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Coastal Zone Ecosystem Services: From science to values and decision making; a case study

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HIGHLIGHTS

- We investigate socio-ecological system complexity for informed decision making.
- We provide recommendations on how to value stock and flows of ecosystem services.
- We transfer biophysical data and welfare value estimates between estuaries.
- Context dependency and value transfer possibilities vary among ecosystem services.
- Results imply a need for careful use of value transfer for informed decision making.

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ABSTRACT

This research is concerned with the following environmental research questions: socio-ecological system complexity, especially when valuing ecosystem services; ecosystems stock and services flow sustainability and valuation; the incorporation of scale issues when valuing ecosystem services; and the integration of knowledge from diverse disciplines for governance and decision making. In this case study, we focused on ecosystem services that can be jointly supplied but independently valued in economic terms: healthy climate (via carbon sequestration and storage), food (via fisheries production in nursery grounds), and nature recreation (nature watching and enjoyment). We also explored the issue of ecosystem stock and services flow, and we provide recommendations on how to value stock and flows of ecosystem services via accounting and economic values respectively. We considered broadly comparable estuarine systems located on the English North Sea coast: the Blackwater estuary and the Humber estuary. In the past, these two estuaries have undergone major land-claim. Managed realignment is a policy through which previously claimed intertidal habitats are recreated allowing the enhancement of the ecosystem services provided by saltmarshes. In this context, we investigated ecosystem service values, through biophysical estimates and welfare value estimates. Using an optimistic (extended conservation of coastal ecosystems) and a pessimistic (loss of coastal ecosystems because of, for example, European policy reversal) scenario, we find that context dependency, and hence value transfer possibilities, vary among ecosystem services and benefits. As a result, careful consideration in the use and application of value transfer, both in biophysical estimates and welfare value estimates, is advocated to supply reliable information for policy making.

1. Introduction

Although our understanding of the functioning of coastal and marine ecosystems, their reactions to pressures, and their contribution to human well-being is still limited, it is clear that very valuable assets are at risk and require more sustainable and adaptive management. The flexibility focus of adaptive management allows us to adjust to the new knowledge and new drivers and pressures, including climate change. Adaptive management provides a practical framework for implementation of the Ecosystem Approach and ecosystem services concept.

Ecosystem services valuation is currently faced with several challenges, including the need to better understand: socio-ecological system complexity, especially when valuing ecosystem services; ecosystems

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stock and services flow sustainability and valuation; the incorporation of the issues of scale and aggregation when valuing ecosystem services; and the integration of knowledge from diverse disciplines for governance and decision making (Valuing Nature Network, 2011).

Here we begin to look for insights into these issues by considering saltmarshes in two estuarine systems located on the English North Sea coast: the Blackwater and the Humber estuaries. We also acknowledge that evidence drawn from a small number of case study sites does not in itself provide robust evidence base. Although these estuaries are close geographically and geomorphically, and agricultural impacts from the catchments are probably broadly comparable (Shepherd et al., 2007), there are marked differences in other characteristics such as the legacy of varied industrial activities within the catchments (Neal and Robson, 2000; Neal and Davies, 2003).

The valuation of ecosystem services can become complex when, within a given ecosystem, interdependent ecosystem services are potentially available and fundamentally interlinked (Fisher et al., 2009). Our case study focuses on ecosystem services that can be jointly supplied by saltmarshes but can be independently valued in economic terms. The biophysical links between the configuration of ecosystem structure and processes that are present at a given time (stock) and the ecosystem services they provide over time (flows) are investigated through an examination of the carbon cycle. One possible way to tackle the problem of aggregation in valuation analysis is through value transfer, a method by which the value estimated for an ecosystem service or environmental benefit in a specific area (the study site) and time is applied to another area (the policy site) and time (Navrud and Ready, 2007). Valid and reliable benefit transfer requires a set of quite stringent conditions (Eftec, 2009); hence we highlight the need for the integration of knowledge about the value of ecosystem services from diverse disciplines from natural sciences (e.g. biogeochemistry, ecology, marine biology) to social sciences and environmental economics for improved decision making.

A set of global and regional socio-economic drivers such as land conversion and reclamation, agricultural runoff, pollution etc. leads to multiple environmental pressures on the coastal areas. Another key pressure on estuarine habitats, and their associated ecosystem services, is sea level rise. Because of sea level rise intertidal habitats are often 'squeezed' between the sea and sea defence or coastal protection structures (Doody, 2004).

The Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC 5) (Church et al., 2013) predicts between 19 and 83 cm of sea level rise by the end of the century, depending on greenhouse gas emission scenario, which concurs with an earlier estimate of 32 cm sea level rise by 2050 (Rignot et al., 2011). These are likely to be conservative estimates as the models are not yet able to accurately predict rapid dynamic changes in the Antarctic ice sheet (Church et al., 2013). If these more extreme predictions prove correct, such a rate of sea-level rise would be unprecedented on the timescale of human settlements. Response strategies and adaptation measures may well require a radical shift away from the 'hold the line' hard defences approach. A different flood defence and coastal protection strategy, able to selectively protect 'high value' coastal areas/assets while at the same time being able to maintain or expand intertidal habitats may need to be implemented. One option is coastal managed realignment (MR) (Elliott et al., 2014; Mazik et al., 2010), which has been implemented with different degrees of success in several estuaries in our study region (see the Online Managed Realignment Guide on-line map - http://www.abpmer.net/omreg/).

The case study includes a scenario analysis to investigate the future evolution of saltmarshes. Coastal and marine ecosystem services and related benefits may either be enhanced or put at risk depending on whether conservation policies such as the EU Directives on Habitats (92/43/EEC) and Birds (2009/147/EC) and the Marine Strategy Framework Directive (2008/56/EC) remain in place and/or are strengthened; or, on the other hand, a European policy dilution trend may become a reality. At the time of writing, extreme weather and flooding took place in Great Britain with devastating consequences (e.g. Somerset). We consider a baseline scenario in which some conservation policies such as managed realignment (MR) have already been put in place, securing a minimum of ecosystem services (business as usual scenario) and two extreme but still plausible future scenarios. These are a scenario in which implementation of conservation policies (e.g. an extended MR) is reinforced allowing maximisation of ecosystem services provision (*optimistic* scenario), and a scenario in which the implementation of conservation policies is weakened leading to continued degradation of saltmarshes at current estimated rates and to the loss of ecosystem services (*pessimistic* scenario). To test our ability to integrate biophysical sciences and economics, we explore the complexity of saltmarsh ecosystems through the stock and flows of carbon, and assess the economic value of the estuarine services through the goods/benefits they supply to society ('healthy' climate; food; and nature recreation) (Luisetti et al., 2011a). At the same time we clarify the meaning of 'marginality' (in economics terms) for the stock and the flow of ecosystem services when environmental changes such as those suggested by our optimistic and pessimistic scenarios are involved (Turner et al., 2003). We also explore the extent to which value transfer techniques could be applied.

2. Methodological challenges

In this paper we focus on some of the challenges faced when trying to construct a more robust evidence base for the incorporation of the ecosystem services concept into practical coastal management. We recognise that the provision of 'evidence', the process of policymaking and the delivery of policy are not separate activities. Coastal/marine management is part of a wider system that is composed of hierarchies and networks (including networked publics) and the interrelationships between them (Potts et al., 2014). Our focus is on the building and testing of the evidence base but with due regard for user needs.

2.1. Challenge 1: socio-ecological system complexity when valuing ecosystem services

Complexity in valuing ecosystem services can arise when within a given ecosystem interdependent ecosystem services are potentially available and fundamentally interlinked (Fisher et al., 2009). Coastal and marine system complexity (Fig. 1), following the framework set out by Fisher et al., can be conceptually separated into four components: basic pressures and structure, intermediate ecosystem services, final ecosystem services, and goods/benefits (Potts et al., 2014).

We investigate complexity in valuing ecosystem services by using a case study focusing on marine and coastal ecosystem services that can be jointly supplied but independently valued in economic terms. The economic efficiency of coastal MR as a policy response to the loss of intertidal ecosystem services has been analysed in previous studies on the Humber (Turner et al., 2007) and Blackwater (Luisetti et al., 2011a) estuaries. In our case study we first revisit the results of Luisetti et al. (2011a) for the Blackwater estuary study but re-analyse them under different future environmental scenarios. Based on these new biophysical and economic estimates, and using value transfer techniques (Navrud and Ready, 2007), we assess the ecosystem services and benefits provided by the MR sites in the Humber estuary.

The benefits identified and estimated in this study are: 'healthy climate' contributed to via carbon sequestration and storage, which is linked to climate regulation by removing CO_2 from the atmosphere); food provision (fish, via fisheries production in nursery grounds), and nature recreation (nature watching and enjoyment via socially valued seascapes). We recognise that in some estuaries the supply of raw material and energy are also important but less so in our case study estuaries. Other benefits provided by the intertidal areas of these estuaries such as, for example, flood defence and erosion control and bioremediation of waste may also be important (see the Adaptation Sub-