Science of the Total Environment 545–546 (2016) 219–226

Contents lists available at ScienceDirect

Science of the Total Environment

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

Estimating cultural benefits from surface water status improvements in freshwater wetland ecosystems

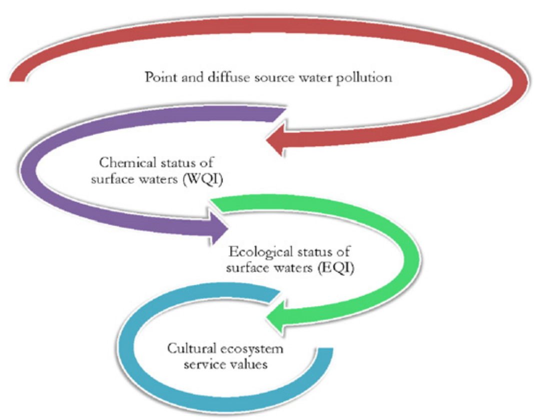
Peter Roebeling [a,*], Nelson Abrantes [a], Sofia Ribeiro [b], Pedro Almeida [b]

[a] CESAM, Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
[b] Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

HIGHLIGHTS

- We determine and relate ecological and chemical status of freshwater systems, and
- Willingness-to-pay for cultural ecosystem services from surface water status, to
- Establish relationship between surface water status and cultural ecosystem values.
- We observe positive exponential relationship between chemical and ecological status.
- We observe decreasing marginal benefits from improvements in surface water status.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 21 September 2015
Received in revised form 14 December 2015
Accepted 14 December 2015
Available online 31 December 2015

Editor: D. Barcelo

Keywords:
Ecological status
Chemical status
Cultural ecosystem services
Willingness-to-pay
Benefit-function transfer

ABSTRACT

Freshwater wetlands provide crucial ecosystem services, though are subject to anthropogenic/natural stressors that provoke negative impacts on these ecosystems, services and values. The European Union Water Framework Directive aims to achieve good status of surface waters by 2015, through implementation of Catchment Management Plans. Implementation of Catchment Management Plans is costly, though associated benefits from improvements in surface water status are less well known. This paper establishes a functional relationship between surface water status and cultural ecosystem service values of freshwater systems. Hence, we develop a bio-economic valuation approach in which we relate ecological status and chemical status of surface waters (based on local physio-chemical and benthic macro-invertebrates survey data) to willingness-to-pay (using benefit-function transfer). Results for the Pateira de Fermentelos freshwater wetland (Portugal) show that the current status of surface waters is good from a chemical though only moderate from an ecological perspective. The current cultural ecosystem service value of the wetland is estimated at 1.54 m€/yr— increasing to 2.02 m€/yr in case good status of surface waters is obtained. Taking into account ecosystem services and values in decision making is essential to avoid costs from externalities and capture benefits from spill-overs — leading to more equitable, effective and efficient water resources management.

* Corresponding author.
E-mail addresses: peter.roebeling@ua.pt (P. Roebeling), njabrantes@ua.pt (N. Abrantes), sofia.helena@ua.pt (S. Ribeiro), pedrof.almeida@ua.pt (P. Almeida).

http://dx.doi.org/10.1016/j.scitotenv.2015.12.063
0048-9697/

1. Introduction

Freshwater wetlands are extremely productive and provide crucial ecosystem services that influence climate, nutrient cycles and primary productivity on a global scale — hence contributing directly and indirectly to welfare and human well-being (Costanza et al., 1997; Keddy et al., 2009). These as well as other ecosystems are subject to several anthropogenic and natural stressors, including from pollution, population growth, economic development, resource depletion and climate change (Teles et al., 2007; Reid et al., 2010). The sum of these anthropogenic and natural stressors has often had a devastating impact on wetland ecosystems, resulting in a loss of ecosystem services and associated values (Keddy et al., 2009; De Groot et al., 2012).

The European Union (EU) Water Framework Directive 2000/60/EC (WFD) recognizes the need to avoid long-term deterioration of freshwater quality and, hence, aims to achieve a "good status" for all surface waters across the EU member states by 2015 — implying both a "good ecological status" and "good chemical status". Good ecological status is defined by the WFD in terms of biological, hydrological and chemical characteristics, and is relative to the status apparent in similar systems with minimal anthropogenic impact. Good chemical status is defined by the WFD in terms of compliance with environmental quality standards for selected chemical substances.

To this end, the WFD requires the definition of Catchment Management Plans (CMPs) — including objectives for all water bodies, justifications for not achieving these objectives, and the programme of measures required to meet these objectives. While the implementation of CMPs is known to be costly for farmers, industries and citizens (e.g. Roebeling et al., 2009, 2014; Cools et al., 2011; Vinten et al., 2012; Windolf et al., 2012), the associated economic benefits from improvements in surface water status are less well known (Van Houtven et al., 2007; Griffiths et al., 2012).

