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Research article

Translating Ecological Integrity terms into operational language to inform societies

Silvia de Juan[a,*], Judi Hewitt[b], Maria Dulce Subida[c], Simon Thrush[d]

[a] Institute of Marine Sciences (ICM-CSIC), Passeig Marítim de la Barceloneta, n° 37-49, 08003, Barcelona, Spain
[b] National Institute of Water and Atmospheric Research, P.O. Box 11-115, Hamilton, New Zealand
[c] Núcleo Milenio – Center for Marine Conservation, Estación Costera de Investigaciones Marinas, Pontificia Universidad Católica de Chile, Santiago, Chile
[d] Institute of Marine Sciences, The University of Auckland, Auckland, 1142, New Zealand

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ABSTRACT

It is crucial that societies are informed on the risks of impoverished ecosystem health for their well-being. For this purpose, Ecological Integrity (EI) is a useful concept that seeks to capture the complex nature of ecosystems and their interaction with social welfare. But the challenge remains to measure EI and translate scientific terminology into operational language to inform society. We propose an approach that simplifies marine ecosystem complexity by applying scientific knowledge to identify which components reflect the state or state change of ecosystems. It follows a bottom-up structure that identifies, based on expert knowledge, biological components related with past and present changing conditions. It is structured in 5 stages that interact in an adaptive way: stage 1, *in situ* observations suggest changes could be happening; stage 2 explores available data that represent EI; stage 3, experts' workshops target the identification of the minimum set of variables needed to define EI, or the risk of losing EI; an optative stage 4, where deviance from EI, or risk of deviance, is statistically assessed; stage 5, findings are communicated to society. We demonstrate the framework effectiveness in three case studies, including a data poor situation, an area where lack of reference sites hampers the identification of historical changes, and an area where diffuse sources of stress make it difficult to identify simple relationships with of ecological responses. The future challenge is to operationalise the approach and trigger desirable society actions to strengthen a social-nature link.

1. Introduction

With an increasing demand for natural resources in a world of rapid biodiversity loss and environmental change, society needs to be well-informed about the consequences of changes in the environment (Cardinale et al., 2012). A two-way communication between scientists and society is critical, as there is an increasing demand to find new ways to conceptualise problems and find solutions in liaison with managers, politicians and common citizens (Carpenter et al., 2009; Castree, 2015; Chapin et al., 2010; Leslie and McLeod, 2007). We, ecologists, need to reduce the gap between the scientific knowledge we generate and its potential contribution to the well-being of societies. This social-ecological interaction is called the "new social contract" by the State of the Planet Declaration (2012), and, as Castree (2015) notes, we "need to link high quality, focussed scientific research to new policy-relevant interdisciplinary efforts for global sustainability". But this "new social contract" implies that societies, encompassing decision-makers to end-users, need to be informed by credible and relevant evidence of not only the nature of environmental changes but on how those changes might feedback to affect the welfare of societies. In other words, Anthropocene societies need to be capable of not only building evidence-based relevant policy directed towards local-to-global problems, but also accurately measure the impact of those policies on the sustainability of human – natural systems.

The DPSIR framework (Drivers–Pressures–State change–Impact–Response) has been proposed as a systems-based approach that captures key relationships between society and the environment, and it is deemed useful for communicating environmental research to non-scientists (Atkins et al., 2011; Mangi et al., 2007). DPSIR seeks to integrate ecological and social information in a framework that takes account of the impacts of human activities on the functioning of ecosystems and the effects on society, and then introduces the need to apply measures to prevent or control adverse changes (Lonsdale et al., 2015). Moreover, it has been extended to

* Corresponding author.
E-mail address: sdejuan@icm.csic.es (S. de Juan).

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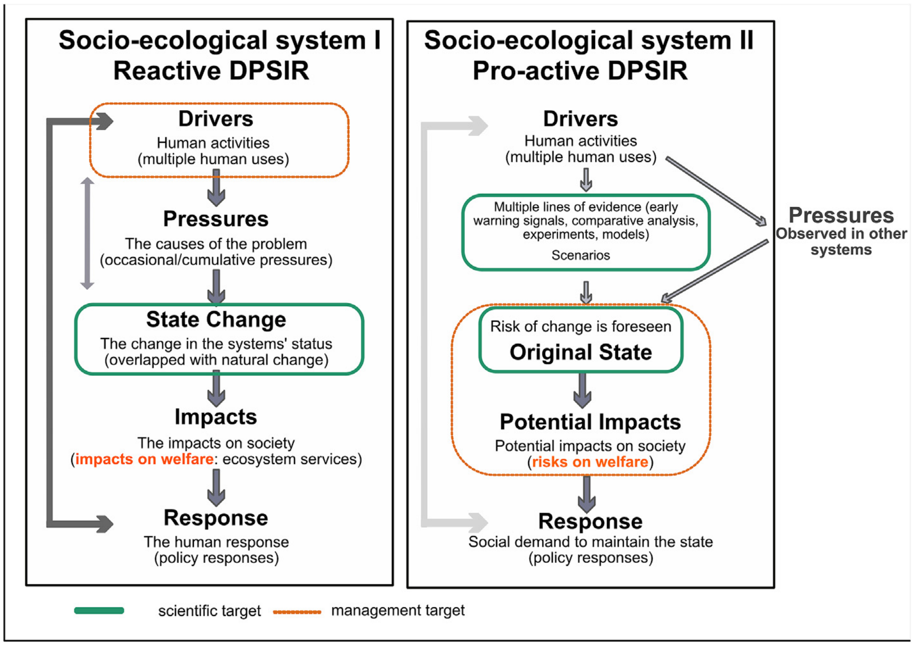

