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An ecosystem service approach to support integrated pond management: A case study using Bayesian belief networks – Highlighting opportunities and risks

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ABSTRACT

Freshwater ponds deliver a broad range of ecosystem services (ESS). Taking into account this broad range of services to attain cost-effective ESS delivery is an important challenge facing integrated pond management.

To assess the strengths and weaknesses of an ESS approach to support decisions in integrated pond management, we applied it on a small case study in Flanders, Belgium.

A Bayesian belief network model was developed to assess ESS delivery under three alternative pond management scenarios: intensive fish farming (IFF), extensive fish farming (EFF) and nature conservation management (NCM). A probabilistic cost-benefit analysis was performed that includes both costs associated with pond management practices and benefits associated with ESS delivery.

Whether or not a particular ESS is included in the analysis affects the identification of the most preferable management scenario by the model. Assessing the delivery of a more complete set of ecosystem services tends to shift the results away from intensive management to more biodiversity-oriented management scenarios.

The proposed methodology illustrates the potential of Bayesian belief networks. BBNs facilitate knowledge integration and their modular nature encourages future model expansion to more encompassing sets of services. Yet, we also illustrate the key weaknesses of such exercises, being that the choice whether or not to include a particular ecosystem service may determine the suggested optimal management practice.

1. Introduction

Freshwater ponds are multi-functional ecosystems that provide a broad set of social, ecological and economic benefits for human well-being (IUCN, 1997; Bekefi and Varadi, 2007; EPCN, 2007; Downing, 2010). These benefits are collectively referred to as ecosystem services (Daily, 1997; MEA, 2005). Typical services of pond systems include fish production, water supply, nutrient retention, carbon sequestration, biodiversity and recreational use (EPCN, 2007). Despite the high potential of ponds for the provisioning of multiple services, evaluations of management practices typically focus on a limited number of services, such as fish production, whereas other benefits are frequently overlooked (Pechar, 2000). More recently, the awareness of the importance of social and ecological aspects of pond management is rapidly growing, amongst others through the implementation of the common fisheries policy of the European Union, which strives toward sustainable aquaculture, and the Strategic Plan for Biodiversity 2011–2020, which aims to stop biodiversity loss by 2020 (UNEP/CBD, 2010). Currently, there is a strong need to take into account the multi-functionality of pond ecosystems during the development of management plans. Models and decision support tools are

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useful instruments to guide the development of such management plans. Although several studies have been conducted on multi-functionality of pond systems (Céréghino et al., 2010; Kloskowski, 2011), integration of this multi-disciplinary knowledge into practical management suggestions is rarely done.

In the past, several decision support systems have been specifically designed to aid the development of management programs for freshwater ponds and lakes (e.g. Gawne et al., 2012; Gutiérrez-Estrada et al., 2012). Although these tools have proven to be promising in suggesting alternative management practices during adaptive pond management, they generally focus only on one or a very limited number of objectives. The majority of benefits, especially the less tangible ones, are frequently omitted, which may lead to wrong, ill-informed decisions. An approach that takes into account ecosystem services (ESS), as mentioned by Soto et al. (2008), can tackle this problem due to its ability to identify, model and assess a more encompassing set of benefits associated with ecosystems. This can guide pond management toward a more balanced delivery of economic, social and ecological benefits, where benefits are optimized and trade-offs between benefits are revealed. Cost-benefit analysis (CBA) is a convenient method to put the ESS approach into practice (Newton et al. 2012). CBAs include both costs associated with management practices and benefits associated with ESS delivery. As the benefits of ESS delivery can be expressed in monetary terms (Costanza et al., 1997), costs and benefits can be compared directly and management decisions can be optimized toward more cost-effective ESS delivery. These CBAs have been referred to as environmental CBAs by Atkinson and Mourato (2008). As management of natural systems is inextricably linked with uncertainties, knowledge on the uncertainties associated with particular management outcomes is valuable and should be taken into account in CBAs (e.g. Bianchini and Hewage, 2012; Karmperis et al. 2012). Research of Newton et al. (2012) indicates that calculated net benefits can be highly sensitive to market price fluctuations. Although the importance of risks in environmental management is widely recognized, explicit consideration of uncertainties in environmental CBAs is currently limited (e.g. Ticehurst et al., 2007; Barton et al., 2008).