Recognizing the multiple provisioning, regulating, habitat and cultural ecosystem services from freshwater systems (TEEB, 2013), this study focusses on the cultural ecosystem service benefits from changes in surface water status as these have received relatively little attention to date (see De Groot et al., 2012). Although many studies estimate the cultural benefits from discrete changes in chemical and/or ecological quality of surface waters using environmental valuation techniques (e.g. Tumay and Brouwer, 2007; Saz-Salazar et al., 2009; Martin-Ortega and Berbel, 2010; Nallathiga and Paravasthu, 2010; Guimarães et al., 2011; Zhang, 2011; Martínez-Paz et al., 2014), only few studies allow for the estimation of cultural benefits from non-discrete (continuous) changes in the chemical status of surface waters using meta-analysis (e.g. Van Houtven et al., 2007; Johnston and Thomassin, 2010).

There is, however, a lack of studies that consistently assess the economic benefits from non-discrete (continuous) changes in the ecological and chemical status of surface waters (i.e. surface water status as defined in the WFD) — clearly mirrored by the recognition that there is a need to get a better understanding of the links between biodiversity, ecosystem services and ecosystem service values (Polasky and Segerson, 2009; TEEB, 2010). Valuation studies, like the abovementioned, assess the benefits from hypothetical changes in surface water status (expressed in pictures and/or descriptions) that are not explicitly related to the actual ecological and chemical status (or underpinning indicators and parameters) of the aquatic ecosystem. Hence, these studies are of limited use in the development of CMPs where decisions on water quality management (measures) need to be related to risks, costs, efficacy and benefits. There is a need for studies that consistently assess the cultural ecosystem service benefits from non-discrete (continuous) changes in surface water status (i.e. ecological and chemical status) — hence bridging a prominent gap between bio-physical and socio-economic sciences (Mendelsohn and Olmstead, 2009; TEEB, 2010).

This paper aims to establish a functional relationship between surface water status and cultural ecosystem service values of freshwater systems. To this end we develop a bio-economic valuation approach, in which we relate the ecological and chemical status of surface waters (based on physio-chemical and benthic macro-invertebrates survey data) to willingness-to-pay for cultural ecosystem services from surface water status (using benefit-function transfer techniques). A case study is provided for the *Pateira de Fermentelos* freshwater wetland in the Cértima catchment (central Portugal) — estimating the cultural ecosystem service values of the freshwater wetland in its current as well as good status.

2. The Cértima catchment study area

The Cértima catchment is a sub-catchment of the Vouga river basin located in central Portugal, with a catchment area of about 538 km^2 (Fig. 1). The Cértima river has a length of about 43 km and, before flowing into the Águeda river, opens-up into the *Pateira de Fermentelos* — a natural freshwater wetland with an area of about 5 km^2 (Maria et al., 2006). The *Pateira de Fermentelos* forms part of the Natura 2000 Network and is considered an important fishing and recreational area (Maria et al., 2006), with eel being the most representative and high economic value fish species and where outings, boating, bird-watching and hiking are the most important recreational activities (CMA, 2013).

Given its specific water dynamics and configurations, the *Pateira de Fermentelos* is predisposed to receive and accumulate contaminants from point (industrial and domestic) and diffuse (agricultural) sources (Teles et al., 2007; Ferreira et al., 2010). Due to the introduction of agricultural fertilizers and pesticides, the increase in population and corresponding urbanization as well as industrialization in the Cértima catchment, the *Pateira de Fermentelos* experienced increased water pollution over the last decades (Maria et al., 2006; Teles et al., 2007; Serpa et al., 2014). This resulted not only in a threat to fish populations, but also reduced the swimmability of its waters (Teles et al., 2007).

3. Methods

To estimate the cultural ecosystem service benefits from improvements in surface water status, a bio-economic valuation approach is developed that relates:

i. the ecological status (using the freshwater Ecological Quality Index, *EQI*; INAG, 2009) of surface waters (based on benthic macro-invertebrates survey data; Silva, 2008), and
ii. the chemical status (using the Water Quality Index, *WQI*; see Russell et al., 2001) of surface waters (based on physio-chemical survey data; Silva, 2008), to:
iii. willingness-to-pay (*WTP*) for cultural ecosystem services from surface water status (using benefit-function transfer techniques; Van Houtven et al., 2007).

The next sections provide a detailed description for each of these steps.

3.1. Ecological Quality Index (EQI)

The freshwater Ecological Quality Index (*EQI*) represents the relationship between the values observed for a particular biological indicator at a study site, and the corresponding biological indicator value for a reference site of the same type (INAG, 2009). Based on benthic macro-invertebrates surveys in the Cértima catchment (Silva, 2008; see Appendix A for details), the biological indicator is given by the Portuguese Invertebrate Index for Southern rivers ($IPtI_s$) that is calculated as a combination of several metrics (INAG, 2009):

$$IPtI_s = 0.4S + 0.2EPT + 0.2(IASPT - 2) + 0.2\log(Sel.EPTCD + 1) \quad (1)$$

where S is the total number of identified macro-invertebrate taxa (family level), EPT is the number of families belonging to the Ephemeroptera,