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Discussion

Drivers and pressures – Untangling the terms commonly used in marine science and policy

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ABSTRACT

In the marine sciences an increasing number of studies on environmental changes, their causes, and environmental assessments emerged in recent years. Often authors use non-uniform and inconsistent definitions of key terms like driver, threats, pressures etc. Although all of these studies clearly define causal dependencies between the interacting socio-economic and environmental systems in an understandable way, still an overall imprecise wording could induce misunderstanding at higher policy levels when it comes to integrated ecosystems assessments. Therefore we recommend using unified definitions for a better communication between science and management within national, regional and international environmental policies, for example the European Marine Strategy Framework Directive (MSFD). With this article we provide definitions compatible with the driver-pressure-state-impact-response (DPSIR) approach. Although most examples are MSFD related and thus have a marine focus the definitions are intended to be equally applicable for other systems and are usable world-wide. We suggest sticking to these definitions for an easy and simplified knowledge transfer from science to management, since DPSIR model is already accepted as a helpful tool for structuring and communicating ecosystem analyses.

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1. Introduction

Worldwide human population is increasing while natural resources remain limited. Consequently, the usage and exploitation of available natural resources has been and will be intensified. In the oceans, increasing and diverse exploitation of marine resources has already led to augmenting human-induced alterations to ecosystems, particularly within sea shelf, coastal and estuarine environments (Kappel, 2005; Elliot, 2014). This has necessitated development of different regional and national legislative initiatives aimed at protection and restoration of marine ecosystems and further adequate and sustainable management of marine resources (Foster and Hawar, 2003; Parsons, 2007; Rutherford et al., 2005). One of the most recent important, the European Marine Strategy Framework Directive (MSFD) (EU-COM, 2008) requires all European marine waters to obtain and/or maintain good environmental status by 2020 (2008/56/EC). Herein, the MSFD required an ecosystem-based management approach (Borja et al., 2010, 2014), since it implies integrated management of human activities based on best available scientific knowledge about all ecosystem components (including humans), their dynamics and interactions, in order to achieve sustainable use of ecosystem goods and services and maintain ecosystem integrity (Elliot, 2011; Yanez-Arancibia et al., 2013). The ecosystem approach is vital for understanding causal dependencies between human activities and their various impacts on marine ecosystems, which has been identified as a major challenge within the contemporary marine science (Borja, 2014). It requires integration of knowledge across different ecosystem components, linking physical, chemical and biological aspects with existing and emerging anthropogenic factors. As a result, there is an exponential increase in marine studies focused on drivers of ecosystem change and assessment of associated pressures on the state of the ecosystem (Fig. 1).

But with the growing scientific interest in issues related to marine ecosystem-based management, inconsistency in usage of terms like *'driver'* and *'pressure'* also increases (cf. eg. Borja et al., 2006; Halpern et al., 2007, 2008; Kristensen, 2004; Link et al.,

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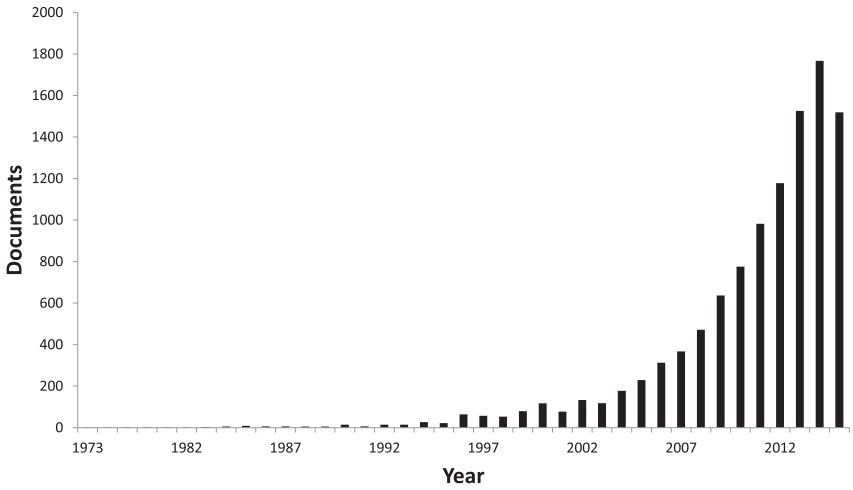

Fig. 1. Number of publications with the keywords 'ecosystem' and 'assessment' and 'marine' and 'pressure' or 'driver' over the past 45 years in the field of environmental science (Scopus Analyzer, 2015).

