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Linking marine fisheries to environmental objectives: a case study on seafloor integrity under European maritime policies

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ABSTRACT

Fisheries is regarded a significant impact to the marine environment, and the management of fisheries under maritime environmental policies will be an important task for the future. A relative ecological risk model is applied to define risk components of gain and loss in relationship to 7 demersal fishing métiers for the seafloor ecosystem in the German EEZ. Four scenarios are evaluated against the policy goals from European maritime policies. It is shown that two measures combined in an integrative assessment, i.e. effort reduction to MSY and areal closures, are likely to meet requirements from 3 environmental policies, i.e. the Marine Strategy Framework Directive, the Habitats Directive, and the Common Fisheries Policy. Sustainability in terms of maximum sustainable yield for fisheries is likely to provide only partial improvement of the environmental status of the marine ecosystem. The implementation into the pressure-state-response framework of environmental management is discussed.

1. Introduction

'Seafloor integrity' is one of the marine ecosystem descriptors proposed by the Marine Strategy Framework Directive (MSFD-2008/56/EC). It comprises both the physical structure and the biotic composition of the benthic community, and the characteristic functioning of the ecosystem component (Cardoso et al., 2010). Improving the ecological status of the marine environment is a major goal of modern maritime policies. MSFD aims at maintaining or restoring 'good environmental status' for the seafloor, where fisheries are regarded as a major impact on benthic ecosystems (Kaiser et al., 2002; Pedersen et al., 2009a). Management is based on assessments of the ecological quality of the marine environment, and of the human activities in the marine environment. Whereas methods for evaluating and managing the effects of hazardous substances as a 'classical' problem are well established, the way in which effects from nonconventional pressures (i.e. fisheries, hydromorphological change) are assessed is far from clear, as there is no clear way to undertake integrated assessments of multiple pressures and to account for multiple management objectives (Apitz et al., 2006).

In recent years, three main assessment methodologies have evolved, i.e. pressure-state-response (PSR) models aiming at indicator-based management concepts (Greenstreet et al., 2009; Link et al., 2010; Rochet and Rice, 2005), process-based ecological risk assessment (ERA) models able to treat uncertainty in data and processes (Fock, 2011; Hayes and Landis, 2004; Landis and Wiegers, 1997), and score-based impact or vulnerability models preferably useful for broad scale assessments due to the wide range of impacts analyzed and the many ecosystem components covered (Ban et al., 2010; Halpern et al., 2008; Stelzenmüller et al., 2010b).

Based on the OECD model for sustainability indicators (OECD, 1993), PSR models have become highly influential in developing policies. In its extended form (DPSIR) PSR is state-of-the-art for integrated marine assessments in Europe (EEA, 2009). Key concept of PSR models is the description of the

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Table 1 – Ecological indicators to indicate the good environmental status of the seafloor, i.e. good seafloor integrity[a].

Indicators proposed for seafloor integrity
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)
Extent of the seabed significantly affected by human activities (such as dredging, trawling or other alterations which may influence the substrate) for the different substrate types (6.1.2)
Presence of particularly sensitive or tolerant species (6.2.1)
Multi-metric indexes assessing functionality of the benthic system, such as such as the proportion of opportunistic to sensitive species (6.2.2)
Proportion of number or biomass of individuals above some specified length/size (6.2.3).
Parameters (slope and intercept) of the size spectrum of the aggregate size composition data (6.2.4).

[a] European Commission Decision (2010/477/EU) on criteria and methodological standards on good environmental status of marine waters.

environmental state evidenced by means of an indicator value. PSR rationale has tailored recent maritime legislation in Europe, i.e. MSFD and Water Framework Directive (WFD, 2000/60/EC), in that policy performance is evaluated through a set of traceable indicators each assigned to a specific ecosystem descriptor. However, the link between indicator and pressure may not be defined in all its intricacies or be even indirect, and 'decoupling' indicators may be applied if state and pressure trends do not correspond any longer (OECD, 2003). Thus, indicators are not applicable to integrating assessments for more than one pressure (Table 1).

