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Viewpoint

"And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management

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ABSTRACT

The marine environment is a complex system formed by interactions between ecological structure and functioning, physico-chemical processes and socio-economic systems. An increase in competing marine uses and users requires a holistic approach to marine management which considers the environmental, economic and societal impacts of all activities. If managed sustainably, the marine environment will deliver a range of ecosystem services which lead to benefits for society. In order to understand the complexity of the system, the DPSIR (Driver-Pressure-State-Impact-Response) approach has long been a valuable problem-structuring framework used to assess the causes, consequences and responses to change in a holistic way. Despite DPSIR being used for a long time, there is still confusion over the definition of its terms and so to be appropriate for current marine management, we contend that this confusion needs to be addressed. Our viewpoint advocates that DPSIR should be extended to DAPSI(W)R(M) (pronounced *dap-see-worm*) in which **D**rivers of basic human needs require **A**ctivities which lead to **P**ressures. The **P**ressures are the mechanisms of **S**tate change on the natural system which then leads to **I**mpacts (on human **W**elfare). Those then require **R**esponses (as **M**easures). Furthermore, because of the complexity of any managed sea area in terms of multiple Activities, there is the need for a linked-DAPSI(W)R(M) framework, and then the connectivity between marine ecosystems and ecosystems in the catchment and further at sea, requires an interlinked, nested-DAPSI(W)R(M) framework to reflect the continuum between adjacent ecosystems. Finally, the unifying framework for integrated marine management is completed by encompassing ecosystem structure and functioning, ecosystem services and societal benefits. Hence, DAPSI(W)R(M) links the socio-ecological system of the effects of changes to the natural system on the human uses and benefits of the marine system. However, to deliver these sustainably in the light of human activities requires a Risk Assessment and Risk Management framework; the ISO-compliant Bow-Tie method is used here as an example. Finally, to secure ecosystem health and economic benefits such as Blue Growth, successful, adaptive and sustainable marine management Responses (as Measures) are delivered using the 10-tenets, a set of facets covering all management disciplines and approaches.

1. Introduction

The marine environment is a complex system of interactions between morphological and physical structures, continuously varying physico-chemical processes and varying ecological structure and functioning (Fig. 1). It is the composite set of interrelationships whereby the environment influences the biota (e.g. sandbanks supporting burrowing sandeels), the biota modifies itself (e.g. predator-prey relationships) and the biota also modifies the environment (e.g. burrowing worms causing physical and biogeochemical changes in sediments) – respectively termed the *environment-biology*, *biology-biology* and *biology-environment* links (Gray and Elliott, 2009) (Fig. 1). Superimposed on this dynamic ecosystem, the intensity of anthropogenic activities both varies and is increasing, and pressures from these activities may affect the natural environment and subsequently this may have a knock-on effect on society (Burdon, 2016). Management of the marine environment therefore requires a holistic approach that recognises the complexity of the system and accommodates the diverse range of uses and users (de Jonge et al., 2003; Atkins et al., 2011; Pinto et al., 2014; Turner and Schaafsma, 2015). This is particularly the case as there is only one major idea in marine environmental management – *to maintain and protect the ecological structure and functioning while at the same time ensure that it maintains ecosystem services from which society can obtain*

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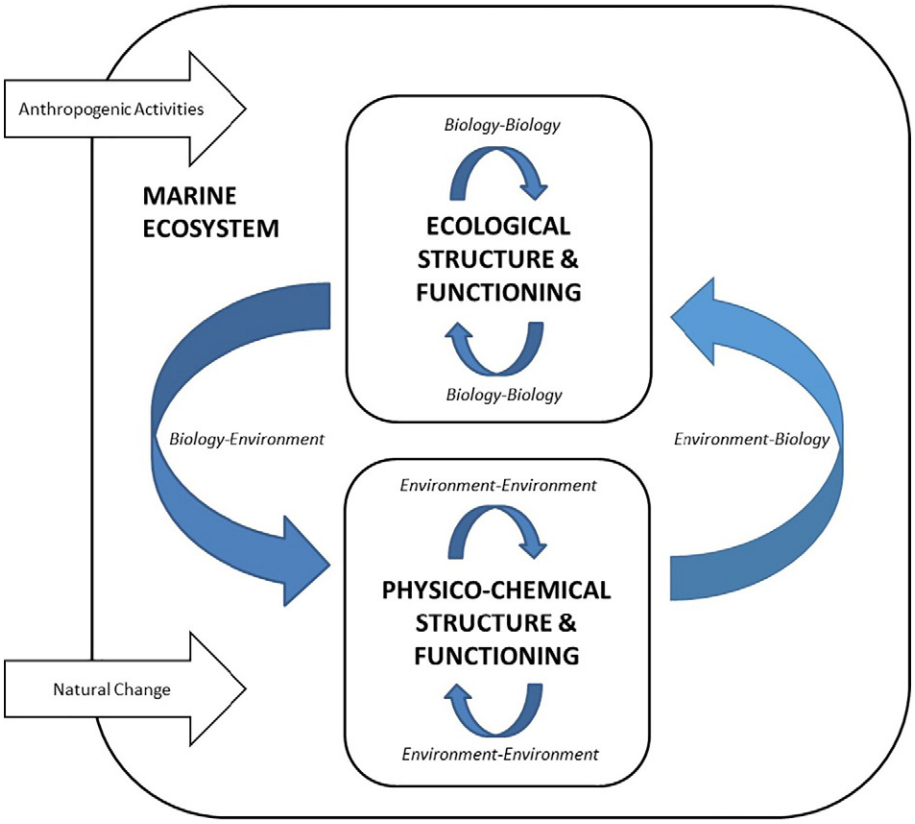

