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Analysis

Combining expert elicitation and stated preference methods to value ecosystem services from improved lake water quality

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ABSTRACT

With increasing attention on the contribution of ecosystems to human well-being, there is a need for tools that integrate ecological and economic models for valuing ecosystem services. To address this, we develop a protocol for linking ecological processes and outcomes to human preferences, which combines environmental modeling, expert elicitation, and nonmarket valuation methods. Our application values reductions in nutrient loads to lakes in the southeastern US. The innovation centers on how biochemical measures of water quality (e.g., chlorophyll *a*) are translated into terms that are meaningful to individuals who derive ecosystem services from them. Using expert elicitation data, we estimate a model linking changes in biochemical measures to an index of eutrophication in lakes. We then develop a stated preference survey including (a) detailed descriptions of the perceptible outcomes – e.g., water color, clarity – associated each eutrophication index level; and (b) policy scenarios involving state-level changes in lake eutrophication conditions. We estimate a function that predicts households' willingness to pay for changes in lake water quality. We demonstrate the protocol through a case study examining the benefits of lake quality improvement in Virginia as a result of recent policies to reduce nutrient loads in the Chesapeake Bay watershed.

1. Introduction

Ecosystems provide valuable services to households and businesses, but a number of challenges make it difficult to estimate the monetary value of these services. While economists have developed an impressive collection of methods for valuing nonmarket and public goods, practical applications that seek to value changes in ecosystem services face additional challenges. For example, quantitative measurements of ecosystem health (such as nutrient concentrations in surface water) are typically not good descriptors of the actual services that people perceive and derive value from. Nonetheless regulators usually set management goals based on chemical, physical, or biological properties of the resource. This creates disconnects between how ecosystem quality is assessed, how ecosystem services are defined, and the way that economists go about measuring the value of these services. Many otherwise carefully executed ecosystem service valuation studies do not deliver on their policy promise, owing to this difficulty in precisely linking changes in the valued services to the physical outcomes of a policy shock.

Our research addresses this problem by developing an integrated ecosystem services valuation protocol that connects changes in ecosystem health indicators to changes in economic value in a way that maintains direct linkages between physical measures, service levels, and household preferences. Our specific application values reductions in nutrient loadings to freshwater lakes in the southeastern United States. The US Environmental Protection Agency (EPA) has encouraged states to set numeric criteria for nitrogen, phosphorus, and chlorophyll *a* concentrations as a way of controlling eutrophication (Kenney et al., 2009; Reckhow et al., 2005; USEPA, 2010). Jurisdictions must also develop Total Maximum Daily Load (TMDL) limits for impaired waters. The economic benefits that these ambient standards and TMDLs provide, however, arise from people's preferences and the underlying services they receive. Thus while quantitative indicators are invaluable for assessing ecosystem health and establishing policy objectives, the benefits they provide can be difficult to conceptualize. In contrast descriptive narratives of quality improvements are useful for communicating the possibility of benefits, but their imprecise nature is what led the EPA to encourage the development of numeric criteria in the first place.

In this paper we present an approach that combines water quality modeling, expert elicitation, and a stated preference survey to quantify the linkages between changes in nutrient loadings, changes in ambient

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concentrations, changes in ecosystem service levels, and ultimately nonmarket values for quality improvements. Expert elicitation is a formal process used to systematically elicit and quantify judgments from scientific experts. In our case we used expert elicitation to collect data from water quality experts and estimate a functional relationship linking observations of specific ambient water quality parameters in the study area lakes to a five-level, multi-attribute eutrophication index. Because eutrophication manifests itself differently in different systems, we used expert elicitation to specifically establish this relationship for reservoirs in the Southeastern region of the United States. Each level of the index was described to experts using narrative descriptions for a defined set of attributes, including clarity, color, algae, aquatic life, and odor. Then, to understand how the public values different eutrophication states and quantify their willingness to pay for less-eutrophic conditions, we applied a stated preference approach. Our stated preference survey took the narrative descriptions from the expert elicitation and modified them to be more accessible to a non-technical audience and, at the same time, consistent with the descriptions presented to experts. Although numeric water quality indexes have been widely used in previous economic valuation studies (Van Houtven et al., 2007), one of the main advantages of this index approach is the direct connection it provides between experts' and lay persons' understanding of water quality. Importantly, the year-long development of our stated preference survey involved substantial back and forth between the water quality experts who developed and conducted the expert elicitation and reviewed the stated preference scenarios, the economists who were translating their knowledge into survey-appropriate descriptions, and individuals from the lay public who were involved in focus groups and pretest interviews. This combination of expert elicitation and stated preference surveying offers an innovative approach for linking changes in chemical and biological water quality parameters, which are typically used as measurable indicators of ecosystem health, with attributes that are more closely linked to the types of ecosystem services that individuals recognize and value in lake water quality. It also provides an approach for linking water quality and preferences that we expect will be more explicit and transparent for policy makers.

