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Review

How to value biodiversity in environmental management?

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ABSTRACT

Biodiversity is globally recognised as a cornerstone of healthy ecosystems, and biodiversity conservation is increasingly becoming one of the important aims of environmental management. Evaluating the trade-offs of alternative management strategies requires quantitative estimates of the costs and benefits of their outcomes, including the value of biodiversity lost or preserved. This paper takes a decision-analytic standpoint, and reviews and discusses the alternative aspects of biodiversity valuation by dividing them into three categories: socio-cultural, economic, and ecological indicator approaches. We discuss the interplay between these three perspectives and suggest integrating them into an ecosystem-based management (EBM) framework, which permits us to acknowledge ecological systems as a rich mixture of interactive elements along with their social and economic aspects. In this holistic framework, socio-cultural preferences can serve as a tool to identify the ecosystem services most relevant to society, whereas monetary valuation offers more globally comparative and understandable values. Biodiversity indicators provide clear quantitative measures and information about the role of biodiversity in the functioning and health of ecosystems. In the multi-objective EBM approach proposed in the paper, biodiversity indicators serve to define threshold values (i.e., the minimum level required to maintain a healthy environment). An appropriate set of decision-making criteria and the best method for conducting the decision analysis depend on the context and the management problem in question. Therefore, we propose a sequence of steps to follow when quantitatively evaluating environmental management against biodiversity.

Contents

1. Introduction

Biodiversity is increasingly recognised as one of the cornerstones of healthy ecosystems (Kremen, 2005; Worm et al., 2006; Duffy et al., 2007; Hector and Bagchi, 2007; Pinto et al., 2014). The loss of biodiversity due to human action has the potential to reduce multitrophic-level interactions (Costanza et al., 1997; Schneiders et al., 2012) and cause trophic cascade repercussions (Lindberg et al., 1998; Österblom et al., 2007; Tylianakis et al., 2008). Legislatures and international treaties increasingly reflect this need to protect biodiversity, with the convention of biological diversity (CBD; UNEP, 1992) as the first treaty in international law to

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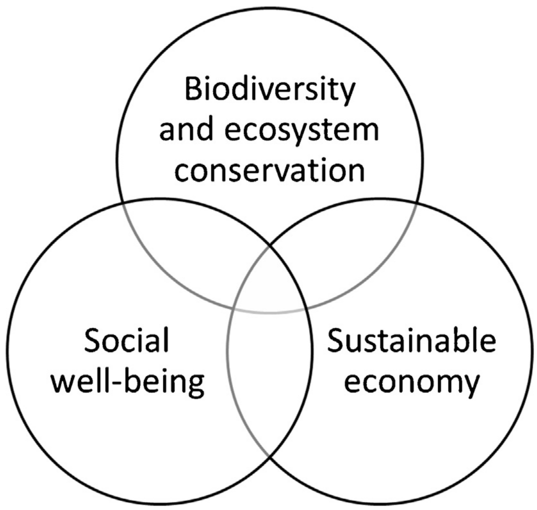

Fig. 1. The concept of ecosystem-based management covers the ecological, economic, and social aspects of environmental issues, aiming for sustainable development by acknowledging their interplay.

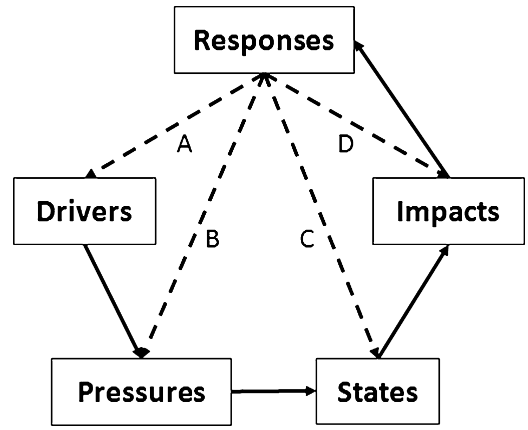

Fig. 2. The DPSIR problem-structuring framework for environmental management analysis. The various ways to manage the system appear as links A–D with descriptions in the text. The diagram is modified from the doctoral thesis of Lehikoinen (2014).

emphasise the vital importance of biodiversity conservation. More recently, the European Union (EU) has also begun to emphasise the importance of biodiversity, as is evident in the EU Biodiversity Strategy, an important policy driver; biodiversity is also one of the descriptors of Good Environmental Status in the Marine Strategy Framework Directive (MSFD; European Commission, 2008).