Score-based impact assessments are destined to undertake integrative large-scale assessments, given that the score-based characterization of impacts aims at delivering commensurable scales for all pressures. In turn, state of the ecosystem as independently obtained target measure is not an essential element of impact assessments, although in some cases ecosystem state is directly derived from the impact however not as independent measure (e.g. in HELCOM, 2010). Often, the link between pressure and ecosystem is established through matrices (e.g. Robinson et al., 2008) based on the concept of component interaction matrices (e.g. Shopley et al., 1990).

In data rich environments and where high resolution of impacts is requested, ecological risk assessments (ERA) combine the merits of large-scale analyses with the modeling of stressor-component interaction processes such as mortality. Through its conceptual working steps, it is a systematic means by which risks may be understood and their estimation may be improved (Fock, 2011; Graham et al., 1992; Harwell et al., 1992; U.S. Environmental Protection Agency, 1998) and can solve complex ecological problems (Lackey, 1998). As relative ERA, cumulative impacts from different pressures can be analyzed and compared across a range of ecosystem components (Fock, 2011). The concept of risk has two sides, in that on the one hand threats ('downside risk') and on the other hand opportunities as positive consequences ('upside risk') can be imaged, both with their associated uncertainties (Chapman, 1997).

For WFD purposes and thus not yet assigned to marine offshore waters, mainly indicator-based methodologies have been applied for assessments of benthic environments, either with a focus on integrating pressures (Aubry and Elliott, 2006) or on the state of the benthic environment (Borja et al., 2009a; Magni et al., 2005). As a novel approach, the application of both up- and downside risk is exemplified for the benthic ecosystem component in the German EEZ of the North Sea in relation to different fishing métiers. The concept of negative risk as a measure of impact on an ecosystem component as part of the impact assessment (Fock, 2011) is complemented with a further measure of effect on the state of the ecosystem component through a gain function. Prior to the risk assessment, the mapping of fisheries (Fock, 2008) and the identification of conservation issues in relation to fisheries (Pedersen et al., 2009a) were undertaken. Environmental objectives relevant to European maritime environmental policies under MSFD or the Habitats Directive (HD-92/43/EEC) are addressed, and it is demonstrated how multiple pressures and multiple objectives can be integrated into one assessment protocol. Links to the PSR methodology are outlined and prospective development of this standard methodology with regard to risk assessment models and Bayesian networks are discussed.

2. The concept of loss and gain in defining objectives

A link between human activity and ecosystem component can be defined as that a human activity (e.g. fisheries) exerts several pressures (e.g. abrasion, extraction of biomass, . . .), which affect ecosystem components in different ways. Ecosystem component and pressure are quantitatively defined by their state (quantity, extension). Ideally, a state is discrete and measurable, it is sensitive to changes in an ecosystem and its response is specific to certain pressures (Link et al., 2010). For fisheries as a source of pressure, a suite of state indicators is available (e.g. measures of fishing effort Piet et al., 2007). The state of ecosystem components (e.g. benthos, birds) is defined in terms of certain endpoints (biomass per unit, abundance, diversity, etc).

In both the ERA and the PSR framework, the link between pressure and ecosystem component is formalized in a conceptual modeling step (Fig. 1A) (U.S. Environmental Protection Agency, 1998), however this link is treated differently. In the PSR framework, the state of the indicator is a direct consequence of the pressure (Fig. 1B), which is the basis for the indicator-based rationale.

This concept bears a number of caveats. First, the conciseness of the link itself depends on the adequate representation of underlying processes, the adequate selection of the indicator and the degree of resolution and aggregation the state indicators have (see hierarchy of indicators in Piet et al., 2007) considering that univariate numerical state variables might not be able to reflect actual complexities in ecosystems (Rees, 2009). Indices require careful validation and selection from the suite of available