Ecological Economics 137 (2017) 184–194

Contents lists available at ScienceDirect

Ecological Economics

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

Analysis

A Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes

Arnaud Reynaud[a,b,*], Denis Lanzanova[b,c]

[a]Toulouse School of Economics, INRA, University of Toulouse Capitole, Toulouse, France
[b]European Commission, Joint Research Centre (JRC), Directorate D – Sustainable Resources, Water and Marine Resources Unit, Ispra, Italy
[c]Center for Development Research (ZEF), University of Bonn, Bonn, Germany

ARTICLE INFO

Article history:
Received 1 August 2016
Received in revised form 24 February 2017
Accepted 2 March 2017
Available online 21 March 2017

Keywords:
Lakes
Ecosystem services
Meta-analysis
Non-market valuation
Geospatial data
Global scale

ABSTRACT

This study presents the first meta-analysis on the economic value of ecosystem services delivered by lakes. A worldwide data set of 699 observations drawn from 133 studies combines information reported in primary studies with geospatial data. The meta-analysis explores antagonisms and synergies between ecosystem services. This is the first meta-analysis to incorporate simultaneously external geospatial data and ecosystem service interactions. We first show that it is possible to reliably predict the value of ecosystem services provided by lakes based on their physical and geographic characteristics. Second, we demonstrate that interactions between ecosystem services appear to be significant for explaining lake ecosystem service values. Third, we provide an estimation of the average value of ecosystem services provided by lakes: between 106 and 140 USD$2010 per respondent per year for non-hedonic price studies and between 169 and 403 USD$2010 per property per year for hedonic price studies.

1. Introduction

Out of all the surface freshwater on Earth, about 90% is contained in natural and artificial lakes (Shiklomanov and Rodda, 2003). Being one of the most important sources of water for human and for economic use, lakes provide many services. Some of them are directly valued by humans (water supply, flood damage reduction) whereas others have positive impacts mainly on the environment (e.g. improved wildlife habitat). Since most of these services are not traded on markets, assessing their economic value is not straightforward. As a result, a wide non-market valuation literature has developed with some recent empirical applications to lakes, see for example Artell (2014). Due to the wide range of valuation methods, characteristics of lakes and value estimates, it is still difficult to assess whether general results emerge from this literature. This is the main issue we address here.

We propose to conduct a meta-analysis of the economic value of ecosystem services provided by lakes. We wish to identify if there exists a valuation function that relates the ecosystem service value of a lake to its physical, economic and geographic characteristics. Our analysis relies on the most extensive global database of non-market and market valuations of ecosystem services provided by artificial and natural lakes (699 values extracted from 133 studies).

We argue that the results of this meta-analysis might be useful for decision-making. First, there remain substantial debates on the economic value of ecosystem services provided by lakes (Magat et al., 2000; Viscusi et al., 2008; Sander and Polasky, 2009). A good understanding of the physical, economic and geographic characteristics of lakes upon their economic value may inform decisions related to their use, conservation or restoration. Second, it is not clear that the relationships obtained with the existing meta-analyses for other water bodies (e.g. rivers, wetlands, transitional and coastal waters) may be used for lakes. Since some services provided by lakes are quite specific, we may indeed expect specific economic values for this type of water body (see Supporting Information S1).

To our best knowledge, our meta-analysis is the first one focusing on a large set of ecosystem services specifically provided by lakes. From a methodological point of view, our meta-analysis combines information reported in primary studies with geospatial data from geographic information system (GIS) data layers and other external sources. In addition, we explore how antagonisms and synergies between ecosystem services are valued by respondents. This is the first meta-analysis to incorporate simultaneously these two characteristics (external GIS data and ecosystem service interactions).

* Corresponding author at: Toulouse School of Economics, University of Toulouse Capitole, Allee de Brienne, 31000 Toulouse, France.
E-mail addresses: arnaud.reynaud@inra.fr (A. Reynaud), lanzanov@uni-bonn.de (D. Lanzanova).

http://dx.doi.org/10.1016/j.ecolecon.2017.03.001

The remainder of this article is organized as follows. Section 2 is devoted to the presentation of the meta-database. In Section 3, we conduct the econometric analysis of economic values provided by lake ecosystem services. Section 4 presents our main results.

2. Meta-Database on Values of Ecosystem Services Provided by Lakes

2.1. Building of the Meta-Database

The scientific references have been selected through systematic searches of the keywords "Valuation and Lake", "Value and Lake", "Willingness to pay or WTP and Lake", "Stated preferences and Lake", on search engines and on the websites of major publishers of academic journals (Scopus, Science Direct, Wiley, Web of knowledge, RepEc, AgEconSearch). Similar searches were also conducted on databases specialized in environmental valuation. Lastly, the "grey literature" was searched using various search engines (including Google Scholar and Science.gov). This is important to reduce the influence of a potential publication bias in the meta-regression analysis. In total, the literature search process took about one year (December 2013–December 2014) and it led us to examine over 300 studies.

