluations, minimum sample estimation (replications of samples) is strongly recommended. It will be a task of the working group to advice for the more relevant method per habitat, according to the pressure type. Lots of standards already exist for many types of habitats, but still need harmonization at the EU level. For example, it is recommended to use the ISO method (ISO, 2011) for marine soft-bottom macrofauna monitoring. Ultimately, a guidance of recommended methods for each pair of habitat X pressure types, including sub-regional specificities, should be produce to ensure comparability at the European scale.

The spatial planning of the monitoring (for each nested assessment scale, spatial resolution of sampling locations, etc.) depends of BH2 metrics, habitat type, pressure type, exposure to pressure (scale and intensity) and (sub-)regional potential specificities. This issue should be further discussed by expert groups. Furthermore, monitoring budget constraints often play a role. Optimization with other indicators monitoring requirements (notably BH1 and BH3) and with existing or future monitoring programmes (both on ecological and disturbance parameters) should be investigated.

Monitoring frequencies should also be discussed. It will be determined by the natural variability of biological and environmental parameters, at the scale of habitat, and by the variability of anthropic disturbances (intensity and frequency). A cost-benefit analysis should also be conducted, including optimized monitoring (both between indicators, and with other biodiversity and pressure/activities monitoring programmes).

The inventory of existing monitoring programmes, through ICG-COBAM works (monitoring template) and other working groups (e.g. FP7 STAGES, FP7 JMP North Sea and Celtic Sea, JRC MSFD art.12 report on art. 11 reporting, etc.) would be useful, compared to technical requirements (monitoring parameters) of benthic indicators, to identify gaps and potential adaptation needed. These monitoring requirements should be clearly defined, to be submitted to BDC and OSPAR meetings, in order to be integrated in the OSPAR CEMP (Coordinated Environmental Monitoring Programme).

Monitoring requirement for BH2 need further discussion and works in COBAM and the expert group. Ideally, a guidance document, or more probably a set of guidance documents (according to each habitat and/or pressure types), should be produced to advice on detailed and specific BH2 monitoring requirements and facilitate its implementation. These documents should include potential (sub)-regional specificities. It will be a step by step work, which will need to prioritize habitat/pressure pairs.

### 1.7. Baseline and GES principles

According to ICG-COBAM (2012) and previous experts meetings, the following baseline and assessment value setting methods are strongly recommended for BH2:

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- **Baseline setting: Method A (“reference” state, with negligible impacts).** An existing “reference” state, simultaneously monitored with assessed observations units, for each habitat type, is the most scientifically robust, transparent and comprehensible method. Furthermore in the context of climate and global changes, past (historical data) or modelling of “reference” states are less robust and relevant, and should be avoided for condition assessment, except for some extreme cases (no actual “references” existing at all assessment scales). As BH2 is conceptually calibrated along a pressure gradient, the reference may accommodate some impacts as long as the assessed gradient of resulting state cover the GES/no GES range (expected shift of the community at this boundary) (Elliott et al., in press). As Marine Protected Areas (MPAs) begin to recover to a less impacted state (if adequately managed), the number and quality of “reference” areas will increase. Experts’ judgement is recommended as an integral part of the baseline setting approach for benthic habitats. However, in specific local context (depending of the area to be assessed) pristine (or least damaged) benthic habitats communities may not be present any more due to widespread and long term chronic fishing pressure. In this case, an alternative reference setting principles could include the use of a high percentile value of a set of index values from a least disturbed area and period (of 6 years for reporting). The precise percentile value used can be adjusted to the degree of chronic fishing pressure, or any other chronic human pressure, using a well-defined expert judgement rule, in the specific assessed area. If sufficient reference values of good quality are available, the construction of a depth-reference value model is recommended, because it enables the estimation of reference values for assessment areas with insufficient benthos data. See Van Loon et al. (in press) and Annex 3 (BH2-B) for more details and specific application.
- **Assessment value setting: Method 3 (assessment value set as a deviation from the baseline).** The specific state which are set should account for the natural variability in space and time of the habitat type and its potential for recovery (resilience). The complementary use of experts’ judgements is recommended.

According to BH2 definition and stage of development, a qualitative assessment value has actually been discussed in experts group and defined as: “Anthropic pressures are at a level (both intensities and frequencies) that does not adversely compromise recovery (resilience) of benthic habitat communities, both in its diversity, structure and functions”.

The progressive operationalisation of BH2 would enable to quantify and estimate this assessment value and current quality status compared to available baselines, for each habitat and pressure type prioritised. Development of future integrated assessment, by combining other indicators (specifically area-related ones for wider scales) would enable to produce spatial distribution of assessment values for this value, for each assessed habitat and pressure type prioritised (See EcApRHA deliverables 2.3 , 4.1 and 5.6, and Elliott et al, in press) .

In addition to these well-defined principles, the setting of baselines and GES requires testing/validating by case studies (See II.1) and calibrated by the implementation of BH2 at (sub-)regional scale (See III.2).

### II.1. Case studies

Dataset requirements for BH2 are defined here at parameters level, but need further discussion and works in COBAM and the expert groups for agreement on each specific metrics depending on all specific habitats and pressures types. But methodological development is yet sufficiently advanced so than several case studies have already been conducted (See IV.1) and submitted to BDC 2015 in a “testing report” (BDC

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15/3/Info.2 Add.1 - E) and to BDC 2016 as partial contribution to the Intermediate assessment<sup>14</sup>. Sub-regions coverage and representativeness (both on habitat and pressure types) depend on CP's involvement and data availability. Data flows and author copyrights needs to be further discussed and agreed. Ideally, a guidance document, or more probably a set of guidance documents (according to each habitat and/or pressure types), should be produced to advice on BH2 data requirement and facilitate its testing and assessment, for each habitat and pressure type. These documents should include potential (sub)-regional specificities.

### II.2. Data flows

Further considerations are needed, depending on habitat and pressure types. Once the common assessment method is defined, comparable monitoring have to be in place to produce data, in order to compute any indicator (fig.3). There are actually many gaps, both on methods, ongoing relevant monitoring and data availability, to assess or even test BH2 for all habitats and pressure types. BH2 requires thus further work and relevant monitoring to be fully operational at (sub-) regional scale to address all MSFD/OSPAR issues. Nevertheless, previous and ongoing works already enabled to demonstrate soundness and potential of this indicator, and contribution to a partial assessment. The aim of this operationalisation phase is to make the best use of the OSPAR Contracting Parties' expertise and propose a global expertise by sharing, helping or conducting analyses on the most as possible dataset, as much as possible representative of sub-regions, to further test and develop the BH2 indicator. Ongoing relevant monitoring (See chapter I) is anyway a preliminary step required to provide relevant datasets (fig. 3). Before sharing the datasets, a charter should be signed by authors to protect those copyrights and guarantee them involvement in the process and further potential publication (scientific articles and/or OSPAR reports). Even for The Water Framework Directive assessment - the actually only implemented and reported (to European Commission) assessment of BH2, applied to some coastal habitats exposed to eutrophication (nutrients inputs) – the completion, accessibility or availability of data was heterogeneous between Member States.