Fig. 1. A conceptual model indicating the linking and feedback between abiotic and biotic attributes of the marine ecosystem (Burdon, 2016).

benefits (Elliott, 2011). As such, integrated marine management needs to consider the environmental, economic and societal impacts of all activities (see de Jonge et al., 2012; Puente-Rodríguez et al., 2015). The Ecosystem Approach, enshrined in 12 principles by the UN Convention on Biological Diversity (CBD, 2000), provides the guiding principles for such an integrated management (Elliott, 2011).

It is argued here that in order to fully achieve the Ecosystem Approach in marine management then an interdisciplinary approach is required which bridges the divide between the natural environment and society (Borja et al., 2016a, 2016b; Burdon, 2016; Turner and Schaafsma, 2015). As implied by such a complex system, the approach requires a large level of detail (de Jonge and Giebels, 2015) as well as to be fully linked to an operational policy life cycle to ensure that measures reflect societal goals and objectives (Cormier et al., 2017). It is recognised, however, that effective marine management requires the complexity of the marine system and the links between the environment and society to be firstly understood by managers, policymakers and stakeholders (Beaumont et al., 2007) and secondly carried out with their involvement (Newton and Elliott, 2016).

The DPSIR (Drivers-Pressures-State-Impact-Response) approach is an accepted, valuable and holistic problem-structuring framework which can be used to assess the causes, consequences and responses to change (Atkins et al., 2011; de Jonge et al., 2012; Gregory et al., 2013; Pinto et al., 2013). As a concept, it has long been used to integrate and provide structure to the management of environmental systems (Atkins et al., 2011; Patrício et al., 2016). From its origins in the unpublished report by Rapport and Friend (1979), it was further developed from an 'Organisation for Economic Co-operation and Development' (OECD) approach which aimed to link anthropogenic Pressures with State changes and Impacts (OECD, 1994), and has since been often used within an environmental context (EEA, 1995; Turner et al., 1998; Elliott, 2002; Atkins et al., 2011; Gari et al., 2015; Smyth et al., 2015; Smith et al., 2016).

A key strength of the DPSIR framework is that it captures simply the key relationships in environmental management (Svarstad et al., 2008; de Jonge et al., 2012). DPSIR models have been applied to many systems in which the boundary of the management system depends on the issue of interest and its conceptualisation (Atkins et al., 2011). Feedback loops between the management Responses and the Drivers and Pressures are also of importance, as are the effects of natural change on the system (Fig. 2). Within a marine context, applying the DPSIR framework to marine management is therefore consistent with the Ecosystem Approach (Karageorgis et al., 2006; de Jonge et al., 2012; Cooper et al., 2013).

Despite its strengths, the DPSIR framework has been criticised within the literature (e.g. Berger and Hodge, 1998; Rapport et al., 1998; Rekolainen et al., 2003; Gregory et al., 2013) and there appears to be confusion surrounding the terminology of the various elements. In particular, confusion exists between definitions of Drivers and Pressures and also in the distinctions between State and State change and between these and Impacts, the latter often being regarded as impacts on the natural system, the human system or both. Several recent reviews have specifically focussed on applications of DPSIR (and its derivatives) in the coastal and marine environment (e.g. Gari et al., 2015; Smith et al., 2016; Lewison et al., 2016; Patrício et al., 2016). This paper does not replicate those reviews, but aims to focus specifically on the confusions in the DPSIR terminology as justification for improving the framework for practicable management purposes. The confusion between the DPSIR components is illustrated in Table 1 together with suggestions for potential solutions to address these anomalies/queries. To be valuable for management purposes and to provide clarity to science regarding the advice needed, we advocate that this confusion needs to be removed. Therefore, we track the evolution of the various approaches while presenting a solution to the anomalies using an integrated model for marine management and for differing spatial scales of management.