This paper discusses a methodology to perform an environmental, probabilistic CBA to assess the effect of different pond management practices on ESS delivery, and analyses the effect of taking more/less putative ecosystem services into account. As the outcome of such CBAs may strongly depend on the type and number of ESS taken into account, we assessed the sensitivity of the CBA outcomes on including or excluding particular services into the analysis. For this purpose, a Bayesian belief network (BBN) model was developed to model ecosystem functioning and service delivery of a single pond. This study focusses both on the potential of BBNs to facilitate cross-disciplinary communication for knowledge integration as well as on the sensitivity of ESS assessments to the set of services taken into account.

2. Methods

2.1. Study area

The pond complex 'Vijvergebied Midden-Limburg', located in the north-eastern part of Belgium (Fig. 1), was selected as study

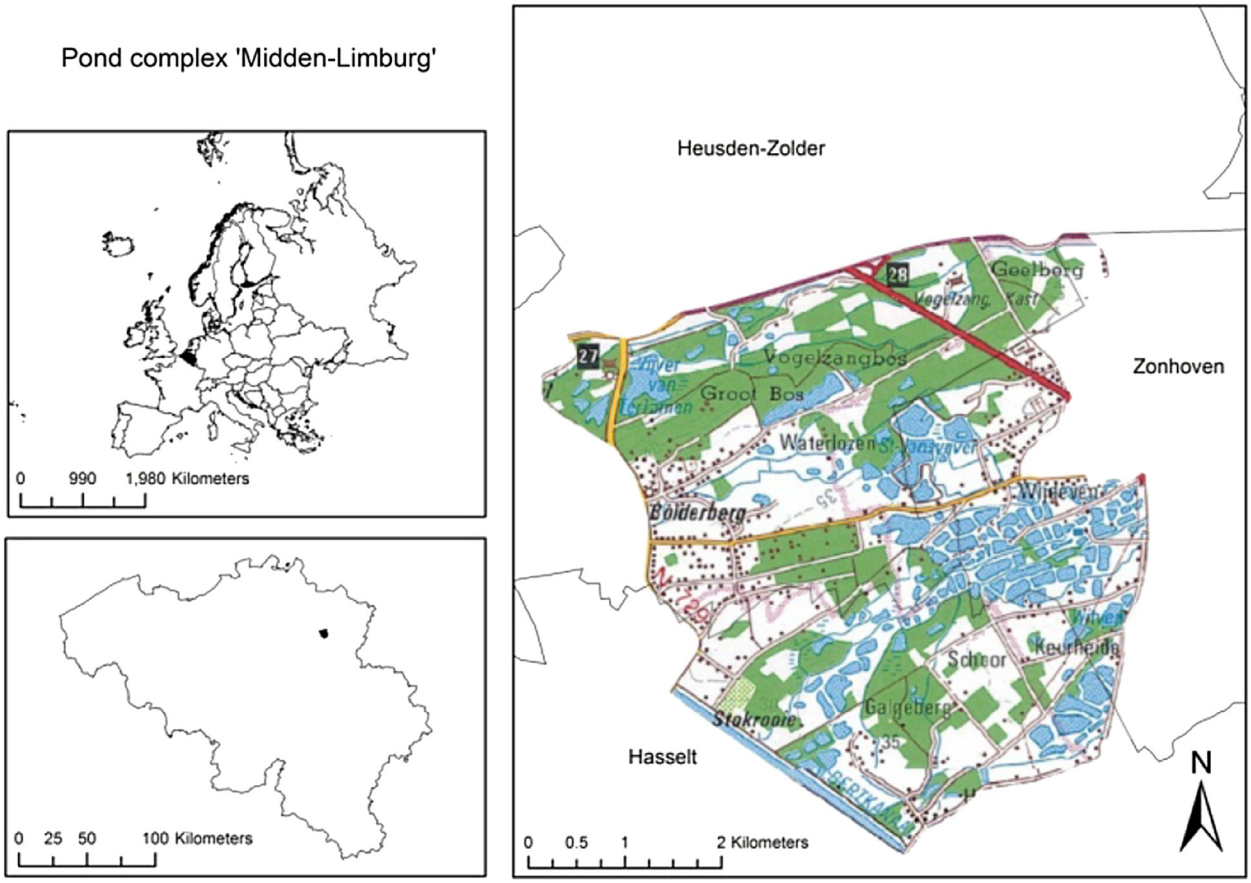

Fig. 1. Pond complex 'Midden-Limburg', located in the North-East of Belgium, in West-Europe.