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<sup>14</sup> Results for the OSPAR intermediate assessment (2017) are available at <https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/habitats/condition-of-benthic-habitat-defining-communities/>

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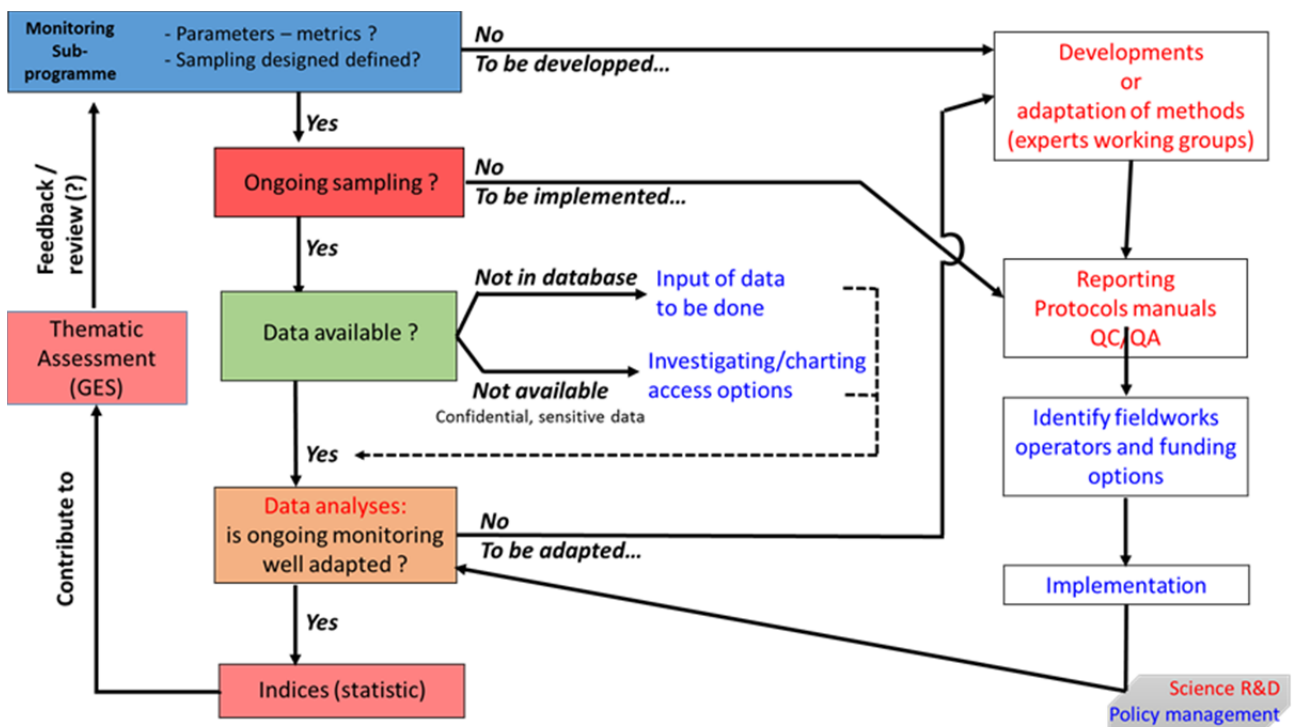


Figure 3: Technical process to implement an operational thematic assessment, at indicator or more integrated levels.

### III.1. Protocol for status assessments (principles)

This includes sampling procedure, assessment scales, (sub)regional specificities, rule of combination of parameters, data analysing procedure, computation of the indicator to an Ecological Quality Ratio (EcoQR) and then setting up of an EcoQ (assessment of Ecological Quality) relevant for management (setting up of Ecological Quality Objectives, EcoQO).

For BH2, several protocols will be necessary for each prioritised habitat and pressure types to be assessed.

Annexes 2 and 3 details principles and protocols for these 2 specific assessments.

### III.2. Protocol for status assessments (baselines and GES setting, reporting)

This is the last phase of operationalisation, to be further considered when all previous phases will be sufficiently advanced. For threshold between GES and no GES, a preliminary dialogue and agreement with policy-makers and decision committees is needed (setting up of EcoQ and EcoQO, definition of thresholds). Furthermore, case studies at European or Regional scales can be informative, but final calibration need defined and operational monitoring programme: updated OSPAR CEMP (Coordinated Environmental Monitoring Programme), according to technical specificities and monitoring requirements.

Reporting process depends deeply on the temporal planning of the monitoring, and the temporal planning of the overall assessment itself. At least one reporting every six years should be warranted, at the European scale, for all the habitats to which this indicator is applied. The possibility of reporting or assessing with a higher frequency should be further discussed.

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### IV.1. Work plan for the development of the indicator

France (Muséum National d'Histoire Naturelle) volunteered to lead the development of this indicator for OSPAR, according to previously submitted and updated work plan. Many Contracting Parties (CPs) regularly contributed, but all CPs are more than welcome to participate and involve in this development and operationalisation process. National research projects are also actively contributing with national funds, notably "Southern North Sea Project" (2014-2016, coordinated by Willem Van Loon, NL) and "BenthoVAL" (2014-2016, coordinated by Olivier Gauthier, FR) and are expected to contribute to many steps of the development process, including case studies. Since 2015, the EcApRHA research project (2015-2017, agreement n°. 11.0661/2015/712630/SUB/ENVC.2 OSPAR), co-financed by the European Union, led by OSPAR secretariat with 9 partners, including OSPAR indicators leads, include to forward this indicator project plan. This notably by investigating links with other indicators (benthic, pelagic and trophic) in order to develop more integrated assessment in close links with OSPAR/COBAM related experts groups. A key element of this work is the involvement of experts from each CP to ensure a scientifically robust, transparent and representative process and facilitate appropriation for management issues. The OSPAR benthic expert group solicited through ICG-COBAM and EcApRHA works, coordinated and animated by all benthic indicators leads, is the core working group to ensure this coordinated development and link with national (similar projects) and international (e.g. ICES, JRC, FP7, etc.) expertise. Further development priorities are described in the OBHEG Terms of Reference and work plan.

Lead expert and contact for France is Laurent Guérin ([laurent.guerin@mnhn.fr](mailto:laurent.guerin@mnhn.fr)), for BH2 development coordination.

#### The role of the indicator lead includes:

- Draft, update and report on the indicator specific documentation, notably CEMP guidelines and Technical specification, and where relevant specific indicator work plan;
- Guide the work on further development of the indicator, keeping in mind and contributing as much as possible to integration methods development (through Basecamp, e-mail, teleconferences and physical meetings), notably ensure coherence and complementarity between indicators and integration methods development;
- Contribute to the organisation (notably agenda items) and participate to dedicated benthic habitat workshops as needed (at least once per year) and possible;
- Ensure information flow and coordinated work between involved experts and with other OSPAR indicators leads and BHEG co-chairs, relevant OSPAR committees (notably ICG-COBAM and BDC) and other relevant benthic expert groups (e.g. ICES, JRC, HELCOM, BARCON);
- Submit specific indicator documentation for reviews to all involved COBAM-BHEG experts, other indicator leads, COBAM-BHEG co-chairs and COBAM. Update and validate documentation, as much as required for reporting, according to progress made (e.g. through workshops or any related working group or project) and comments received, acknowledging all significant contributions.

#### The role of each involved expert includes:

- Anticipate as much as possible and estimate approximately dedicated individual and/or team resources (dedicated expert time and capacity to attend workshops), available into the timescale and for milestones. Let's keep informed BHEG co-chairs, and any relevant indicator lead (for specific technical task), to enable adapt the work plan to current total OSPAR expertise resources and highlight potential needs of extra resources for specific tasks, to be forwarded to COBAM and BDC;
- Regularly participate to discussions through Basecamp, e-mail, teleconferences and, as much as possible, meetings;

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- Identify relevant national similar project, experts, relevant case studies, and facilitating communication and data flows;
- Actively contribute all along the development process of benthic habitat assessment and monitoring methods, as described in terms of reference, work plan and workshops agendas.
- Review, comment and amend, if needed, relevant (according to expert's specific fields of expertise) draft deliverables submitted by BHEG co-chairs or indicator leads.

The detailed work plan and the list of currently identified expertise resources for COBAM-BHEG, as of 10 July 2017, is presented in the OBHEG multi-year work plan.

The need for further method development and the lack of adequate data or access to existing data (biological, environmental and pressure) compromise the establishment of clear and accurate state-pressure relationships, and thus the possibility to define accurate assessment values at OSPAR scale. However, such assessment could be undertaken in certain areas where there is sufficient data. The lack of data is due to both lack of appropriate monitoring (e.g. for offshore habitats) and barriers to data flows.

a. Barriers and gaps:

Method development:

Within an assessment concept, you have to consider the data (see data use and availability), the baseline data ("reference" with low or least disturbance) and the type of indicator (e.g. variety of WFD and MSFD benthic indicators). Currently, the assessment method/framework is defined, but can benefit from further harmonization regarding practical implementation, regarding indicator types, baseline setting and data gathering. This method harmonization should lead to a more confident, large scale evaluation of the benthic status, which is in line between the involved countries.

