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Embedding ecosystem services into the Marine Strategy Framework Directive: Illustrated by eutrophication in the North Sea

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ABSTRACT

The introduction of the Marine Strategy Framework Directive (MSFD) with its focus on an Ecosystem Approach places an emphasis on the human dimensions of environmental problems. Human activities may be the source of marine degradation, but may also be adversely affected should degradation compromise the provision of ecosystem services. The MSFD marks a shift away from management aiming to restore past, undegraded states toward management for Good Environmental Status (GEnS) based on delivery of marine goods and services. An example relating ecosystem services to criteria for Good Environmental Status is presented for eutrophication, a long recognised problem in many parts of Europe's seas and specifically targeted by descriptors for GEnS. Taking the North Sea as a case study the relationships between the eutrophication criteria of the MSFD and final and intermediate marine ecosystem services are examined. Ecosystem services are valued, where possible in monetary terms, in order to illustrate how eutrophication affects human welfare (economic externalities) through its multiple effects on ecosystem services.

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1. Introduction

Growing realisation of the extent of human impacts on global ecosystems and the declining capacity of these ecosystems to provide the services on which we depend (e.g. Millennium Ecosystem Assessment, 2003; Halpern et al., 2008) has led to the concept of an "Ecosystem Approach" (EA) which may be defined as "a resource planning and management approach that integrates the connections between land air water, all living things, human beings their activities and institutions" (Farmer et al., 2012). The approach recognises the total dependence of human activities on the ecosystems in which they take place (Boumans et al., 2002). Three characteristics of an EA are: a multisectoral focus responding to the multiplicity of pressure placed on the environment; the inclusion of ecosystem services in decision making, reflecting the multiplicity of benefits to be derived from marine ecosystems; and the subsequent tight coupling between social and ecological systems (Tallis et al., 2010). Ecosystem services are defined as "the aspects of ecosystems utilized (actively or passively) to produce human well-being". According to Fisher et al. (2009), ecosystem services are ecological phenomena from which humans derive benefit. The incorporation of ecosystem services into environmental management is receiving increasing attention internationally (e.g. CSIRO, 2003; Millennium Ecosystem Assessment, 2003; EPA, 2009). Development of an effective EA requires a multidisciplinary approach incorporating the complexity of ecological and social systems.

The Marine Strategy Framework Directive (MSFD) (European Commission, 2008), the environmental pillar of the EU Integrated Maritime Policy is a European Union directive with the aim of "maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean healthy and productive". The directive mandates an EA and obliges EU nations to achieve Good Environmental Status (GEnS) within member states' Exclusive Economic Zones (EEZs) on a regional seas basis by 2020. Introduction of an EA represents a major shift in marine environmental management for the EU away from the "deconstructing structural" approach of previous environmental legislation, such as the Urban Wastewater Treatment, Nitrates (Commission of the European Communities, 1991a,b) and the Water Framework (WFD) Directives (European Commission, 2000), and toward a more "holistic functional" approach with a focus on marine ecosystem services (Borja et al., 2010).

In the MSFD, 11 descriptors of GEnS are specified for which targets must be set by each EU member state. While some of the GEnS descriptors are already relatively well understood and, in the case of eutrophication, overlap with the WFD, others are new and

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have received less scientific attention. Existing regional seas agreements are to be used where possible to harmonise implementation of the directive to achieve GEnS at the regional sea level. Implementing the MSFD through an EA presents a major challenge to European scientists and decision makers due to the large spatial scale of MSFD jurisdiction, its comprehensive environmental scope and its social–ecological focus (Mee et al., 2008; Atkins et al., 2011). In particular the MSFD presents a challenge in linking traditional metrics of environmental monitoring to the representation of status in terms of ecosystem quality and sustainable use of marine ecosystem services.

The task group for the eutrophication descriptor under the MSFD defined eutrophication. Eutrophication is "a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services" (Ferriera et al., 2010). The criteria for assessment of eutrophication under the MSFD are nutrient levels (criterion 5.1); direct effects of nutrient enrichment (criterion 5.2) and indirect effects of nutrient enrichment (criterion 5.3). Subcriteria are defined under each criterion including nutrient concentrations (5.1.1) and ratios (5.1.2); Chlorophyll concentrations (5.2.1) water transparency (5.2.2) abundance of opportunistic macroalgae and shifts in florisitic composition (5.2.4); abundance of perennial seaweeds and seagrasses (5.3.1) and dissolved oxygen (5.3.2).

