Ecological Economics 128 (2016) 55–67

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Processes for the sustainable stewardship of marine environments

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ARTICLE INFO

Article history:
Received 20 October 2015
Received in revised form 14 April 2016
Accepted 18 April 2016
Available online 4 May 2016

Keywords:
Adaptive marine management
Baltic Sea
Cost–benefit analysis
Balance sheet approach
Future scenarios

ABSTRACT

Sustainable stewardship of the marine environment necessitates a holistic approach encompassing all the relevant drivers, activities and pressures causing problems for the natural state of the system and their impact on human societies today and in the future. This article provides a framework as well as a decision support process and tool that could guide such an approach. In this process, identifying costs and benefits of mitigation is a first step in deciding on measures and enabling instruments, which has to be accompanied by analyses regarding distributional effects (i.e. who gains or loses) related to different targets and policy instruments. As there are risks of future irreversible regime shifts and even system collapses, the assessments have to be broadened to include scenarios on possible future developments as well as ethical considerations. In particular, a deeper sustainable management strategy may be needed to respond to possible future increases in the rate of environmental change, amongst growing evidence of external pressures, interactions and non-linear dynamics. This adaptive management strategy should focus on building the resilience required to cope with and adapt to change.

1. Introduction

The aim of a sustainable stewardship is to maintain an ecosystem capable of providing a range of ecosystem services now and in the future (Turner, 2000; Elliott, 2014). One challenge lies in understanding the complexity of the processes and functions within the ecosystem and how human behaviour and actions affect the ecosystem and the services and benefits it provides to human societies. Another challenge lies in implementing a strategy that is able to cope with an uncertain future.

The paper focuses on marine ecosystems as examples of complex entities of plant and animal life and their physical environment providing important flows of provisional and cultural ecosystem services (Turner and Schaafsma, 2015). In this context it seeks to provide answers to the following questions: What are the management tools needed to address the environmental problems in marine ecosystems? To what extent can we rely on cost–benefit analysis and environmental impact assessments, and what other considerations might be needed to appropriately guide policies and marine governance?

The paper highlights the different challenges that marine stewardship is facing, and presents an analytical framework to identify the main components of a decision support system (scoping method, process models, indicators, scenarios and socio-economic and political/cultural appraisal) for an adaptive management strategy. The results from two empirical Baltic Sea studies are used to illustrate how this decision support system could be furnished with relevant information. Finally the paper discusses the implications for marine management based on the theoretical framework and the empirical information drawn from different Baltic Sea studies.

2. The Baltic Sea — Environmental Challenges and Current Management

The governance[1] of the marine environment is a relationship between two systems: a 'system-to-be-governed' and a 'governing system' (Jentoft, 2007). The system to be-governed consists of the

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[1] Governance can be defined as the policies, politics, legislation and administration required or desired by management of an area. This includes the structures and processes for collective decision-making involving both state and non-state (profit and non-profit) actors on different levels — local, regional, national, European and global (Rosenau, 2003).

http://dx.doi.org/10.1016/j.ecolecon.2016.04.010
0921-8009/

ecosystem and its resources, as well as drivers, activities and pressures affecting the state of the ecosystem, and the impact this has on human well-being. The governing system is made up of institutions and steering mechanisms aimed at preserving or improving the state of the ecosystem. Both systems are diverse, complex, dynamic, potentially confusing to users/stakeholders and vulnerable. This complexity requires an integrated governance system which aims to harmonise a number of diverse interests, especially in multi-state regional seas such as European waters in general and the Baltic Sea in Particular (e.g. Boyes and Elliott, 2014, 2015).

2.1. The System to Be Governed

An understanding of the 'system to be governed' is central to management. That is, understanding the state of the marine ecosystem and its fundamental processes and how it impacts human wellbeing as well as identifying the endogenic and exogenic drivers and pressures affecting the state; exogenic pressures are those operating from outside the system being managed (such as climate change) whereas endogenic pressures are created inside the system (such as fishing) (Elliott, 2011).

The Baltic Sea is globally one of the largest brackish water bodies, containing inflowing seawater from the North Sea and freshwater from its large catchment area (Ducrotoy and Elliott, 2008). It is connected to the Atlantic via the narrow and shallow Danish Straits, which limits water exchange in the Sea and hence the pulses of oxygen-rich water are episodic. Furthermore, its thermohaline and geomorphological characteristics have produced a halocline, which limits the vertical mixing of water and thus the oxygenation of bottom waters (Voipio, 1981; HELCOM, 2007, 2009). These conditions reduce bottom water renewal and the water residence times in the Baltic deeps are up to 40 years causing hypoxia and decreasing the ability of sediments to retain phosphorus (Leppäranta and Myrberg, 2009; HELCOM, 2007, 2009). The biodiversity of the Baltic Sea has usually been considered as low, but recently Telesh et al. (2011) showed that Baltic Sea species diversity is higher than previously thought.