One of the critical points is the determination of baseline data, which are lacking for many habitats at the OSPAR scale for different pressures, and especially for abrasion by bottom trawling fisheries. This compromises our knowledge of a sustainable condition for certain habitats, which are continuously under high pressure levels. "Pristine" baselines (no disturbance) are lacking for most of habitats, which compromise our knowledge of the potential best condition of natural habitat communities (Elliott et al, in press). It is not practical or feasible to use this pristine state as an environmental target everywhere, but is useful to understand its natural dynamic and recovery potential. Next to it, the approach to determine the baseline and to benchmark the "reference" values between countries is a point of attention for future assessments. Increasing establishment and management of Marine Protected Areas (including Marine Natura 2000 sites), notably including "no take or low pressure areas" could help to provide data and test approaches in the future, for the relevant habitat types.

Cumulative Effects

The cumulative effects of co-occurring pressures (different pressure at the same place and the same time range) are not yet assessed. According to the actual gaps of knowledge on benthic habitat communities, it will be necessary to first understand and quantify effects of each pressure type, where data are available, before investigating and understanding the effects of cumulative pressures (e.g. whether they are synergetic or antagonistic?). This is an important requirement as many habitats are exposed to multiple pressures. Monitoring of benthic habitats exposed to cumulative pressures, where management measure



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aim progressively for a more sustainable use, even for one pressure type, would help to better understand this in the future.

Data use and availability:

- Many potentially relevant data exist but are not all available (e.g. fishing pressure data at fine spatial resolution or biological data from marine research and marine industry)
- Many biological datasets exists (more or less available), but few have associated proxy or data on pressure at a compatible spatial and temporal scale.
- Most OSPAR Contracting Parties have wide scale marine benthic monitoring (at least for Water Framework Directive). Finer scale networks of state-pressure relationship assessment areas are more heterogeneous and should be further investigated. Developing a coordinate monitoring - or better, a joint monitoring - would be much more cost-efficient and would warranty coherence and robustness for an assessment at (sub)regional scale.
- Each country holds its own data, so a common method (and tools?) still needs to be developed. Development of data flow arrangements to access and analyse data, compute indicators, and compare/inter-calibrate results, is still in progress for WFD. The need for these steps should be anticipated and relevant work should be coordinated at (sub)-regional scale to ensure coherence and facilitate the computation of data for indicator assessment.

b. Cost-effectiveness:

As this indicator is already partly applied and implemented at EU scale for Water Framework Directive (for some coastal habitat types) for eutrophication, it can be considered already partly operational for nutrient inputs and coastal habitats. This common approach is an “umbrella” for several assessments, is based on existing and anticipated monitoring requirements (for OSPAR, MSFD, others European Directives and the Common Fisheries Policy) and is, therefore, cost efficient if coordinated.

c. Further development and roadmap:

The indicators for “Condition of benthic habitat communities” and “physical damage to predominant and special habitats”, are the only OSPAR-wide common agreed benthic habitat indicators. A regional (wide scale) monitoring strategy and technical guidance are partly in place and implemented for some coastal habitats and for nutrient input pressure (Water Framework Directive). The Regional Monitoring Strategy should be further coordinated, extended offshore and adapted for (finer scale) assessment areas, to progressively take into account and assess effects of other types of pressures on each benthic habitat type. As geographical (nested) scales are identified, assessment methods would also be progressively adapted and described.

An Action plan identifying gaps, barriers and solutions to further develop OSPAR benthic indicators, and an integrated assessment, for next assessment cycles, is available in EcApRHA research programme deliverables (<http://www.ospar.org/work-areas/bdc/ecaprha>) and was adapted for the multi-annual OBHEG work plan.

In future development and assessments, consideration could be given to using this common approach to other habitat types, e.g. those listed in the Habitats Directive, OSPAR threatened and declining habitats.

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### IV.2. Resources needed

It is important to distinguish the different successive phases of the operationalisation of an indicator, notably at (sub)-regional scale. All the operationalisation process and some reference documents are detailed in annexes.

- *Methodological development*

Main resources needed at this stage are working time of lead and involved experts, and financial costs for organization and venue to meetings and workshops. Travel expenses to participate in the workshops and meetings will be needed and should be supported by each CP. It is essential that resources (expert time and travelling costs), from all involved CPs are available to support the development of this indicator.

- *Testing (case studies)*

Main resources needed at this stage are working time of lead, involved experts and authors, availability of relevant datasets and financial costs for choosing, analysing and computing the dataset to test the BH2. It is essential that resources (relevant datasets, working time and analysing costs), from all involved CPs are available to support the development of this indicator.

- *Implementing (monitoring, computation and reporting)*

Depending of habitat and pressure types to be assessed, it is actually impossible to estimate the real specific cost of BH2 implementation, until optimised monitoring programme will be clearly defined and detailed. For example, the cost of a (vessel) survey may be high, but the cost for each sample depends of the number of samples realised during the survey. If other indicators needs are covered during the survey (e.g. mammals observation, pelagic habitat sampling, etc.), the global cost is also reduced. Rather than costs, resources needed should be further discussed, and further detailed as indicator development and associated guidance are refined.

At this stage, a coarse estimation of some basic resources needed is the following:

- Vessels, suitable to work from sublittoral to shelf
- Scuba diving sampling
- Adequate equipment (box core samplers, grabs, dredges, etc.) for sampling collection from intertidal to shelf
- Laboratory infrastructure to analyse samples under Quality Controls
- Qualified personnel for sampling, data input and processing, indicator computing and interpreting. Taxonomical, ecological and statistical skills are key requirements.

The actually implemented coastal WFD monitoring should be used to contribute to MSFD and OSPAR requirements, in order to optimize the resources allocation. Nevertheless, it must be acknowledged that the sampling surface covered by WFD is a very low proportion of the total marine waters covered by MSFD (this proportion is different for each country), even if the sources of this pressure are mainly coastal or terrestrial inputs. For all other habitat and pressure types, additional resources are needed to operationalize this indicator at its full potential (all MSFD/OSPAR issues for benthic habitats). Combination with other indicators (integrated assessment) and complementary technologies under development (such as sediment-profile-imagery or biomolecular tools), could improve cost-effectiveness to assess both environmental and disturbance-impact characteristics in large areas.

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### Annex 1 Appendix 1:

Summary description of the existing (mostly WFD) biotic indices using multi-metric calculation. *Update was made through associated research programmes (Southern North Sea, BenthVAL and EcAprHA): See Annex 2 for details of WFD indices and methods used in OSPAR maritime area.*