The remainder of the paper is organized as follows. In Section 2 we place our research in context by reviewing background information that is relevant for ecosystem services valuation as related to water quality. In Section 3 we present our analytical framework in three subsections that describe (a) the water quality models; (b) expert elicitation analysis; and (c) the process used to translate the experts' understanding into the descriptions used in the survey. It also presents the details of our survey and econometric models, and Section 4 contains a case study. The policy context for our case study is the recently promulgated TMDL limits established by EPA for the Chesapeake Bay, which has received considerable regulatory and media attention. In addition to improving conditions in the Bay estuary, the rule is expected to reduce nutrient loads and improve water quality throughout the Bay's 64,000 square mile watershed. We examine the benefits of the expected lake water quality improvements in the state of Virginia, much of which lies within the Bay watershed. We find that the Chesapeake TMDL will improve lake water quality in Virginia by an amount sufficient to generate $184 million per year in aggregate benefits for residents of the state. Although this estimate is of policy interest, the main objective of the case study is to illustrate a common ecosystem service valuation problem, and to demonstrate the advantages of our approach for addressing it. The paper's main contribution therefore is the development of an integrated protocol combining expert elicitation and stated preference techniques, which would be of use in many practical valuation contexts. We conclude the paper in Section 5 by discussing in greater detail the potential of our approach to advance the practice of ecosystem service valuation generally.

2. Background

The basic ecosystem service valuation problem we address is illustrated by Fig. 1, which traces how a change in an environmental input filters through the system to produce a change in human well-being. Note that the change in actual services and behavior (box 3) is preceded by physical changes that are not generally observed by households. For example, the process begins with a shock to an environmental input to the ecosystem, such as nitrogen loading in our study (box 1). This produces a physical change in the ecosystem (box 2), which is measured by an indicator such as nutrient concentrations in the water. Scientific assessment and regulatory decisions are usually based on the information in box 2, but this is still a secondary outcome for purposes of environmental valuation. It is the perceptible change in the ecosystem and the resulting change in the quantity or quality of services derived from the ecosystem (shown in box 3) that directly impact human well-being. In the case of nutrients, the perceptible ecosystem changes relate to observable features of water bodies, such as color, clarity, smell, and abundance of aquatic life. Box 4 illustrates the final step linking a change in services to preferences and monetary value.

Many studies have addressed a subset of the individual steps shown in Fig. 1. However, relatively few have developed protocols that formally link all four components. For example, there is a large literature applying stated preference methods to value changes in water quality (see Johnston et al., 2005; Van Houtven et al., 2007 for summaries of this literature). Because the water quality changes described in the surveys must be expressed in terms that are understandable to a non-technical audience, they are often non-specific in their correspondence to measurable biophysical parameters. A good example of this is the lake visitation choice experiment used by Roberts et al. (2008), which includes an attribute for the presence/absence (and risk) of an algae bloom at the destination. The study addresses boxes 3 and 4 quite effectively, but by abstracting from boxes 1 and 2 it does not allow policy analysis of how changes in nutrient levels map to changes in the likelihood that a bloom will appear. Other studies (e.g. Egan et al., 2009) have used revealed preference methods to directly link measured water quality to behavior. This approach connects boxes 2 and 4, thereby leaving latent the process by which individuals translate ecosystem quality into ecosystem services. While this strategy is attractive in its ability to directly connect policy targets to valuation, identification and interpretation challenges can be substantial due to uncertainty about the connections underlying the reduced form relationship. Finally, several studies have employed an approach in which multiple pollution parameters are aggregated to a one dimensional index of water quality (USEPA, 2002, 2009a,b). The best known technique characterizes quality along the 0 to 100 scale, based on the results of an expert elicitation

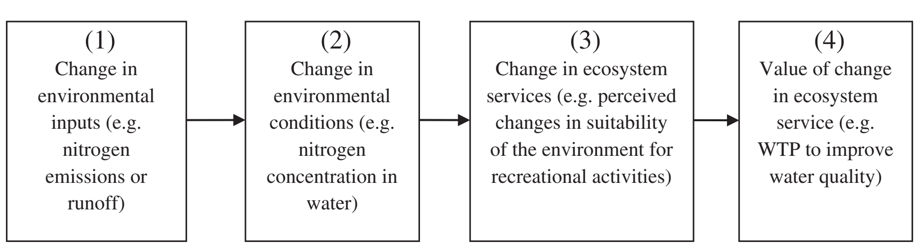

Fig. 1. Measuring the value of a change in ecosystem services.