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Integrating benthic habitat indicators: Working towards an ecosystem approach

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ABSTRACT

The Marine Strategy Framework Directive (MSFD) requires an ecosystem-based approach to assess the state of Europe's seas. To date, assessment is carried out on an indicator by indicator basis. Integration of indicators is required to undertake a more holistic assessment of the state of the marine environment. Here, an integrated approach to assess benthic habitats is proposed. Within this conceptual method, four OSPAR benthic habitat indicators relating to biodiversity (D1) and sea-floor integrity (D6) descriptors are linked together. For the integration, benthos, environmental and anthropogenic pressure data are required. State indicators are assessed along a gradient of pressure to facilitate threshold values to be quantified and provide advice on management measures. The method also includes a feedback system whereby best available evidence on benthos, its sensitivity and disturbance assessments can be replaced with ground-truthed data. The proposed method can be expanded to include other related indicators under the different descriptors (e.g. commercial fish and shellfish (D3), food webs (D4) and eutrophication (D5)) where relevant. The concept is a first step towards integration of benthic indicators and could be applied to monitoring requirements under other Directives such as the Habitat or Water Framework Directive.

1. Introduction

The Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) aims to implement an integrated ecosystem-based approach in order to manage anthropogenic activities and achieve Good Environmental Status (GES) of the marine environment by 2020 [1]. To achieve an ecosystem view of the marine environment under the MSFD, 11 descriptors are described [1] ranging from maintaining biodiversity (D1), marine food webs (D4), sea-floor integrity (D6), to minimising eutrophication (D5) and contaminants (D9). These descriptors are each made up of numerous criteria through which reporting by Member States is required [2].

Multiple indicators enable responses to anthropogenic pressures to be analysed more widely and provide a better understanding of their responses on benthic communities [3–5]. However, due to the complex nature of the marine environment, there is some overlap between indicators used to report on the different descriptors and criteria, and the MSFD's first reporting cycle has been criticised for its poor coherence (e.g. [6–8]). Gaps in information required to carry out assessment of the marine environment also exist [6,9]. Overarching knowledge gaps include: lack of pristine reference areas, or values to compare state related indicators against to set baselines; varying spatial scales; and a holistic approach to assess different aspects of the marine ecosystem [10].

One increasingly popular method to undertake integrative and ecosystem based assessment of the marine environment is through Multi-Metric Index (MMI) tools [11,12]. MMI tools enable the state of the marine environment to be monitored and assessed through the use of various metrics to derive a single value caused by anthropogenic pressures [11,13]. MMI tools are commonly used to provide a simple measure of the state of the marine environment for policy decisions such as Good Ecological Status (GEcS) within the Water Framework Directive (WFD; 2000/60/EC) [11,13].

Numerous integrated indicator tools have been developed in recent decades (reviewed by [14]). However, these tools suffer from the lack of pristine reference areas or levels to assess baselines and disturbance

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Table 1
OSPAR benthic habitat indicator summary.

Indicator	Aim	Measurement unit
Typical species composition (BH1)	To measure changes in the proportion of typical species within different benthic habitats when a physical or chemical disturbance occurs, compared to pristine reference or least damaged conditions.	Percentage change.
The condition of benthic communities (BH2)	To measure changes in the condition of benthic communities' through biological diversity indices (e.g. Shannon-Wiener or Margalef), biological traits indices (e.g. Infaunal Trophic Index, fuzzy correspondence analysis) or multivariate community composition changes, along a gradient of anthropogenic pressure.	Ecological Quality Ratio (the ratio of the value of the indicator for the considered habitat benthic community against that of a least damaged community).
The extent of physical damage of benthic broad habitat types (BH3)	To assess the extent and degree of potential physical disturbance on benthic broad-scale habitats caused by anthropogenic pressures by combining data on anthropogenic activities with the sensitivities of underlying benthic habitats mapped.	Square kilometre and percentage of benthic broad-scale habitat disturbed.
The area of habitat loss (BH4)	To assess the proportion of the area of benthic habitats that are permanently, or for a long-lasting period lost due to anthropogenic pressures.	Square kilometre and percentage of habitat lost.
The size-frequency distribution (BH5)	To assess the effects from physical disturbance or hypoxia on bivalves or other sensitive benthic species.	Number or biomass of individuals per size class[a].