COASTAL MACROALGAE		
INDICATOR	CP APPLYING for WFD	BRIEF DESCRIPTION AND REFERENCES
RSL	IE, UK, NO, ES	“Reduced species list” is an indicator that includes 5 components: species richness (from a reduced list of between 68 and 70 species) /proportion of Rhodophyta/ proportion of Chlorophyta/ proportion of opportunistic species/ratio of perennial to annual forms. Wells et al. 2007: Mar. Pollution. Bull. 55: 151–161. Recently adapted to Southern Spain (Bermejo et al, 2012: Ecol. Ind, 12: 46-57)
CFR	ES	“Quality of rocky bottoms”. This indicator includes: percentage cover of characteristic macroalgae/ macroalgae population richness / percentage cover of opportunistic species. (Juanes et al, 2008. Ecol. Ind, 8: 351-359)
p-MarMAT	PT	“Portuguese marine macroalgae assessment tool”. This indicator contemplates all the components of the RSL method, including an additional parameter of % coverage of opportunistic species. Neto et al. 2011, Ecol. Ind: in press.
MAB	IE, UK, DE	“Macroalgae blooming”, which measures 5 components: % cover of algae from the intertidal area / total extent of algal blooms/ biomass of algae/ biomass of algae over the affected bloom area/ presence of entrained algae. Scanlan et al, 2007: Marine Poll. Bull., 55: 162-171
RICQI	ES	“Rocky Intertidal Community Quality Index”. It includes: ESS: ecological status similarity, PC: presence of Cystoseira; Morphologically Complex Algae; Species Richness and Faunal cover. Díez I., M. et al 2012. Ecol. Ind, 12: 58-71
Subtidal algae	NO, SE, DK	This indicator incorporates: depth extension of selected perennial macroalgae species / cover of macroalgae along depth gradients / macroalgae composition in rocky littoral and sublittoral zones (based on the integration of multiple parameters). Krause-Jensen et al, 2008. Ecol. Indicat. 8: 515-529
COASTAL ANGIOSPERMS		
INDICATOR	CP APPLYING	BRIEF DESCRIPTION AND REFERENCES
Intertidal <i>Zostera</i>	UK, IE, NL DE (only bed extent), FR	Multimetric indicator for <i>Zostera</i> communities. It includes three parameters: 1: Species composition; 2. Seagrass abundance (acreage/bed extent) and 3. Seagrass abundance (coverage/density)
BENTHIC INVERTEBRATE FAUNA		
INDICATOR	CP APPLYING	BRIEF DESCRIPTION AND REFERENCES
BEQI	BE	Benthic ecosystem quality index. Indicators included: density, biomass, species richness, species composition changes (Van Hoeij et al., 2007. Report NIOO/NIOZ).
BEQI-2	NL	Benthic ecosystem quality index 2. Indicators included: species richness, Shannon index and AMBI; univariate calibration (Van Loon et al., Report, 2011)
M-AMBI	ES, FR, DE	Multimetric-AMBI: Species richness, Shannon diversity, and AMBI, multi-variate calibration (Muxika et al., Marine Poll. Bull., 2007. Mar. Poll. Bull., 55: 16-29).
IQI	IE, UK	Infaunal quality index (IQI) is comprised of three indicators: species richness, Simpson diversity and AMBI (Borja et al., Marine Poll. Bull., 2007)
NQI	NO	Norwegian quality index: includes SN-diversity, total abundance and AMBI (Josefson et al., Marine Poll. Bull., 2009).
P-BAT	PT	Portuguese benthic assessment tool. Indicators included: Margalef species richness, Shannon diversity and AMBI (Teixeira et al., Marine Poll. Bull., 2009).
BQI	SE	Benthic Quality index. Indicators included: species richness and total abundance

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		(Josefson et al., 2009).
DKI	DK	Danish quality index. Indicators included: AMBI, Shannon's diversity, total abundance and species richness (Josefson et al., Marine Poll. Bull., 2009).
BOPA	ES	Benthic Opportunistic Annelida Amphipoda Index /Benthic Opportunistic PolychaeteAmphipoda Index. It uses the ratio between opportunistic polychaete and amphipods frequencies. Dauvin, J.C., T. Ruellet, 2007. Mar. Pollut. Bull, 55(1-6), 215-224.
BHQ	SE	Benthic Habitat Quality index. Used in analyze of sediment profile image. Tested against organic enrichment, oxygen deficiency, physical disturbance (e.g. trawl fishery). Nilsson H.C. and Rosenberg R., 1997. Marine System, 11, 249-264.

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## ANNEX 2

### OSPAR – Common Biodiversity Indicators

#### **Condition of benthic habitat communities (BH2-A): Some coastal habitats in relation to nutrients and/or organic enrichment**

#### Guidelines for Coordinated Environmental Monitoring Programme (CEMP)

*Last submission to OSPAR Secretariat and BDC (March 2017), OSPAR Benthic Habitat Expert Group (June 2017), COBAM (December 2017). All comments received to date are addressed in this updated version.*

*Next submission planned for adoption: BDC (February 2018)*

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The CEMP guidelines are a tool for clearly documenting the detailed methodology for the monitoring and/or assessment of the individual parameters/indicators so as to ensure transparency, coherence and consistency in the implementation of such monitoring and assessment. *These guidelines should outline the monitoring and assessment requirements for the components outlined within the CEMP and should be developed for each element (i.e. common indicators)*

## 1 Introduction

Coastal waters represent the interface between land and ocean and are defined under Water Framework Directive (WFD) as extending one nautical mile from a baseline defined by the land points where territorial waters are measured. “Water bodies” have been defined by European Union Member States by subdividing these coastal waters, along the coast, according to their hydrological characteristics. Some coastal waters of OSPAR Contracting Parties have, to a varying degree, been affected by nutrient and organic enrichment (either as a direct or indirect effect of nutrient inputs or of organic matter enrichment) and this may lead to nuisance and toxic algal blooms, loss of benthic habitats by shading out benthic vegetation and modification of benthic fauna communities due to specific sensitivities. “Coastal habitats”, are defined here according to the Marine Strategy Framework Directive (MSFD) terminology, as the seabed and subsoil on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured.

From Solheim et al. (2012):

“The biological quality elements required for the integrated assessment of ecological status (WFD Annex V) of coastal waters are phytoplankton, macroalgae, angiosperms and benthic fauna.



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The WFD requires that standardised methods are used for the monitoring of the quality elements, and that the good status class boundaries for each biological quality element are intercalibrated across Member States sharing similar types of water bodies.

The WFD requires that the overall ecological status of a water body is determined by the results for the biological or physicochemical quality element with the worst class determined by any of the biological quality elements. This is called the “one out - all out” principle. The rationale of this principle is to avoid averaging the impacts on different quality elements due to different pressures and therefore overlook some significant pressures, and also to provide sufficient protection of the most sensitive quality element to a significant pressure.”

By definition, the WFD aims to assess ecological quality status of water bodies, reflected by quality elements such as benthic invertebrates or macroflora. Benthic habitat communities are thus mainly assessed for the WFD to reflect the main pressures in the coastal zone, such as direct or indirect effects of nutrient and organic enrichment, notably due to nutrients inputs (as terrestrial or freshwater sources of pressure) in the OSPAR Maritime Area. Contaminants are generally assessed in sediment. For these reasons, WFD monitoring was generally designed to avoid other pressures, and assess only the effects of nutrient and organic enrichment (including for reference stations). This does not mean that the indices used are not sensitive, per se, to other pressure types, but currently several statistical indices used, notably those including a species sensitivity classification, have been developed and calibrated to assess nutrient inputs or organic matter enrichment . MSFD new requirements lead to a reconsideration / adaptation of monitoring, to take into account and assess other pressure types (both inshore and offshore).

## 2 Monitoring

Specific monitoring programme have been implemented for Water Framework Directive, to provide data for this specific assessment. For benthic habitats, specific habitat sub-types sampled, sampling methods reference condition used are detailed in following chapters.

### Benthic Invertebrates

Sampling methods used for the benthic multimetric indices, habitat types sampled and the source to derive reference conditions are summarised in Table 1. Mostly a Van Veen grab or an equivalent is used for taking sublittoral samples and a corer for intertidal habitats. The number of spatial replicates, sampling occasions and the total area surveyed for the classification of a water body varies by country. All of the indices are designed to assess subtidal soft bottom sediments and in some member states also intertidal habitats. The reference conditions are derived from historical data or sites with least disturbed conditions where available, supported by expert knowledge and in some cases also statistical modelling.

Table 1: Sampling method, habitat types sampled and reference conditions for the assessment of benthic invertebrates

