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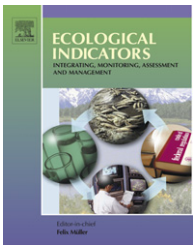

A conceptual framework for selecting environmental indicator sets

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ABSTRACT

In recent years, environmental indicators have become a vital component of environmental impact assessments and "state of the environment" reporting. This has increased the influence of environmental indicators on environmental management and policy making at all scales of decision making. However, the scientific basis of the selection process of the indicators used in environmental reporting can be significantly improved. In many studies no formal selection criteria are mentioned and when selection criteria are used they are typically applied to indicators individually. Often, no formal criteria are applied regarding an indicator's analytical utility within the total constellation of a selected set of indicators. As a result, the indicator selection process is subject to more or less arbitrary decisions, and reports dealing with a similar subject matter or similar geographical entities may use widely different indicators and consequently paint different pictures of the environment. In this paper, a conceptual framework for environmental indicator selection is proposed that puts the indicator set at the heart of the selection process and not the individual indicators. To achieve this objective, the framework applies the concept of the causal network that focuses on the inter-relation of indicators. The concept of causal networks can facilitate the identification of the most relevant indicators for a specific domain, problem and location, leading to an indicator set that is at once transparent, efficient and powerful in its ability to assess the state of the environment.

1. Introduction

National and international environmental regulations are rapidly increasing in number, which has lead to a boom in environmental assessment reports (EEA, 1999; McRae et al., 2000; Wascher, 2000; World Resources Institute, 2000; EEA, 2001; OECD, 2001; The Heinz Center, 2002; UNEP, 2002; EPA, 2003; EEA, 2005b; Esty et al., 2005; World Resources Institute, 2005). Environmental assessments have become commonplace in planning and evaluation at all scales of decision making, from private enterprises to town councils, governments and international forums. Environmental indicators, as prime assessors of the pressures on the environment, of the evolving state of the environment, and of the appropriateness of policy measures, have come to play a vital role in environmental reporting.

Environmental indicators have taken on such importance because they provide "a sign or signal that relays a complex message, potentially from numerous sources, in a simplified and useful manner" (Jackson et al., 2000, p. vii). Environmental indicators provide an important source of information for policy makers and help to guide decision-making as well as

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monitoring and evaluation (OECD, 1999), because they can provide valuable information on complex issues in a relatively accessible way. However, it is a major challenge to determine "which of the numerous measures of ecological systems characterize the entire system yet are simple enough to be effectively and efficiently monitored and modeled" (Dale and Beyeler, 2001, p. 4).

In an earlier paper (Niemeijer, 2002), data-driven and theory-driven approaches to the development of environmental indicator sets were examined. In the process of writing that paper, it was realized that while indicator reports and their use of indicators is undeniably useful, there is still considerable room for improvement in the indicator selection process. As Dale and Beyeler (2001, p. 6) observe, "lack of robust procedures for selecting indicators makes it difficult to validate the information provided by those indicators." A more rigorous and transparent indicator selection process will increase both the value and the scientific credibility of environmental assessment reports and ensure they meet management concerns (Belnap, 1998; Slocombe, 1998; Dale and Beyeler, 2001). Another benefit of a more structured indicator selection process is that it allows for proper conceptual validation of indicators (Bockstaller and Girardin, 2003). It may also help in identifying indicators that can link ecological dimensions with environmental, social and economic dimensions, which is vital for good policy making (Niemi and McDonald, 2004).

While a number of conceptual frameworks are used within the context of environmental assessments (for example EPA (1998) ecological risk assessment framework), the most common frameworks used in indicator based studies are the driving force–pressure–state–impact–response (DPSIR), pressure–state–response (PSR), or driving force–state–response (DSR) conceptual frameworks, which organize and structure indicators in the context of a so-called causal chain (e.g., Hammond et al., 1995; OECD, 1998, 1999; Smeets and Weterings, 1999; EEA, 2000; Wascher, 2000; Bridges et al., 2001; OECD, 2001). In the causal chain, social and economic developments are considered driving forces that exert pressure on the environment, leading to changes in the state of the environment. In turn, these changes lead to impacts on human health, ecological systems and materials that may elicit a societal response that feeds back on the driving forces, pressures, or on the state or impacts directly (Smeets and Weterings, 1999, p. 6).

In this paper it is argued that these causal chain frameworks should be used to frame the indicator selection process. In current practice, indicators are often selected either based on historical practices and regulations or based on "intuitive assessment of experts" (Bossel, 2001, p. 2) and on the degree to which they meet a number of criteria individually (e.g., NRC, 2000; OECD, 2001; EEA, 2005a), rather than on the basis of how they jointly provide an answer to our environmental questions. As Swart et al. (1995) argue, it is important to distinguish between criteria that apply to indicators as a set, and those that apply to individual indicators. Conceptual indicator frameworks can potentially play an important role in the indicator selection process and in developing consistent indicator sets. This is especially true in situations where the whole range from driving forces and pressures to environmental impacts needs to be covered.

In this paper an enhanced DPSIR framework (eDPSIR in brief) is used that does not consider individual causal chains but, inspired by systems thinking (Odum, 1953), tackles the complexities of the real world by looking at causal networks in which multiple causal chains interact and inter-connect (Niemeijer and de Groot, 2007). The concept of causal networks in itself is not new. Causal networks have been used in mathematics (Perl, 2001) and, referred to as causal webs, also in the fields of health and environmental health (e.g., Kay et al., 2000). The idea of applying a systems approach to indicator selection is not new either (e.g., Bossel, 2001). What is novel in the approach taken here is the integration of familiar concepts, such as the systems approach, causal networks and the DPSIR framework in a systematic indicator selection procedure that makes the inter-relation of indicators an explicit part of the indicator selection process. The need for such a systematic, transparent and generally applicable indicator selection procedure was again underlined as a key finding in a recent report from the US National Commission on Science for Sustainable Forestry (NCSSF, 2005, p. 28) that stated:

> "The bottleneck in effective selection and use of indicators is not a lack of good indicators or good science, but rather the lack of [...] a clear process for selecting indicators [...] The reliability of identified measures is frequently questioned, at least in part because selection of indicators often has lacked transparency, social inclusiveness, and/or a logical structured process of selecting indicators."

This paper consists of two parts. The first part begins with a brief introduction of the concept of environmental indicators and causal-chain frameworks. It then moves to a discussion of indicator selection and its impact on indicator reporting. The second part introduces the enhanced DPSIR framework and, using a concrete example, illustrates how this so-called eDPSIR framework can lead to better and more transparent indicator selection.

2. Environmental indicators and their selection

2.1. *Environmental indicators and the causal-chain frameworks*

Hammond et al. (1995, p. 1) describe an indicator as "something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. [...] Thus an indicator's significance extends beyond what is actually measured to a larger phenomena of interest". To give an example, measuring body temperature not only gives the current temperature of the human body, but if that temperature is higher than normal also provides a strong indication that the person is ill and currently experiencing a virus or infection. So body temperature is not just a temperature indicator, but also a human health indicator.