[a] Note: within the OSPAR region the method for BH5 has not yet been developed and its unit may be subject to change.

gradients against [12]. Additionally, trying to synthesise many aspects of the marine environment into a single value leads to loss of information, thus only approximately reflecting the complex nature of marine systems [10,15]. Most MMI assessment tools use indicators which are measured and assessed at varying levels of confidence and spatial scales adding an additional level of uncertainty. Other difficulties when using MMI tools include, uncertainties in how to weight the different pressure indicators appropriately, and redundancy problems with double counting which can lead to imbalance or bias of certain indicators [10,15].

The aim of this paper is to develop a quantitative integrated method to assess GES of benthic habitats, using benthic habitat indicators under descriptor 1 (biodiversity) and descriptor 6 (sea-floor integrity), with potential implications on other descriptors. To assess GES of benthic habitats, a brief overview of the different types of integration methods is outlined. The OSPAR (Convention for the Protection of the Marine Environment of the Northeast Atlantic) benthic habitat indicators are summarised. The conceptual method on how to integrate these indicators in terms of process and data type is then described. To avoid confusion in terminology, key terms used in this paper are aligned with MSFD and OSPAR language (refer to Supplementary Material).

2. Integration of indicators

Various methods exist to integrate indicators and undertake a global assessment of the marine environment as reviewed by Borja et al. (2014) [10]. MMI tools are more commonly used methods for integration (e.g.[14]). The assessment of cumulative or co-occurring pressures is also frequently used to undertake global assessment of the marine environment (e.g. [16–18]). Quantitative cumulative assessments do not currently incorporate individual indicators and descriptors under the MSFD [19]. The use of more complex modelling techniques such as End to end and Ecopath with Ecosim [20] can also be used. Such models are however, rarely used for larger scale benthic management decisions due to their difficulties in addressing seafloor integrity [20], and the large amount of data required to validate these models. The WFD uses the 'One Out, All Out' (OOAO) approach with regard to the integrated assessment of biological indices. The OOAO approach has, nonetheless been considered erroneous and overly precautious [6,21]. No specific rule has so far been agreed by European Member States for the MSFD [6]. Integrated ecosystem approaches are currently under development in OSPAR [19].

3. Methodology

3.1. OSPAR benthic habitat indicators

Under the OSPAR regional seas convention, five benthic habitat indicators have been proposed. These include: Typical species composition (BH1); Condition of benthic communities (BH2); Extent of physical damage of benthic broad habitat types (BH3); Area of habitat loss (BH4); and Size-frequency distribution of bivalve or other indicator species (BH5) [2,5,22].[1] The overarching aims of these indicators are summarised within Table 1. To undertake an integrative cyclical assessment, the methodologies of the individual benthic indicators are used and linked together through a quantitative feedback loop. All five indicators rely on three main data types:

1. Benthos data comprising of species inhabiting particular seabed types and the seabed itself;
2. Environmental data (e.g. depth, salinity, wave exposure, sediment type) used to classify and model the benthic habitats according to the hierarchical levels of the European Nature Information System (EUNIS) levels alongside benthos data [23]; and
3. Anthropogenic pressure data (e.g. abrasion, siltation, physical disturbance, nutrient enrichement, etc.) [24].

3.2. Benthos and seabed data

Ground-truth sampling from benthic monitoring and assessment, and environmental data are required to identify typical species (BH1) and benthic communities (BH2) occurring at a site scale (100's of meters to 10's of kilometres). Various methods exist to collect benthos data (e.g. cores, visual imagery techniques, trawl surveys, etc.) [25]. Each method has advantages and disadvantages which should be taken into consideration (refer to [26]). If sufficient data are available, broad-scale and biogenic habitat can be predicted and mapped using this benthos data with the support of environmental data (Fig. 1a-c). Using best available evidence on species and benthic habitat sensitivities (by combining resistance and resilience characteristics) for defined anthropogenic pressures, broad-scale sensitivity maps are created (Fig. 1d; BH3; [27,28]). Best available evidence is based on the confidence of sensitivity assessments and the underlying source of benthic data which

[1] Precise methods for the benthic indicators described are currently being developed under the OSPAR convention and should be publically available by the beginning of 2018 (www.ospar.org/work-areas/bdc/ecaprha/cemp-reports and https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/).