Contracting Party	Index	Sampling Method	Habitat type	Reference conditions
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BE	BEQI	Van Veen grab (0.1 m <sup>2</sup> ), 18-20 replicates, yearly	subtidal soft bottom (muddy sediments, fine muddy sand, clean sands)	expert knowledge, historical data, least disturbed conditions; data period 1994-2012, habitat specific
DE	M-AMBI	Van Veen grab (0.1 m <sup>2</sup> ) or corer (diameter 9-15 cm), 6-10 replicates per ecotope, once or twice per year	subtidal and intertidal soft bottom	expert knowledge, historical data, least disturbed conditions
DK	DKI	Van Veen grab (0.1 m <sup>2</sup> ) or Haps-corer (0.0143 m <sup>2</sup> ), 6 (grab) or 40 (corer) replicates, yearly	subtidal soft bottom (sand - mud)	least disturbed conditions
ES	M-AMBI	Van Veen grab (0.1 m <sup>2</sup> ), 3 replicates, 2-6 locations per water body, yearly	subtidal and intertidal soft bottom	expert knowledge, historical data, modelling (extrapolating model results)
ES	BOPA	Van Veen grab (0.1 m <sup>2</sup> ), 3 replicates, yearly	subtidal soft bottom	least disturbed conditions, habitat-specific
FR	M-AMBI	Van Veen grab / Day grab / Smith-McIntyre grab (0.1 m <sup>2</sup> ), 3 locations with 3 replicates each, once per sampling season	subtidal and intertidal soft bottom	expert knowledge, historical data, least disturbed conditions; data period 1995-2006, habitat specific
IE, UK	IQI	Van Veen grab / Day grab (0.1 m <sup>2</sup> ), hand corer (0.01 m <sup>2</sup> ), replicates and sampling occasions variable according to habitats, methodology and required confidence	subtidal and intertidal soft bottom	expert knowledge, historical data, least disturbed conditions, modelling (extrapolating model results)
NL	BEQI2	corer tube, box corer (e.g. Reineck box corer), at least once per year	subtidal and intertidal, all present habitats	historical data for 1991-2006, statistical modelling
NO	NQI1	Van Veen grab (0.1 m <sup>2</sup> ), 4 replicates, yearly	subtidal soft bottom	recent data from least impacted sites
PT	BAT	Van Veen grab (0.1 m <sup>2</sup> ) or equivalent, replicates variable according to habitats and required confidence, once per sampling season	subtidal soft bottom (sand - mud)	existing near-natural reference sites, expert knowledge, historical data, least disturbed conditions
SE	BQI	Van Veen grab, Smith-McIntyre grab (0.1 m <sup>2</sup> ), at least 5 locations per water body, yearly	subtidal soft bottom	expert knowledge, least disturbed conditions

**Macroalgae**

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The sampling method applied to assess macroalgae depends on the location of habitats (Table 2). Opportunistic intertidal macroalgae are often surveyed by aerial imagery. Intertidal and subtidal rocky substrates are assessed by field surveys and diver observations along transects. The sampling procedure, number of spatial replicates, total area surveyed and sampling occasions varies considerably across countries and reflects the methodological diversity of indices used. Reference conditions are mostly based on expert knowledge and existing near-natural reference sites. For several countries historical data is also available.

Table 2: Sampling method, habitat types sampled and reference conditions for the assessment of macroalgae

<b>Contracting Party</b>	<b>Index</b>	<b>Sampling Method</b>	<b>Habitat type</b>	<b>Reference conditions</b>
DE	Opportunistic Macroalgae	aerial mapping (extent) of total area, 3 - 5 occasions per sampling season	intertidal, all habitats	expert knowledge, historical data
DE	HPI	field survey (% cover, taxonomic composition, RSL-Index) along transects and on fixed stations, diver observations along transects (depth limits), sampling occasions variable according to methodology	intertidal and subtidal hard bottom	expert knowledge
DK	Total Macroalgal Cover	diver observations (% cover, total and individual species) along a depth gradient (transect), 2-5 transects per area, 3 replicates each about 25 m <sup>2</sup> , once every 2 years	subtidal hard bottom habitats	Modelling (extrapolating model results), historical data (nitrogen loads)
ES	CFR	field survey, diver observations, 3 replicates (10-100 m <sup>2</sup> ) per assessed level, once per sampling season	intertidal and subtidal hard bottom	existing near-natural reference sites, expert knowledge
ES	RSL	field survey (taxonomic composition, cover), ten replicates, yearly	intertidal hard bottom	existing near-natural reference sites, expert knowledge
FR	QI Sub Mac Fr	diver observations along transect, identification and counting of macroalgae, 10 quadrates (2.5 m <sup>2</sup> ) in upper and 8 quadrates (2 m <sup>2</sup> ) in lower infralittoral of each algal belt, once per sampling season	infralittoral hard bottom	expert knowledge, historical data, least disturbed conditions, existing near-natural reference sites
FR	CCO	field survey, 3 permanent spots per level/belt marked by a	intertidal hard bottom	existing near-natural reference sites & least impacted sites,

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		frame (1.65 x 1.65 m), once every three years		expert knowledge
IE	Opportunistic Green Macroalgal Abundance	field survey, transects across algal beds, at least 5 quadrates (0.25 m <sup>2</sup> ) per transect, once per sampling season	intertidal sediments suitable for green algae	existing near-natural reference sites, expert knowledge, historical data
IE	RSL	field survey, at least 3 sites per water body with 4-5 shore heights and 5 quadrats at each shore height, twice in 6 years	intertidal hard bottom	existing near-natural reference sites, expert knowledge, historical data
NO	MSMDI	diver observations along transects (% cover, depth limits), at least two transects per water body, once per sampling season		expert knowledge, historical data, least disturbed conditions
NO	RSLA	field survey, diver observations, 10-15 m wide transects	intertidal and subtidal hard bottom	existing near-natural reference sites, expert knowledge
PT	PMarMAT	field survey along transects, seven stations per transect with 3 replicates each (quadrates 0.2x0.2 m), 1-3 transects per site, 1-3 sites per water body, once per sampling season	intertidal hard bottom	existing near-natural reference sites, expert knowledge, historical data, least disturbed conditions
SE	MSMDI	diver observations along transects (% cover, depth limits), at least three transects per waterbody, once per year	subtidal, all suitable habitats	historical data, expert knowledge, least disturbed conditions
UK	RSL	field survey along transects, 100-300 m shore length, minimum of 3 sites per water body, once per sampling season	intertidal hard bottom	expert knowledge, historical data, least disturbed conditions
UK	Macroalgal Bloom Assessment	field survey, aerial imagery, multiple quadrats (0.25 m <sup>2</sup> ), replicates vary with extent, patchiness and abundance of macroalgal blooms, once per sampling season	intertidal soft sediment, mussel beds	expert knowledge, historical data

**Angiosperms**

The methods applied for the assessment of angiosperms depends on the surveyed habitat (Table 3). Intertidal habitats are assessed either with aerial imagery or by field surveys. Subtidal habitats are sampled

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by diving surveys along transects. Preferably all existing seagrass beds shall be assessed. Reference conditions are derived from historical data, mostly supported by expert knowledge. Additionally, in some countries existing near-natural reference sites or habitats with least disturbed conditions are considered.

Table 3: Sampling method, habitat types sampled and reference conditions for the assessment of angiosperms

Contracting Party	Sampling Method	Habitat type	Reference conditions
DE - saltmarsh	aerial mapping (extent) in combination with field mapping (extent and zonation), once in six years, some selected sites every 2-3 years	intertidal, all available habitats	existing near-natural reference sites, expert knowledge, historical data, modelling (extrapolating model results)
DE - seagrass	aerial mapping (extent) in combination with field mapping (species composition and density along transects), all seagrass beds, once in six years, some selected sites every year	intertidal, all available habitats	expert knowledge, historical data, modelling (extrapolating model results)
DK	diver observations (% cover) along a depth gradient (transect), about 5 sites per area, yearly	subtidal soft bottom	historical data
FR	aerial photography, field survey, once in 3 years	intertidal and subtidal	historical data, expert knowledge
IE	field survey of all sea grass beds in water body, transects across each bed, one occasion over several years	intertidal seagrass beds	existing near-natural reference sites, expert knowledge, historical data
SE	diving surveys, investigating changes along transects, (cover % of phytobenthic species) together with quantitative sampling, at least three transects per waterbody, yearly	subtidal, all available habitats	expert knowledge, historical data, least disturbed conditions
UK	field survey with quadrat, aerial photography, all seagrass beds, once per sampling season	intertidal and subtidal, all available habitats	expert knowledge, historical data, least disturbed conditions

## 3 Assessment

The current (2017) OSPAR assessment results for the Biological Quality Elements 'Benthic Invertebrates' and 'Macroalgae and Angiosperms' in coastal waters were requested through a data call to WFD national contacts. In addition, information on the indices used and the monitoring stations in coastal water bodies was requested. Information on the methodology of the various benthic indices (sampling strategy, data evaluation, reference conditions, detected pressures) were mainly derived from the WISER methods database and intercalibration reports (Birk et al. 2010, van Hoey et al. 2015).

