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Economic Tools for Valuing Freshwater and Estuarine Ecosystem Services

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1. Introduction

When the well is dry, we know the worth of water.
Benjamin Franklin, *Poor Richard's Almanac*, 1746

Healthy ecosystems provide a variety of services critical for human and non-human life, including air and water purification, flood control, climate regulation, plant pollination, and food and fiber production. Advances in ecosystem sciences over the past several decades have shed considerable light on these diverse benefits afforded by healthy ecosystems (Daily, 1997).

This paper reviews the growing body of research on the economic value of ecosystem services, focusing specifically on water quality and quantity in freshwater and estuarine ecosystems. While its primary emphasis is on valuation of water services, the report can also serve as useful background for understanding how economic valuation might apply to other ecosystem goods and services.

The report describes the different components that are used to determine the total value of freshwater and estuarine ecosystems and examines the tools that economists use to estimate these values, presenting several case studies that show these tools in use. Finally, a conclusion discusses implications of this literature for the improved management of water resources.

North Carolina is particularly rich in freshwater and estuarine ecosystems that the state's citizens rely on for recreation, drinking water, and irrigation, as well as for the flood and pollution control services these waters provide. Our decisions to protect, restore, and manage ecosystems should be based in part on a better understanding of how humans benefit from ecosystems and how human behavior can be modified through regulation, economic incentives, and other policy initiatives. Those who advise policymakers on matters of ecosystem management can learn much from the field of environmental economics on the valuation of ecosystem services. With a better understanding of the often neglected and undervalued ecological benefits of improved management of water quality and quantity, we will be able to design more effective water management policies.

2. Ecosystem Valuation

> *Water has economic value in all its competing uses and should be recognized as an economic good.*
>
> The Dublin Principles, 1992[1]

Total Economic Value of Water Ecosystems

Government agencies and environmental organizations increasingly recognize that it is useful to measure the benefits and costs of different policy actions that may improve, protect or degrade water resources. Successful long-term economic development depends on wise use of natural resources, and on avoiding, as much as possible, the detrimental impacts of development activities. These impacts can be avoided with more careful planning and design of transportation, urban development, and other infrastructure projects, and by more careful attention to impacts during implementation of the projects (Dixon et al. 1986).

Economic analysis of the environmental impacts of projects and policies has its roots in a body of theory developed by economists Arthur Pigou (1920) and John Hicks (1939). They held that policies and projects should be based on the resulting changes in social welfare, where social welfare is the sum of individual welfare. Individual welfare is measured by each person's willingness to pay (WTP) for the changes brought about by a policy or project. The intuition behind monetary measurement of project benefits is rather straightforward: people show their preferences for those things they desire by their willingness to spend money to purchase them.

The total economic value of an environmental resource can be calculated as a sum of four main components: use value, indirect use value, option value and nonuse value:

- **Use value** refers to the benefit people receive from direct use of the environment: withdrawing water from a river for drinking or irrigation, catching fish in an estuary, for example. Use

[1] The 1992 International Conference on Water and Environment in Dublin, Ireland developed a set of four principles to guide management of freshwater that became known as the Dublin Principles. The other three principles are: (1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels; (3) Women play a central part in the provision, management and safeguarding of water (World Meteorological Organization).

value can also include non-consumptive uses like swimming and boating. Use value can be diminished by pollution or certain types of development.

- **Indirect use value** arises from services that users get indirectly and often some distance away from where they originate. Examples include flood control and pollution filtering functions of wetlands that may benefit people far downstream.

- **Option value** refers to users' willingness to pay (WTP) to preserve the *possibility* of using a resource in the future. An example is the value of protecting a reservoir from nearby development because it might be needed as a future source of drinking water for a municipality.

- **Nonuse value** reflects what people are willing to pay to protect resources they will never use. In the context of water resources, some people may desire to have some free-flowing streams preserved or endangered aquatic species protected out of a sense of environmental stewardship that is unrelated to direct or indirect use, current or in the future.

Total economic value = Use Value + Indirect Use Value + Option Value + Nonuse Value

For monetary valuation, some of these components are easier to measure than others (Pagiola, Bishop and von Ritter, 2004). Use values are generally the most straightforward to measure because there are observable quantities of products consumed as well as market prices that can be used to determine economic value. Recreational use can also be measured by observing the number of visits and the characteristics of visitors and sites. Indirect use values are more difficult to measure for two reasons. First, quantities are often a challenge to measure, e.g., determining the flood control provided by a particular wetland. Second, the indirect uses are not usually traded in marketplaces and therefore have no associated prices. Hence, "shadow values" must be estimated in order to "price" the produced services. Option values and nonuse values are the most difficult to measure because these are not reflected in observable behavior. These values are estimated by using surveys that ask people a series of questions about their willingness to pay for ecosystem services they do not use.

