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Preface

Implementing the European Marine Strategy Framework Directive: Scientific challenges and opportunities

1. Background

The Marine Strategy Framework Directive (MSFD; EC, 2008) is an ambitious European policy instrument that aims to achieve Good Environmental Status (GES) in the 5,720,000 km^2 of European seas by 2020, using an Ecosystem Approach. GES is to be assessed using 11 descriptors and up to 56 indicators (European Commission, 2010), and the goal is for clean, healthy and productive seas that are the basis for marine-based development, known as Blue-Growth. The MSFD is one of many policy instruments, such as the Water Framework Directive, the Common Fisheries Policy and the Habitats Directive that, together, should result in "*Healthy Oceans and Productive Ecosystems* – HOPE". Researchers working together with stakeholders such as the Member States environmental agencies, the European Environmental Agency, and the Regional Sea Conventions, are to provide the scientific knowledge basis for the implementation of the MSFD. This represents both a fascinating challenge and a stimulating opportunity.

2. Context

Scientists have not been idle since the publication of the MSFD in 2008, and even before (Borja, 2006). A SCOPUS search of journals (July 2015) found more than 300 articles related to the MSFD. Several research projects both at EU and national level address the scientific challenges (*e.g.* DEVOTES – www.devotes-project.eu-, KnowSeas, STAGES, Perseus and many more). Furthermore, special sessions have been organized at conferences, including *"Impacts of anthropogenic pressures on coastal ecosystem functioning and services"*, organized in May 2014 at the European Geosciences Union (EGU), and the June 2014 special session "*Marine environmental status and biodiversity: from structure to functionality, delivering ecosystem services*" at the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) conference.

The papers following this short editorial illustrate some of the discussions that took place at these meetings. They address especially Descriptor 5, eutrophication (Ciglenecki et al., 2015; Cristina et al., 2015; Pavlidou et al., 2015). Together, the papers present an interesting gradient of eutrophication assessment, from a sheltered bay (Rogoznica Lake in the Adriatic, Croatia) (Ciglenecki et al., 2015), to coastal examples in the Eastern Mediterranean (Pavlidou et al., 2015) and moving to offshore locations in the Iberian Sea (Cristina et al., 2015). This represents a gradient from the Water Framework Directive transitional waters, to coastal waters and then offshore to the Marine Strategy Framework Directive area.

3. Definitions and vocabulary

The text of the MSFD includes many terms and concepts that lacked precise scientific or operational definitions (Andersen et al., 2013). McLeod and Leslie (2009) offered a definition of Ecosystem Based Management, but there are still "pitfalls" to this approach (Berg et al., 2015). Borja et al. (2013) contributed to define GES and the terminology used in the Driver–Pressure–State–Impact–Response (D–P–S–I–R) is being revised and improved (Gari et al., 2015).

4. Social and economic relevance

The integration of the ecological, economic and social aspects is a pillar of the implementation of the ecosystem approach to management of environmental resources (de Jonge et al., 2012). However, the actual implementation of this paradigm faces many challenges, including the need to involve stakeholders (Hendriksen et al., 2014), despite the difficulty of engaging stakeholders in a really cooperative way (Canu and Solidoro, 2014). Other obstacles are related to (i) issues of scales (Swaney et al., 2012); (ii) spatial issues (Zaucha, 2014), that should be addressed by the Marine Spatial Planning Directive; (iii) temporal issues (O'Higgins et al., 2014); and (iv) issues related to the institutional framework. The different directives, legislative tools and the governance are interwoven (Boyes and Elliott, 2014), with obvious overlaps, but also opportunities for synergies, such as the Mediterranean example given by Cinnirella et al. (2014).

5. Progress on the scientific knowledge basis

Monitoring large areas of the regional seas is scientifically challenging and expensive, but necessary, in spite of the economic crisis, (Borja and Elliott, 2013; Carstensen, 2015). New technological tools such as autonomous submarine gliders may gain increasing importance in monitoring (Suberg et al., 2014). Meanwhile, remote sensing can also make an important contribution to monitoring large areas of the regional seas that would be

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prohibitively expensive using research vessels. Cristina et al. (2015) describe how Medium Resolution Imaging Spectrometer (MERIS) Algal Pigment Index 1 products can be used, in order to support the implementation of the MSFD with respect the Descriptor 5 (Eutrophication). The study is applied in SW Iberia and underlines the importance of performing an error estimation of the satellite product, before using it for GES assessment and model verification. Combining tools such as Ocean color with existing techniques such as CHEMTAX (Goela et al., 2014) can be particularly effective, as can innovative tools such as genomics (Bourlat et al., 2013).

As a complement to observations, numerical ocean models are widely-used tools to describe and project changes in the physical and biogeochemical status of the ocean, over time scales of days to several decades (*e.g.* IPCC predictions at the 2100 horizon, IPCC, 2013). During the last twenty years, due to the substantial increase in computing power and based on a better understanding of marine ecosystems, ocean models and coupled hydrodynamical–biogeochemical models have evolved towards increasingly complexity; so they can now contribute to integrated ecosystem assessments (Pastres and Solidoro, 2012). Ocean models are used now in operational mode (~7 days forecast, *e.g.* http://www.myocean.eu), in the framework of Copernicus, for the prediction of physical and biogeochemical processes (*e.g.* Teruzzi et al., 2014). Models allow for space-time inter-extrapolation of observed data and run on the knowledge of physical and ecological processes that are embedded within the model (Cossarini et al., 2009). They also provide estimates of indicators and parameters that cannot be measured routinely in monitoring programs. Examples are secondary production, and parameters in deep seas that can be used to identify ideal conditions, to be used as a reference. Piroddi et al. (2015) have reviewed available ecological models, to assess status according to the MSFD. Models can also be used to evaluate the effectiveness of alternative restoration management (Canu and Solidoro, 2014), and have been used to predict how climate variability and change may be an obstacle to achieving GES (Elliott et al., 2015).

However, the assessment of potential changes in some GES indicators, such as biodiversity, poses a perennial problem for ecosystem modelers. These challenges were discussed during the EGU and IMBER thematic sessions that led to this section of Continental Shelf Research. The main limitation is that biodiversity is defined usually by species richness and/or evenness whereas, at present, ocean biogeochemical models are based upon a pre-defined structure in which the number of species does not change; they actually aggregate large number of species into a single or few state variables. Furthermore, a refined representation of ecosystem models to the species level would increase model uncertainty, due to the substantial lack of information to parameterize this type of models (*e.g.* Ruiz and Kuikka, 2012; Bruggeman and Kooijman, 2007). Hence, ocean models are still considered as poor predictors of biodiversity, whereas there is a crucial need to produce reliable projections of the effects of human interventions on living communities (*e.g.* IPBES projections). In conclusion, ocean models are very powerful for the physics, chemistry and low trophic levels but there is a need for innovation so that existing models connect with GES and ecosystem and services. It is therefore urgent to develop specific approaches that are able to connect the outputs of ocean models to some descriptors of GES that are poorly addressed so far. For example, the integration of ecological and end-to-end models (Rose et al., 2010), giving quasi real-time assessments of ecological conditions, is one of the next steps.

Some studies have a regional sea focus (Fleming-Lehtinen et al., 2015), while some focus especially on one descriptor, for example Descriptor 1 (biodiversity) (Strong et al., 2015). Thus, another important challenge is how to best aggregate the multiple indicators, descriptors and spatial–temporal scales (Borja et al., 2014), likewise how to assess the environmental status using an integrated tool (Andersen et al., 2014). Harmonizing such a tool across the European regional seas will be a pivotal advance, in the near future, for the timely implementation of the MSFD.

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