WFD assessment results for benthic invertebrates were provided from nine of the eleven OSPAR member states with coastal water bodies in the North Sea or North East Atlantic (Table 4). The assessment results

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for macroalgae and angiosperms were available from seven countries. For the Netherlands and Belgium this quality element is not relevant in coastal waters. The French data showed the results for the subcomponents of the macrophytes assessment from different assessment periods, but no aggregated classification of the water bodies. The majority of the status reports are from the 2<sup>nd</sup> assessment cycle of the WFD (2010-2015). Assessment results from Ireland and Wales date from the first cycle (2009).

Table 4: Data availability on WFD assessment results for benthic invertebrates and macroalgae/angiosperms

	BE	DE	DK	ES	FR	IE	NL	NO	PT	SE	UK
Benthic Invertebrates	-	x	x	x	x	x	x	x	-	x	X
Macroalgae/Angiosperms	nr	x	x	x	x*	x	nr	x	-	x	X

nr=not relevant

-x\* no aggregated status

Detailed assessment methods and intercalibration exercise are available at:

[http://ec.europa.eu/environment/water/water-framework/objectives/status\\_en.htm](http://ec.europa.eu/environment/water/water-framework/objectives/status_en.htm)

Details on metrics and indices used by Contracting Parties are described in the following chapters.

## Benthic Invertebrates

The status of benthic fauna is generally assessed with a multimetric index, as the WFD requires the inclusion of the metrics taxonomic composition, diversity, abundance and taxa sensitive to disturbance. In the OSPAR region eleven different benthic assessment approaches are applied (Table 5). With the exception of the Spanish BOPA (Benthic Opportunistic Polychaete Amphipoda Index), all approaches comply with the WFD requirements. Most of the countries use a similar approach with the AMBI (AZTI Marine Biotic Index) as a metric indicating anthropogenic disturbance, a diversity index (Shannon index, Simpson index or Margalef) and the number of species. The Belgian BEQI with the metric taxonomic composition (Bray-Curtis similarity) has a different approach where the assessment is performed on habitat level instead of the sample level. The BOPA used in Andalusia is based on the relative abundance of opportunistic polychaetes and amphipods but lacks a metric for diversity. The BOPA index is also the only assessment approach that has not been intercalibrated within the North East Atlantic intercalibration exercise (van Hoey et al. 2015).

In the UK and Norway additional indices are applied for the assessment of benthic fauna in coastal waters. The *vas deferens* sequence index (VDSI) is an imposex tool used in the UK as a subcomponent for the status assessment of invertebrates. Norway assesses some coastal water bodies with univariate diversity indices (Table 6).

Table 5: Multimetric indices for the assessment of benthic invertebrates [Table\_2\_Multimetric\_Indices.xls]

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<b>Contracting Party</b>	<b>Index</b>	<b>Metrics</b>	<b>Reference</b>
BE	BEQI Benthic Ecosystem Quality Index	number of species, abundance, biomass, Bray-Curtis similarity	Van Hoey et al. (2007), <a href="http://www.beqi.eu">http://www.beqi.eu</a>
DE	M-AMBI Multivariate-AZTI Marine Biotic Index	factor analysis: number of species, Shannon index (H'), AMBI	Borja et al., (2004), Muxika et al. (2007), <a href="http://ambi.azti.es">http://ambi.azti.es</a>
DK	DKI Danish Quality Index	number of species, abundance, Shannon index (H'), AMBI	Borja et al. (2007)
ES	M-AMBI Multivariate-AZTI Marine Biotic Index	factor analysis: number of species, Shannon index (H'), AMBI	Borja et al., (2004), Muxika et al. (2007), <a href="http://ambi.azti.es">http://ambi.azti.es</a>
ES	BOPA Benthic Opportunistic Polychaete Amphipoda Index	relative abundance of opportunistic polychaetes and amphipods	Dauvin & Ruellet (2007)
FR	M-AMBI Multivariate-AZTI Marine Biotic Index	factor analysis: number of species, Shannon index (H'), AMBI	Borja et al., (2004), Muxika et al. (2007), <a href="http://ambi.azti.es">http://ambi.azti.es</a>
IE, UK	IQI Infaunal Quality Index	number of species, Simpson index, AMBI	Philips et al. (2014)
NL	BEQI2 Benthic Ecosystem Quality Index 2	number of species, Shannon index (H'), AMBI	Van Loon et al. (2015)
NO	NQI1 Norwegian Quality Index	number of species, AMBI	Rygg (1985, 2002)
PT	BAT Benthic Assessment Tool	factor analysis: Margalef (D), Shannon index (H'), AMBI	Teixeira et al. (2009), Marques et al. (2009)
SE	BQI Benthic Quality Index	number of species, abundance, relative abundance of sensitive and tolerant species	Leonardsson et al. (2009)

Table 6: Additional indices for the assessment of benthic invertebrates [Table\_3\_Additional\_Indices.xls]

<b>Contracting Party</b>	<b>Index</b>	<b>Method</b>	<b>Reference</b>
NO	Density Index (DI)	univariate	Rygg 2014
NO	Shannon Index (H')	univariate	Shannon (1949)
NO	Hurlbert Index (ES100)	univariate	Hurlbert (1971)
UK	Vas deferens sequence index (VDSI)	imposex tool	Gibbs et al. (1987)

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**Macroalgae**

The indices for the assessment of the subcomponent macroalgae apply either to intertidal and/or subtidal macroalgae on rocky shores or to blooming opportunistic macroalgae. Some countries have developed several indices (e.g. DE, FR, UK). Information on 15 approaches used in nine Contracting Parties to OSPAR have been compiled (Table 7). Opportunistic macroalgae are assessed in Germany, Ireland and the United Kingdom. These indices are designed to survey intertidal soft bottom habitats suitable for green algae growth and to map the extent and density of algal beds (Table 2). Various indices have been developed for the classification of macroalgae on rocky habitats. Metrics used are species richness, coverage, depth limits or proportion of opportunistic and sensitive species. An index adopted by several countries is the Reduce Species List (RSL) developed by Wells et al. (2007). The RSL is a multimetric index based on the principle that species richness has been shown to remain constant in the absence of anthropogenic disturbance. Metrics incorporated in this index are number of species, proportion or number of red and green algae, proportion of opportunistic species and the ratio of perennial forms (ecological status group 1) to annual or ephemeral forms (ecological status group 2).

Table 7: Indices for the assessment of macroalgae

<b>Contracting Party</b>	<b>Index</b>	<b>Metrics</b>	<b>Reference</b>
DE	Opportunistic Macroalgae	spread and density of opportunistic macroalgae	Kolbe (2007)
DE	HPI Helgoland Phytobenthic Index	taxonomic composition, cover, density, depth limits	Kuhlenkamp & Bartsch (2007)
DK	Total macroalgal cover	total macroalgal cover (%) per water depth (not yet fully approved)	Carstensen et al. (2008)
ES	CFR Quality of Rocky Bottoms	coverage, fraction and richness of characteristic macroalgae	Juanes et al. (2008), Guinda et al. (2008)
ES	RSL Reduced Species List	number of species, proportion of green algae, number of red algae, proportion of ESG 1, proportion of opportunistic species, shore description	Wells et al. (2007), Bermejo et al. (2012)
FR	QI Sub Mac Fr Quality index of subtidal macroalgae of French Channel and Atlantic coast	depth of infralittoral belts, density of structuring species, number of characteristic species, densities of opportunistic species, presence of "good ecological status species", biodiversity, stipe length and surface of epibionts of Laminaria hyperborea	Derrien-Courtel & Le Gal (2009)
FR	CCO Cover, Characteristic species, Opportunistic species on intertidal rocky bottoms	contribution of each macroalgal community (belt) to the total cover of a given intertidal rocky shore, number of characteristic species, cover of opportunistic species in every belt	Ar Gall & Le Duff (2010)
IE	Opportunistic Green Macroalgal Abundance	total cover, total affected area, biomass	Scanlan et al. (2007)
IE	RSL	number of species (green, brown, red algae,	Wilkinson et al.