Based on their abstract, studies have been first classified as *irrelevant*, *potentially relevant* and *relevant*. Irrelevant studies (studies without any reference to one or several lakes or those which did not report any economic valuation results) where disregarded at this first step. Further investigations were then conducted on potential relevant studies in order to reclassify them either as irrelevant or relevant. Lastly, all studies considered as relevant were downloaded and an additional screening process was conducted to decide if they had to be included or not in the final database.

This selection procedure led us to retain 133 studies, see Supporting Information S2 for the full reference list. A vast majority of the database is made of peer-reviewed articles (110 studies), the second category the most represented being institutional reports (11 studies). Studies are quite recent on average. Among the 133 studies of the database, 58 have been published after 2010, 52 between 2000 and 2010 and the remaining before 2000.

All continents are represented in our database, with an over-representation of North-America. North-America ranks first with 71 studies (68 studies deal with United States). The second continent the most represented is Europe with 30 studies. As already mentioned, United States are by far the country for which we have the most of studies. This may result from a selection bias since our systematic searches for lake valuation studies have been done in English. It may also reflect the fact that hedonic price approaches have been extensively used in this country for valuing housing amenities.

A single study may report multiple lake values, either because several lakes are considered or because of the use of several valuation methods or scenarios. Due to multiple values per study, we have 699 observations (i.e. lake ecosystem service values) in our final sample located all over the world, see Fig. 1. This represents on average a little bit more than 5.2 observations per study. Again, United States rank first with 376 observations. They are followed by Norway (66 observations), Turkey (26 observations), New-Zealand (25 observations), Finland (23 observations) and Japan (19 observations).

2.2. Ecosystem Services Provided by Lakes

For each primary valuation study (or for each observation in case of multiple observations per study) we have identified the ecosystem services provided by the considered lake. In total, we have gathered economic values for 12 different ecosystem services provided by lakes, see Fig. 2. These services belong to three categories of ecosystem services (provisioning services, regulation and maintenance services, cultural services) presented in Supporting Information S3.

Not surprisingly, the vast majority of ecosystem services for which a lake value is associated with belongs to the cultural service category. We have categorized the cultural services in our database slightly differently compared to the list presented in Supporting Information S3. In particular, the "recreation service" has been split into several sub-services: fishing, boating, swimming, camping, sightseeing and unspecified recreational services. In addition, the "amenity" sub-service has been created for studies based on the hedonic price (HP) approach. As explained in Lansford and Jones (1995), an HP study of shoreline and "near-the-lake" properties captures an important component of the recreational and aesthetic values that are provided by the existence of such a lake. There is however no direct correspondence between these amenities and the cultural service category defined in Supporting Information S3. In our database, among the cultural service category, the "amenity" service ranks first (244 observations) followed by the different recreational services such as "fishing" (265 observations) and "boating" (183 observations).

For provisioning services, we have only 25 observations for the "water for drinking" and the "water for non-drinking purposes" services. Lastly, we have 206 observations of economic values for regulation and maintenance services. The majority (193 observations) refers to the "maintaining populations and habitats" service, whereas the remaining observations deal with the "flood protection" service and the "erosion prevention" service.

Some studies value only one particular lake ecosystem service, but a significant number of them provides values for two or more services, Fig. 3. The number of ecosystem services valued in each study varies from 1 to 7, with an average a little bit higher than 2. This raises an interesting identification issue since, in most cases, a direct correspondence between a particular service and its associated economic value does not exist. This identification issue might be particularly relevant to address in case of complementarity or substitutability relationships among services. Indeed, in all previous meta-analyses on water ecosystem services, it has been assumed that the economic value of a water body is a linear function of the ecosystem services provided. We argue that such a specification could be questioned in case of tradeoffs or synergies between ecosystem services. Since there are complex relationships among ecosystem services (Fu et al., 2011; Raudsepp-Hearne et al., 2010) , the value for a specific ecosystem service might depend upon the other ecosystem services provided. Not introducing interactions across ecosystem services may then lead to biased estimates in the meta-analysis. It also raises some concerns vis-a-vis the common use of a "value catalog approach" for transfer of ecosystem service values.

2.3. Reconciling Lake Values

Lake values have been reported in the literature in many different metrics (i.e. willingness to pay per unit of area or per person, marginal value, capitalized value), using different currencies and for different periods of time. In order to enable a comparison across studies, all these values must be standardized. As explained by Ghermandi et al. (2010) or by Londoño and Johnston (2012), the standardization of different and heterogenous metrics used to value ecosystem services is a difficult and controversial task. But such adjustments are required to reconcile variable definitions across studies (commodity consistency requirement), and are nearly universal in meta-analyses of ecosystem service values (Johnston and Rosenberger, 2010; Nelson and Kennedy, 2009). We explain here how ecosystem service values from the original studies have been normalized.