In particular due to its enclosed nature, the Baltic Sea is vulnerable to internal and external pressures (Elmgren and Larsson, 2001; Möllmann et al., 2009; Carstensen et al., 2014) and hence its state has changed profoundly during the last centuries, including non-linear and abrupt changes, i.e. regime shifts (Österblom et al., 2007). Such changes become of increasing social concern if they affect ecosystem services and the range of benefits provided to human society. This increases the importance of having holistic assessment tools which convey the overall health for seas such as the HOLAS tool for the Baltic (Borja et al., 2016). Future environmental changes in the structure and processes of the Baltic Sea ecosystem may significantly reduce the functioning of the system (Ducrotoy and Elliott, 2008) and in turn the production of ecosystem services and their delivery of societal benefits. Model simulations of future Baltic Sea oceanographic conditions, as well as its food web, show previously unobserved ecosystem perturbations (Meier et al., 2012a; Niiranen et al., 2013), and that the risk for future abrupt ecosystem changes cannot be overlooked (Borja et al., 2016).

Anthropogenic nutrient loads have changed the Baltic from an oligotrophic (nutrient poor) to a eutrophic (nutrient rich) state during the last century (De Jonge and Elliott, 2001; Savchuk et al., 2008). A set of eutrophication-related symptoms denote poor ecosystem health (Tett et al., 2013). The potentially toxic algal summer blooms have increased substantially during the last decades (Kahru and Elmgren, 2014). The proportion of sea floor bottoms with low or no oxygen, and thereby locally reduced benthic fauna and worsened conditions for fish spawning, have also increased substantially (Laine, 2003; Savchuk et al., 2008 and references therein; Carstensen et al., 2014). These pressures together with overfishing, changes in the abundance of seals and climate change have caused several regime shifts in the food web (Fig. 1). In the 1950s there was a shift from seal to cod domination (Österblom et al., 2007) followed by a further regime shift in the late 1980s from cod to sprat domination (Möllmann et al., 2009).

Contamination from hazardous substances, small oil spills and the increased risk of major oil spills, increases in invasive species and marine litter also affect the environmental status of the Baltic Sea. The sea surface temperature has increased by more than 0.7 °C during the 20th century (Rutgersson et al., 2014) and future climate change is projected to have significant impacts on the ecosystem (Meier et al., 2012a, 2012b).

The integrated assessment of the health of the Baltic indicates the cumulative nature of the human impacts (Borja et al., 2016) and hence the management measures required to improve or remediate the system. The changes to the Baltic Sea ecosystem during the last two centuries have been triggered by different drivers, such as population growth, intensification of industry and trade activity as well as related land use changes (O'Neill et al., 2014). Within society this economic growth has been associated with changes in consumption patterns, e.g., increased meat in the diet as well as increases in energy use and traffic (Gustafsson et al., 2012).

Changes in the Baltic Sea ecosystem affect the ecosystem services which generate benefits to human societies. To understand how degradation can be tackled it is necessary to identify all ecosystem services and their interconnections and the conceptual framework set out by Fisher et al. (2009) can help to reflect this complexity. It distinguishes between ecosystem structure and basic processes, intermediate services, final services and benefits. It also helps to avoid a double counting error when services are valued in monetary terms. Fig. 2 identifies the important ecosystem services of the Baltic Sea and shows, as an example, how the final ecosystem service and benefit of food (in terms of fish landings) depends on many intermediate ecosystem services and processes, such as habitat, food webs, nutrient buffering, and resilience.[2]

There are interdependencies between environmental state changes, impacts and policy responses. For example, oil spills and the consequences of invasive species may reduce benefits, such as the recreational benefits, obtained by mitigating eutrophication (Hyytiäinen and Huhtala, 2014). The presence of hazardous substances influences the quality and value of fish, and marine litter reduces recreational values. Furthermore, there is a dynamic interplay of different pressures and the activities and drivers which cause them. This in turn leads to a change of the state of the sea and its impact on the provision of ecosystem services. Several different plausible future scenarios for the Baltic Sea are possible depending on a combination of what prevention and mitigation measures are adopted, and how drivers, activities and pressures over which the Baltic Sea countries have limited control are managed (e.g. climate, world economy, and global population). Therefore, the precise nature of the change process is subject to uncertainty as is the need for and efficacy of necessary amelioration measures in terms of the social costs and benefits of reaching a good environmental status (e.g. Borja et al., 2013).

2.2. The Governing System

Global and regional agreements, EU directives and national laws as well as hierarchies of administrative bodies including departments, ministries, and agencies, all affect and complicate the management of marine environments, including the Baltic Sea (Boyes and Elliott, 2014, 2015). Hence, the regional environmental governance of the Baltic Sea ecosystem is a fragmented web of national, European, and international governance (Gilek et al., 2011; Hassler, 2011; Karlsson et al., 2011; Kern, 2011). However, with the EU-inclusion of all littoral Baltic Sea countries except for Russia, this governance is becoming more

[2] Here resilience is defined as the ability to bounce back from the adverse effects of stressors, in itself an inherent property of a healthy ecosystem (e.g. Elliott et al., 2007; Tett et al., 2013).