2010; Maxim et al., 2009; Oman et al., 2009, Sundblad et al., 2014), which potentially may lead to misapplication and therefore misunderstanding among researchers, managers, decision-makers and other stakeholders. An overall usage of concerted terminology is necessary to eliminate confusion hampering successful implementation of ecosystem-based management and integrated policy. Here we examine the variation in usage of the commonly accepted terms and propose a set of consistent and universally valid definitions which are understandable for different groups of potential users and are applicable for integrated ecosystems assessments within environmental policies. Our focus lays predominantly on examples from the marine realm referring to the Driver-Pressure-State-Impact-Response framework (DPSIR), yet the proposed definitions of the DPSIR terms are intended to be applicable for other ecosystems and different frameworks (e.g. PSR), and will support communication between researchers and policy-makers. To exemplify the usage of these terms we will focus on the MSFD which covers a wide range of ecosystem aspects and functions (2008/56/EC), being a good case for demonstrating the necessity of the consistent terminology. To successfully implement MSFD, all coastal member states of the European Union have to work together through interdisciplinary knowledge exchange of various fields of science and policy in order to achieve GES in their interconnected marine waters. Therefore, a huge amount of effort is necessary to align monitoring and measures between the member states requiring clear and coordinative understanding of driver-pressure-state-impact-response relationships and talking the same language is a crucial prerequisite for this.

2. Examples of inconsistent usage of the terms 'driver' and 'pressure'

As mentioned above the most confusing words of the DPSIR framework are 'driver' and 'pressure' which are elaborated in more detail in the following sections.

2.1. 'Driver'

A brief research on the usage of the term *driver* revealed rather diverse understanding of the 'drivers' in marine ecosystems. For example while some studies define climate change as a driver (MA, 2005), others refer to it as a pressure (Omann et al., 2009) or still others as a threat (Halpern et al., 2008). Confusion concerning the assignment to these three terms seems to be typical and might be related to the various contextual and conceptual frameworks used by the different authors. Within the marine-focused literature many studies consider only anthropogenic factors as drivers or driving forces (Maxim et al., 2009) related to the certain socio-economic activities (Patricio et al., 2014a), while others refer the term 'driver' to both natural and anthropogenic factors (Allen and Fulton, 2010; Harwell et al., 2010; MA, 2005).

More differences were revealed in regards to the level of detail. In most cases, drivers are studied within a specific context and are described with many details and several structural levels (Bulleri and Chapman, 2010). However some authors consider drivers at the highest level, as the overarching economic and social policies of governments or economic and social goals of major industries (Smith et al., 2014). This phenomenon could be correlated to the degree of knowledge about interactions within the ecosystem as well as the availability of relevant information. Some studies divide driving forces further into different categories. The MA (2005) for example, distinguishes between indirect and direct drivers. Hereby indirect drivers are considered to operate more diffusely, e.g. demographic, economic, socio-political, cultural or religious drivers plus science and technology. These indirect drivers include factors which influence the level of production and consumption of ecosystem services and the sustainable use of the resources. In most cases these factors exhibit multiple interactions. Thus a connection between a certain indirect driver and a particular change in the ecosystem is uncommon (MA, 2005). On the contrary, direct drivers like habitat change, over-exploitation, introduction of non-indigenous species, pollution, and climate change are considered to influence ecosystem processes more obviously (MA, 2005).

There are also studies with driving forces divided into more than two categories (Rodríguez-Labajos et al., 2009; Spangenberg, 2007). Spangenberg (2007) defined three categories of drivers; a) physical primary drivers (mainly resource consumption and pollution), b) secondary drivers (politics and policies) and c) tertiary drivers (structures incl. ideologies). Rodríguez-Labajos et al. (2009) differentiate two criteria, the direct linkage between the driver and a pressure and the long term influence of societal behaviour. Based on these criteria they further divide drivers into four categories. While the primary driver (economic activities with a direct pressure) and the secondary driver (policy level) are quite similar to the Spangenberg (2007) definition, the 'tertiary driving forces' represent the level of ideology and lifestyle and finally the

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