For those environmental services provided by water ecosystems that are not priced and traded in a marketplace, environmental economists have developed a set of methods to estimate their economic value. Two major categories of methods are used: stated preference and revealed preference methods. Stated preference methods use surveys to elicit directly from individuals the economic value they assign to non-market ecosystem services. Revealed preference methods rely on observations of the choices that people make to infer values of resources they are using. No single method is appropriate for every valuation situation.

Despite a growing interest on the part of the academic, governmental, and non-governmental sectors, environmental valuation remains controversial. Even those who accept the rationale for environmental valuation have ongoing debates about methodological issues, including choice of method, survey design, and selection of econometric models (McMahon and Postle, 2000). The biggest controversy, however, arises from ethical concerns about placing monetary values on environmental services (Foster, 1997). Mark Sagoff, an environmental philosopher, argues that people hold altruistic "citizen preferences" about environmental resources and hence cannot engage in meaningful monetary valuations of the resources (1988). He maintains that using aggregated "willingness to pay" estimates in a benefit-cost analysis is an inappropriate way to inform environmental policymaking. Other critics argue that an emphasis on benefit-cost analysis may skew the political process by giving too much influence to the analysts or to the "questionable" information they provide (Shabman and Stephenson, 2000). David Pearce (1999) responds that using resources to pursue a social objective will always impose opportunity costs. So spending more to clean up mercury in the environment means less funding will be available to preserve critical habitat. Therefore, it is appropriate and useful for policy makers to be able to compare the monetary value of different policy options (McMahon and Postle, 2000).

Environmental Valuation Methods

Environmental economists have developed a number of valuation methods, four of which have been used extensively to value services provided by freshwater ecosystems. Table 1 summarizes these four methods, showing which water-related services are appropriate for the method, and outlining data requirements and method limitations.

The most widely used approach to measuring the economic benefits of environmental conservation is the **contingent valuation method**. This is a "stated preference method" that allows a sample of people who benefit from a particular resource to tell researchers directly, through surveys, what they are willing to pay for some improvement in environmental quality. One of the strengths of this method is that it can capture both use value (e.g., drinking water use) and nonuse value (protection of threatened aquatic species) (Mitchell and Carson, 1993). Because of this versatility, it is the most widely used method, although it is controversial because, critics say, people are reporting *hypothetically* on their willingness to pay rather than observed actually spending the money, possibly biasing the resulting valuation estimates (Hanemann, 1995). These concerns can be addressed with careful survey design and implementation (Carson et al. 2001).

How Ecosystem Values Changed a Water Policy Debate in Southern California

One of the best examples of nonmarket values having an impact on public decision-making is the case of allowing tributary waters to flow into Mono Lake in California versus diverting the flows for municipal and industrial water users in Los Angeles. In 1983, the California Supreme Court ordered a reevaluation of Los Angeles' water rights and a balancing of public trust water uses. A contingent valuation study by John Loomis (1987) showed that people were willing to pay for the protection of birds and fish in Mono Lake and that these benefits far exceeded the replacement cost of water from other sources. As a result of this initial study, California's Water Resources Board required that the state's Environmental Impact Report include nonuse ecosystem values in its analysis of water reallocation alternatives. In the analysis, nonuse ecosystem values were compared dollar for dollar to the hydropower and water supply benefits. Eventually, the state required that tributary flows to Mono Lake be increased significantly, and Los Angeles' water rights were cut almost in half. Although the driving concerns were air and water quality, the economic analysis showing that the new allocation generated important nonuse economic benefits likely influenced this major policy shift (Loomis, 2000).

Another widely used approach to valuing water ecosystem services is the **travel cost method**, a "revealed preference" approach that is based on how people make recreational choices (Smith and Desvousges, 1986). The underlying principle is that people spend time and money to travel to and use a site for recreation. There are two main versions of this method (Freeman, 1993). The first version estimates a statistical relationship between the number of visits at a site and the level of travel expenditures by visitors and uses that relationship to estimate the total value of recreation services provided by the site to all users. The second version uses statistical analysis to examine how specific site characteristics influence decisions to recreate at different sites and then to infer the economic value of those characteristics.

Although many environmental goods are not traded in markets, their presence may have an affect on property values. The **hedonic property value method** takes advantage of this connection (Smith, 1993). Land prices are usually higher for land parcels close to lakes or estuaries because of the views and boating or fishing opportunities. By statistical analysis, the part of land values due to these environmental services can be separated out. The method controls for other variables influencing land prices so that any remaining price differential is a measure of the willingness to pay for the unpriced environmental good.

Finally, the **change in productivity method** recognizes that when changes in environmental quality affect the production of marketed goods, these effects can be captured by observing what happens in a related market (Freeman, 1993). So if water pollution reduces fish catches or acid rain reduces timber productivity, we can value those impacts with the price of the resource, e.g., fish or timber. Consider the example of wetlands that provide breeding areas and increased food supply for various nearby fisheries. If these fisheries are commercially exploited, then the value of a wetland can be measured in part by the dollar value of the increase in fish catches resulting from the wetland. This method requires an interdisciplinary approach involving biologists and economists.