Marine eutrophication has been recognised in Europe's coastal waters for over a century (Adeney, 1908) and has been viewed as a significant problem in Europe since the mid-1980s (Rosenberg, 1985), affecting many areas, particularly in the Baltic (Savchuk, 2005), Black (Mee et al., 2005), North and Mediterranean (Pätsch et al, 2010) Seas. Decades of experience with the monitoring and assessment of eutrophication in the North Sea have highlighted several important challenges for future management of eutrophication (Ferriera et al., 2010, 2011; Hering et al., 2010) but have also yielded considerable insight into the ecological complexity which controls the expression of eutrophication (Tett et al., 2003).

The aim of this paper is to describe how ecosystem services relate to assessment of environmental status under the Marine Strategy Framework Directive. The relationship between ecosystem services and the eutrophication descriptor is identified and an ecosystem service valuation approach is applied to the North Sea. The intention of this paper is not to provide an economic analysis of the costs and benefits related to the North Sea eutrophication problem; rather it presents the connections between changes in environmental state and their repercussions regarding the supply of ecosystem services and human welfare.

2. Materials and methods

The large human population (~160 million) and intensive agricultural practices in the North Sea's catchment mean that anthropogenic nutrient loads to the North Sea are high (EEA, 2005), yet oceanic exchange means that anthropogenic contributions to the overall nutrient budget are quite modest. In the relatively poorly flushed, shallower, coastal and southern North Sea, these sources account for 52% (N) and 41% (P) of all external sources (Vermaat et al., 2008). These areas are susceptible to eutrophication. Anoxic sediments and algal blooms have been observed in the German Bight and parts of the Wadden Sea (Van Es and Ruardij, 1982; Brockmann et al., 1988; Hickel, 1998; Druon et al., 2004; Van Beusekom, 2005); the shallow unstratified southern part of the North Sea is prone to high phytoplankton biomass (Radach and Pätsch, 1997; EEA, 2013); nuisance blooms of the foam forming alga *Phaeocystis globosa* are also regularly observed (Lancelot et al., 2005, 2011). Nuisance blooms of opportunistic macroalgae have also been reported in the North Sea (e.g. den Hartog, 1994). The problem of eutrophication in the North Sea has received extensive academic attention, in terms of modelling of nutrient loading (Skogen et al., 2004; OSPAR, 2008; Lenhart et al., 2010; Los and Blaas, 2010), the ecological effects of these loads (Riegman et al., 1990; Tett et al., 2003) and the economic costs of remediation (Hoffmann et al., 2005; Nunneri et al., 2007). There has also been considerable management effort to counteract the effects of eutrophication under the Oslo Paris convention (OSPAR). Fig. 1 provides a visual summary of the spatial distribution of eutrophication in the North Sea. In the context of the MSFD, North Sea eutrophication is a well known and a well understood marine management problem and represents an excellent test case for assessment of the implications of an Ecosystem Approach with its expanded social–ecological focus for environmental management and assessment strategies.

The ecosystem services related to MSFD criteria and subcriteria were specified by listing the associated physical, chemical and biological products and processes and considering the direct and indirect effects of these products and processes on human well-being. The resulting list of ecosystem services was cross-checked with existing lists of ecosystem services (see Saunders et al., 2010; O'Higgins and Roth, 2011. Ecosystem services were distinguished as either intermediate or final based on Fisher et al. (2009). Intermediate ecosystem services are those which affect human well-being indirectly while final services directly affect human well-being.

Management based on consideration of ecosystems services will need some means of intercomparing ecosystem services. Economic valuation of ecosystems provides one such means. Valuation can be based on market values, where available. Where ecosystem services do not have market values, non-market values can be estimated using benefits transfer, a technique whereby economic values for a particular service from one study site are transferred to those of another study site. In order to avoid double counting final ecosystem services only should be valued.

The choice of ecosystem services will be discussed in the next section, however, the following methods were used to value the ecosystem services identified. Estimates of current values of the ecosystem services above were calculated and converted to values in € (2010) using the Consumer Price Index. The economic value of carbon burial by the North Sea ecosystem was based on estimates of carbon export to deep waters by the shelf-sea pump (1.83×10^{-5} t y^{-1}) in Bozec et al. (2006). Estimates of the value of carbon storage were based on European Union allowance of €16.80 $tC^{-1}y^{-1}$ (Point Carbon, 2011). Values for Willingness to Pay (WTP) for recreation in European nations (reported in WTP/individual/yr) were taken from a meta-analysis of recreational values (Ghermandi et al., 2011) and combined with tourism statistics in coastal areas (Eurostat, 2012a). Prices for commercial fish species were taken from Eurostat (2012b). Catch data were taken from ICES FishStat database. Data for three years (2007–2009) were averaged to give a mean annual catch and price.

3. Results

Fig. 2 illustrates the links between the eutrophication criteria and key intermediate services, final services and benefits. The relationships between individual eutrophication criteria and the supply of ecosystem services vary in complexity. There are reasonably direct links between some criteria, the final services they provide and subsequent benefits. For example the abundance

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