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	Rocky Intertidal Macroalgae - Reduced Species List	opportunists, ecological status groups 1 and 2), shore description	(2007)
NO	MSMDI Multi Species Maximum Depth Index	depth limits of 3 to 9 disturbance sensitive species	Kautsky et al. (2007)
NO	RSLA Rocky Shore Reduced Species List with Abundance	number of species (green, brown, red algae, opportunists, ecological status groups 1 and 2), abundance, shore description	Wilkinson et al. (2007)
PT	PMarMAT Marine Macroalgae Assessment Tool	taxa richness, proportion of green algae, number of red algae, ESG ratio, proportion and cover of opportunists, shore description	Marques et al. (2009), Neto et al. (2011)
SE	MSMDI Multi Species Maximum Depth Index	depth limits of 3 to 9 disturbance sensitive species	Kautsky et al. (2007)
UK	RSL Rocky Shore Reduced Species List	normalised number of macroalgal taxa (normalised to shore diversity), proportion of green algae, red algae and of opportunistic taxa, ecological status group ratio	Wells (2006), Wells et al. (2007)
UK	Macroalgal Bloom Assessment	total extent of macroalgal bed, cover of available intertidal habitat, biomass of opportunistic macroalgal mats, biomass over the available intertidal habitat, proportion of entrained algae	Scanlan et al. (2007), Wells et al. (2007)

**Angiosperms**

Indices for the ecological status assessment of seagrass have been developed by six countries (Table 8). Metrics used by most member states are the spatial extent of seagrass beds, number of species and shoot density. Denmark determines the depth limit of seagrass by measuring the percentage of seagrass cover along transects. In Germany an assessment tool for saltmarsh vegetation is used as another subcomponent for the biological quality element.

Table 8: Indices for the assessment of angiosperms

Contracting Party	Index	Metrics	Reference
DE	Assessment tool for intertidal seagrass	proportion of intertidal area covered by seagrass, density within seagrass beds, number of species	Dolch & Reise (2008), Kolbe (2007)
DE	Assessment tool for saltmarsh vegetation	proportion of saltmarsh area within the water body, proportion of the specific saltmarsh zone within the saltmarsh area	Arens (2009)
DK	Depth limit of eelgrass	eelgrass cover (%) per water depth	Krause-Jensen et al. (2005), Duarte et al. (2007)

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FR	Angiosperms	taxonomic composition, spatial extent, shoot density	Auby et al. (2010)
IE	Intertidal Seagrass: Abundance and species composition	spatial extent, shoot density, number of species	Foden & de Jong (2007), Foden & Brazier (2007)
SE	Assessment of Biological Quality Elements - macrovegetation	seagrass shoot density	
UK	Seagrass	taxonomic composition, spatial extent, shoot density	Foden & de Jong (2007), Foden & Brazier (2007)

## 4 Change Management

Since changes of this method often require a more general level of discussion and policy decision making, it is proposed to discuss proposed changes in ICG-COBAM, in link with ICG-C and ICG-EUT, and to make decisions on proposed changes in ICG-COBAM and BDC.

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## ANNEX 3

### OSPAR – Common Biodiversity Indicators

## Condition of benthic habitat communities (BH2-B): Subtidal Habitats of the Southern North Sea

### Guidelines for Coordinated Environmental Monitoring Programme (CEMP)

*Last submission to OSPAR Secretariat and BDC (March 2017), OSPAR Benthic Habitat Expert Group (June 2017), COBAM (December 2017). All comments received to date are addressed in this updated version.*

*Next submission planned for adoption: BDC (February 2018)*

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The CEMP guidelines are a tool for clearly documenting the detailed methodology for the monitoring and/or assessment of the individual parameters/indicators so as to ensure transparency, coherence and consistency in the implementation of such monitoring and assessment. *These guidelines should outline the monitoring and assessment requirements for the components outlined within the CEMP and should be developed for each element (i.e. common indicators)*

## 1 Introduction

In the OSPAR Biodiversity Committee meeting of November 2016, for the Common indicator BH2-B, an assessment sheet containing the Margalef benthos assessment method and its assessment results for the Southern North Sea has been accepted (OSPAR 2016). This assessment sheet builds upon the BH2 common approach CEMP appendix A (OSPAR 2016), applied to the specific context of the Southern North Sea subtidal sediments. This new OSPAR BH2-B method and its results have also been submitted for publication (Van Loon et al. 2017). It is required by OSPAR that each Common indicator has a CEMP guideline, which describes the applied monitoring and assessment method in technical detail, in order that currently participating and new parties can consistently produce or reproduce this type of monitoring and assessment. This BH2-B CEMP technical protocol, which is proposed to be a chapter in the BH2 CEMP, is presented in this document. It is based on the OSPAR BH2-B assessment sheet (Van Loon et al., in press) and on the BENMMI software (Walvoort and Van Loon 2017). This software has been specifically developed for this OSPAR Common indicator, and facilitates the automatic analysis and reporting of the developed Margalef method.

## 2 Monitoring

### 2.1 Purpose

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The purposes of the benthos monitoring in the Southern North Sea are:

- To establish the current state (condition, quality) of the benthic communities in the selected assessment areas
- To detect possible trends in the benthic condition, especially as a result of measures
- To use the available benthos data (a sufficiently large dataset) to estimate reference values

### 2.2 Quantitative Objectives

- At least 10 benthos samples of 0.1 m<sup>2</sup> have to be sampled per national assessment area per monitoring year.
- At least two, and preferably three, monitoring years have to be available within an OSPAR/MSFD assessment period of six years.
- For reference value estimation with sufficient confidence, 6 data years have to be available (quality code 3, see Van Loon et al. 2017). A minimum of 3 data years can be used (quality code 2), but is less reliable. In case of less than 3 data years (quality code 1), the depth-reference model has to be used for reference value estimation.
- For assessment preferably 3 data years have to be available to give sufficient assessment precision. The use of 2 data years is the required minimum; 1 data year cannot be assessed in view of known considerable temporal variation of benthos.

### 2.3 Monitoring Strategy

- For the assessment of benthic community condition (quality) it is essential that all species in the samples, including sessile epifauna, are identified and their abundance quantified. Only mobile epifaunal species (e.g. shrimps and crabs) are removed from the dataset, because these species are quantified unreliably due to their mobility. It is recommended to check the species groups included in the national benthos monitoring programs within OSPAR.
- It is essential that species are identified down to the species level as much as possible. If this is not possible, the next higher taxon level (genus), or if unavoidable higher taxon level (e.g. for some epifauna groups) must be used. Note that the use of subgenus identifications (e.g. genus x sp1; genus x sp2; genus x sp3) is not recommended, according to international taxonomic nomenclature rules.
- The internationally standardized WoRMS taxa name list has to be used. This list discriminates between the standardized names and synonym names; and for the synonyms the standardized names are given. This WoRMS list, with a few additional quality checks used in the Dutch TWN list (e.g. no use of aggregate names) has been implemented in the BENMMI software used for this indicator.

### 2.4 Sampling Strategy

- For use of Margalef D, the larger the sampled area is, the better is the representativeness. Generally, a minimum of 0.1m<sup>2</sup> is recommended per sample, or pooled samples (e.g. for use of 0.078 m<sup>2</sup> box core samples, instead of 0.1 m<sup>2</sup> grabs). Denmark is investigating methods to adapt sampling strategy to the recommendation for SNS Margalef method (Hansen et al., 2017).

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- Samples are first sieved on board of the sampling ship using a sieve of 1 mm mesh size, and the retained benthos is fixated using a final concentration of 4-6% formaldehyde (ISO 2005) or fixated using a final concentration of 70% of ethanol if the samples are identified within 6 months. At the laboratory, the retained benthos is additionally sieved over a sieve with a smaller mesh size, often 0.5 mm. Note that samples primarily sieved over 0.5 mm are not allowed, because these give systematically different results compared to 1 mm sieved samples (higher species richness and abundances).
- Fixed sampling locations have to be used within a national assessment area, because the used of fixed locations reduces the spatial variation and consequently in general gives improved trend analysis results. Random sampling is not used because this will give impaired trend analysis results.