The main idea of environmental management is to safeguard and enhance the environmental state as well as to sustain economic and social benefits from the ecosystems (Elliott, 2011, 2013). Ecosystem-based management (EBM) (Fig. 1), required by both the CBD and MSFD, is shifting the focus towards more comprehensive decision-making processes by recognising ecological systems as a rich mixture of interacting elements and by acknowledging their social and economic features (e.g., Christensen et al., 1996; Ruckelshaus et al., 2008; Gregory et al., 2013). Because preventing the loss of biodiversity is increasingly becoming one of the important aims of environmental management, biodiversity must be defined in an operational way in order to facilitate setting management targets and evaluating management's performance. As stated in Section 2, biodiversity is inherently a multi-dimensional subject, spanning genes and species, functional forms, adaptations, habitats and ecosystems, as well as the variability within and between them. All these dimensions of biodiversity are tightly interconnected, affecting the state, stability, and productivity of the ecosystem as well as ecosystem services (Schneiders et al., 2012), thereby making biodiversity not only an ecological, but also a social and economic issue. This article therefore analyses the value of biodiversity from these three perspectives.

Some see ecosystem services as a means to quantify biodiversity in economic terms, usually defined as the benefits people can extract from ecosystems (Lamarque et al., 2011; Mace et al., 2012). The Millennium Ecosystem Assessment (MA) classifies benefits into four groups: provisioning, regulating, cultural, and support services (MA, 2005). Biodiversity may play three different roles in ecosystem services: as a regulator of ecosystem processes, as a final ecosystem service or as a good (Mace et al., 2012). However, because a description of biodiversity is complicated, accounting for the role of biodiversity or for the impacts of its decline on ecosystem services in general is not straightforward (TEEB, 2010a).

Environmental management problems are typically complex and multidisciplinary, involving various unavoidable trade-offs and uncertainties (Uusitalo et al., 2015) in informed decision-making. Decision analysis can help to structure the problem, to integrate knowledge and any prevailing uncertainty, and to visualise the results (Cooper, 2012; Lehikoinen et al., 2014; Rahikainen et al., 2014). The ultimate goal of decision analysis is to successfully select the management alternative that minimises risks and costs while maximising benefits and public acceptance (Keeney, 1982; Burgman, 2005; Kiker et al., 2005). However, using decision analysis requires that management targets, including biodiversity, have a quantitative value as to make them comparable.

To illustrate the aim of this paper, we use the Driving forces–Pressures–States–Impacts–Responses (DPSIR) framework for structuring problems (Fig. 2), a framework commonly used in the field of environmental management analysis (e.g., Borja et al., 2006; Maxim et al., 2009; Atkins et al., 2011; Gregory et al., 2013). This framework strives to systematically capture and represent the causes and consequences of environmental change as well as human responses to it. Response links A–D in Fig. 2 describe the different ways to manage the system. Links A and B generally relate to managing the principal and secondary causes (Drivers and Pressures) of environmental change, whereas link C represents the actions that strive to control or mitigate the consequences for the ecosystem (State). An example of drivers might include divergent economic or political trends affecting the volume of oil transportations within a certain sea area (see Lehikoinen, 2014). One pressure factor fuelling these drivers that causes or has the potential to cause harmful changes in the state of the ecosystem is a possible oil accident. The likely impact of such an accident on biodiversity would in this case be represented by the DPSIR-element State. After all, the best management alternative depends on the objectives that the society chooses (Impact). In the example provided, this could mean how the people actually value biodiversity. Modifying this decision-making criterion (link D) could therefore change the ranking order of the alternatives (Lehikoinen, 2014).

This review aims to discuss the use of biodiversity as a criterion against which to evaluate the impacts of human activities on the ecosystem and to review the alternative methods applicable for decision-analytical purposes. First, we provide an overview of biodiversity-related terminology and then focus on different approaches that purport to quantify the value of biodiversity. The aim is to provide a comprehensive analysis of the different evaluation techniques for measuring the value of biodiversity in terms of its ecological, economic, and social aspects. Further, we analyse these techniques to propose a suitable protocol for identifying the best decisions for alternative environmental management.