Fig. 1. The reactive and pro-active DPSIR framework: original framework adapted from Atkins et al. (2011) and Elliot et al. (2017a).

incorporate different drivers and pressures, and interactions between these, to provide a nested framework to prioritise efforts and manage in real-world systems (Atkins et al., 2011; Elliott et al., 2017a). We might easily record information on the drivers and pressures, but we, as ecologists, are interested on the state change of ecosystems, either when changes are already observable or when these are foreseen (the desirable target of management). In order to reflect real-world scenarios of ecosystem change, we propose two DPSIR frameworks: a reactive DPSIR, aiming at finding solutions to existing impacts, and a pro-active DPSIR, aiming at forecasting potential pressures to find ways to minimize changes. The reactive framework is intended to (i) recover the original state, or (ii) reach an alternative sustainable state. In the pro-active framework (Fig. 1) the response will come from within the initial state with the aim of maintaining it. Note that the framework includes several feedbacks between scientists, managers and society, as scientific findings need to inform management decisions, management actions should have an effect on the state change of ecosystems, and both managers and scientists should consolidate efforts to communicate with society.

The DPSIR represents many scientific challenges but a major bottleneck to its effective implementation is to communicate this knowledge to promote responsible societies (i.e., Impact-Response components) (Elliott et al., 2017b). In order to address this challenge, we need to 1) apprise the ecosystem status in a variety of human disturbance scenarios, that encompass current status and alternative sustainable uses, reflecting real-world scenarios, and 2) identify integrative indicators of state/state change to transmit complex ecological concepts to society that lead to co-designed solutions.

A new socio-ecological perspective is particularly crucial in coastal areas, where there is a strong cultural and economic dependency of societies on marine ecosystems, and the increasing pressures of human activities might cut off the flow of benefits garnered from marine ecosystem services, jeopardising the long-term well-being of societies (de Juan et al., 2017; MEA, 2005). Considering the diverse nature of impacts on the marine environment, and even the more diverse range of ecosystem responses operating over multiple space and time scales, capturing this complexity by a common metric has been challenging (Kappel et al., 2009; Rombouts et al., 2013). Over the past decades, there has been a plethora of indicators of the ecosystem status, partly triggered by policies like the European Water Framework Directive (2000/60/EC; European Commision, 2000) and the Marine Strategy Framework Directive (2008/56/EC, European Commision, 2008). However, these indicators tend to deal with one major stressor or kind of response from the ecosystem and, in general, they have been designed for a scientific or decision-maker use rather than to inform society at large (e.g., Blanchet et al., 2008; Borja et al., 2008b; Pinto et al., 2009; Van Hoey et al., 2010). The Ocean Health Index (Halpern et al., 2012) is an integrative index that informs on global status of the ocean, but this metric does not consider cumulative or multiple stressor impacts at local or regional scales, and, therefore, operates at scales not relevant across society, but see the more recent OHI + index designed to measure the ocean health at regional or local scales by independent groups of experts (http://www.oceanhealthindex.org/ohi-plus/portal). The welfare of society ultimately relies on a set of ecosystem structures and processes that are essential to maintain the system's resilience and its ability to provide goods and services (Müller and Burkhard, 2007). Therefore, societies rely on functional ecosystems that are resilient to external pressures (Tett et al., 2013). The existing set of indicators of the ecosystem status generally illustrate the ecosystem structure, but provide little information on the ecosystem functioning (Borja et al., 2008a) and, therefore, on its capacity to provide services to society.

A metric(s) that informs of the state or state change of marine ecosystems must encompass complex and scientifically sound information. Ecological Integrity (EI) has been proposed as a concept that captures the complex nature of ecosystems and its interaction with social welfare (Costanza et al., 1992; Karr, 1993). There are numerous definitions for EI but, in general terms, it is a holistic term that seeks to capture our sense of nature, its functionality and self-organising capacity (Tett et al., 2013). In fact, it is perhaps better understood by its absence rather than its presence. Thus, it depends on the wide-ranging perception of nature by societies. Despite the appropriateness of this concept for our objective, the challenge remains on finding how to translate EI terminology into operational language to inform decision makers and society at large. Our approach seeks to simplify complexity based on ecological knowledge, by applying this knowledge to identify which ecosystem components reflect EI. These components should be monitored to inform societies on the impact of existing or potential changes (and thus risk of losing EI), and ultimately aiming to trigger management responses.