### 2.5 Quality assurance/ Quality Control

The following quality control procedures have to be used. These quality control procedures are facilitated by using the BENMMI software:

- Confirm that the dataset used is the validated/correct/official one.
- Check the locations of the samples within the assessment area using a plot. This plot is produced by BENMMI. Check that no geographically outlying samples are present.
- Check the conversion of species names to WoRMS standardized species names using the BENMMI report. If necessary, add additional species conversion records to the species reference file.
- Check the desired removal of mobile epifaunal species using the BENMMI report.
- Check for clear outliers in the average total abundance per sample. For example, in case densities were erroneously used in the benthos input file, the total abundance will be too high.
- Check for outlying samples (with respect to species composition and abundance per species) using the MDS plot. Check the species and abundances of these outlying samples, and judge if these samples can be removed from the dataset.
- Check for samples with outlying combination of  $\ln N$  (natural logarithm of the total abundance) and species richness per sample using the Margalef quality control plot (shows samples outside the 99% prediction interval). Outlying samples can be caused by juveniles (samples below the plot) or biodiversity hotspots or errors in taxa identification (samples above the plot). Check the species and abundances of these outlying samples, and judge if these samples (a) can be corrected in case of extremely high abundance of a specific juvenile species, or (b) the sample should overall be removed from the dataset because of questionable quality. In case of (a), the abundance the specific species can be corrected to a more normal value.
- Use the corrected dataset for re-analysis to produce the final BENMMI results.

### 2.6 Data reporting, handling and management

- The data reporting format, which is used as input format for the BENMMI-tool, is available in the BENMMI user manual, Appendix A (Walvoort and Van Loon, 2017)
- This data reporting format is directly suitable as metadata scheme for ODIMS.



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- The confidence level of the benthos data in general is good. For some specific areas and years, the benthos dataset may reveal deviating behaviour (see quality control procedures in 2.5), and the confidence in these datasets should then be classified as moderate. This situation may occur if project data are used which have been produced by a less experienced and/or quality controlled benthos laboratory; in contrast to monitoring data which are usually produced by highly experienced and quality controlled benthos laboratories.
- For the OSPAR intermediate assessment of the SNS, the participating countries have sent their benthos data to the SNS coordinator for this specific event. In case of new OSPAR or other project data calls, requests for benthos data have to be addressed to the national and subnational data coordinators, which are listed in the OSPAR assessment sheet.

## 3 Assessment

### 3.1 Data acquisition

The national institutes involved are requested to send their relevant benthos data (regarding assessment area, habitat and period), in the **BENMMI data input format**, to the regional coordinator of the North Sea. It is checked by the regional coordinator if the delivered benthos dataset is completely in BENMMI format. If this is not the case, it is requested to the national institute to update the benthos data format to the correct BENMMI input format. An additional advantage of this procedure is that the resulting dataset directly suitable for exchange within OSPAR, and for possible storage within ODIMS.

### 3.2 Preparation of data

- Due to the use of the Margalef index, the limited differences (estimated 10%) between the grab sampler and box core sampling devices used within the Southern North Sea are effectively corrected for. In addition, limited differences in sample volume within the use of a single sampling device, and for the use of different types of grabs, is corrected for.
- The Margalef index values per sample per assessment area are first normalized by dividing with the reference value of the specific assessment area. Second, the average normalized Margalef index value is calculated per assessment area-year (e.g. DE\_DoggerBank-Sand-2015).

### 3.3 Assessment criteria

- The assessment unit/scale is a national area (e.g. the German Dogger bank) combined with the EUNIS 3 habitat (Sand, Mud, Coarse or Mixed) and the assessment year. In the future, the implementation of the new EU habitat classification system (including the depth component) will be tested.
- Reference values for Margalef diversity per national assessment area have been estimated using a variable high percentile method. In this method, using a set of Margalef index values from the specific assessment area, the 99, 95 or 75 percentile index value is taken, depending on the

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average subsurface fishing activity in that area (>0.5, >0.1 or <0.1 subsurface sweeps per year, respectively. See Van Loon et al. 2017 for more details). The obtained estimated reference value estimated is checked by comparing to a model (relation) of the median depth and estimated Margalef diversity reference value.

The formula of this model is:

$$Y = A + (K - A) / (1 + \exp(-B*(x-M)))$$

The model parameters A, K, B, and M are respectively 5.159, 7.79, 0.3054, and 31.49. This model shows three linear segments: (a) a stable linear part at low depth (<20m), (b) a rapid increase in the depth range 20-40 m, and (c) a stable linear part at a depth >40 m.

Note that this model is valid up to 50 m median depth, but has not been validated yet for larger depths. The estimated reference value should deviate less than 0.5 from the model value. If it deviates more, first the data have to be checked, and if necessary re-analysed. If the deviation remains >0.5, the model value has to be used.

- The assessment value has not yet been discussed and agreed in OSPAR (knowledge gap).

### 3.4 Spatial Analysis and / or trend analysis

- The BH2-B Margalef indicator primarily uses spatial average values per assessment area-year for assessment, and is not aimed at small-scale/sample assessment. For the area assessment, the average of preferably three (quality code 3), or possibly two (quality code 2), area-averaged normalised Margalef values is used. However, the range of Margalef diversity scores (and its relation to total abundance) can be obtained from the Margalef quality control plots, available in the BENMMI report file.
- Trend analysis is recommended to be performed for a period of twelve years (mid-term developments) and six years (short term developments). In both cases, at least six data years have to be available to obtain sufficient statistical significance. Normalised Margalef values at the **sample level** have to be used, in order to obtain maximum statistical significance. The Mann-Kendall significance test and the Sen-Teil slope estimation method are recommended, because (a) these tests are independent of the data distribution and (b) the obtained significance values are often lower (better) than using linear regression.
- A confidence interval of 90% is used for this indicator, because of the relatively high variation of benthic index values. This confidence value can be set and adjusted in the BENMMI software.

### 3.5 Presentation of assessment results

- At present a list of assessment areas and their average normalized Margalef score for the current MSFD assessment period (2010-2015) is presented; including the 90% confidence limits (see BH2-B assessment sheet).
- An accompanying bar diagram is presented.

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### 3.6 BENMMI assessment software

- Most of the data analysis and assessment steps described in this CEMP can be performed automatically and standardized using the BENMMI software. This software has been specifically developed for this indicator, is already available for the North Sea partners, and will be made publicly available freeware in spring 2018 (upcoming link: <https://cran.r-project.org/web/packages/BENMMI/index.html>).
- Read the Installation manual and User manual carefully.
- A few specific points of attention in the BENMMI input format are: The essential columns which have to be filled are: OBJECTID (area name), HABITAT (EUNIS 3), SAMPLEID, LAT, LONG, SAMPDEV, AREA (of sample), TAXON, VALUE (abundance), (PRESSURE). The pressure data are optional. Take care that the DATE column is in the ISO format (yyyy-mm-dd), and be aware that Excel sometimes changes this format automatically. Also note that per sample and per species the abundance has to be written into this input format, and that the use of density data is not allowed.
- BENMMI gives accurate error messages in case the input is not yet correct or as expected. These error messages facilitate the easy correction of the input data (see BENMMI user manual, Appendix I).

## 4 Change Management

Since changes of this method often require a more general level of discussion and policy decision making, it is proposed to discuss proposed changes in ICG-COBAM, and to make decisions on proposed changes in ICG-COBAM and BDC.

## References

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ISO, E. (2005). 16665 (2005): Water Quality–Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna.

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OSPAR 2016 – Common Biodiversity Indicators. Condition of benthic habitat communities (BH2).

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Van Loon W.M.G.M., Walvoort D.J.J., Van Hoey G., Vina-Herbon C., Blandon A., Pesch R., Schmitt P., Scholle J., Heyer K., Lavaleye M., Phillips G., Duineveld G.C.A., Blomqvist M. A regional benthic fauna assessment method for the Southern North Sea using Margalef diversity and reference value modelling. Ecological Indicators, in press, 2017.

**OSPAR CEMP guidelines**

Common Biodiversity Indicators: Condition of benthic habitat communities (BH2)

Technical Specifications

Annex 3: Subtidal habitats of the Southern North Sea

Walvoort D.W.W. and Van Loon W.M.G.M., 2017. BENMMI user manual.

<http://publicaties.minienm.nl/documenten/user-manual-benmmi-3-0>.

(will be updated soon with manual version 4.0)