Table 1: Economic Valuation Methods for Water Resources

Method	Approach	Water Service Appropriate for Method	Data Needs	Limitations
Contingent valuation method	Ask people directly their willingness to pay (WTP)	All use values and nonuse values (e.g., drinking water, fishing, protecting species)	Survey with scenario description and questions about WTP for specific services	Potential biases due to hypothetical nature of scenarios

Travel cost method	Estimate demand curve from data on travel expenditures	Recreation: boating, fishing, swimming	Survey on expenditures of time and money to travel to specific sites	Only captures recreational benefits; difficult to apply for multiple destination trips
Hedonic property value method	Identify contribution of environmental quality to land values	Water quality, wetland services	Property values and characteristics including environmental quality	Requires extensive information about ecosystem services at hundreds of specific sites
Change in productivity method	Assess impact of change in water service on produced goods	Commercial fisheries, agricultural uses	Impact of change in water service on production; net value of produced goods	Information on biological impacts of changes in ecosystem services often unavailable

Adapted from Pagiola, Bishop and von Ritter (2004).

Examples of Valuation Studies

In this section, several examples are presented of environmental valuation methods applied to aquatic ecosystems. These studies illustrate a range of applications and provide some details on how the methods are applied. Readers interested in additional details should consult the original publications.

Travel Cost Example: How Does Atrazine Affect Water Recreation?

Dietrich Earnhart and Val Smith (2003) examined the effects of the pesticide Atrazine on water-based recreation at Lake Clinton, Kansas. Atrazine may enhance recreational enjoyment by inhibiting the growth of nuisance algae and thus encourage greater recreation; but the presence of Atrazine in reservoirs may be detrimental to fish populations and hence, reduce recreational use. To quantify and compare these countervailing effects, the authors applied the travel cost method in combination with contingent behavior questions.

The authors conducted a survey of 245 residents of Lawrence, Kansas about their recreational use of Clinton Lake, collecting data on visitation patterns and socioeconomic characteristics. They calculated respondents' travel costs to the lake as the sum of transportation cost (at 31.5 cents per mile), their time costs (wage rate times the two-way driving time), and access fees. In addition, the researchers asked respondents how their chosen destinations would change with various changes in water quality. Some changes were described as a decrease in algae, some were described as a decrease in fish, and some were described as a combination of the two effects of Atrazine.

They found that the average respondent had a $22 trip cost to the lake and made about 3 trips in the previous year. An improvement in algae-related water quality would lead to an average increase of 2.7 visits, while a decline in fish related quality would trigger an average decrease of 0.5 visits. The combination of quality changes would lead to an average decrease of 0.6 visits.

The authors then conducted an in-depth statistical analysis of likely travel behavioral responses to water quality change in light of the countervailing effects of Atrazine on algae quality and fish quality. They examined the tradeoffs for recreators between these two quality dimensions and concluded that for each 1 percent decline in fish-related quality, respondents required a 4.7 percent increase in algal-related quality so as to maintain their same level of recreational enjoyment. While they did not monetize the overall impact of atrazine, they concluded that "knowing the effective rate of exchange between fish- and algae-related water quality in Clinton Reservoir will allow reservoir managers to estimate recreators' responses to future changes in the watershed" (p. 1089).

Hedonic Property Value Example: Effects of Water Quality on Residential Land Prices

Compared to a large number of studies of air quality, the hedonic property value method has been used only a handful of times to value changes in water quality. An excellent example of the potential usefulness of this approach is illustrated by Christopher Leggett and Nancy Bockstael's investigation of whether water quality affects residential property values along the Chesapeake Bay (2000). They were able to take advantage of a favorable geographic situation: "a highly irregular estuarine coastline that supports a lively market for waterfront homes and that exhibits considerable variation in water quality within a small area (p. 122)."

The authors used data from waterfront property sales from 1993 to 1997 in Anne Arundel County, Maryland. One of the most challenging aspects of using the hedonic method is measuring environmental quality for each property site. They used fecal coliform data from samples collected at 104 sites along the county's coastline and constructed a water quality measure based on the distance of each property from the nearest monitoring station.

The results showed that coliform levels had a significant and negative impact on property values. Once the researchers established this significant effect of water quality on property values, they demonstrated how their results could be used to value water quality improvements. They illustrated the usefulness of the hedonic model by focusing on a hypothetical localized improvement in water quality on waterfront property values along the Saltworks Creek Inlet northwest of Annapolis. They found that modest reductions in fecal coliform counts in the middle and upper reaches of the inlet increased property values by 2 percent. While this may appear to be a small impact, the potential gains across all properties in the county could amount to more than $12 million if water quality was improved by a similar amount elsewhere. The study makes a convincing case that waterfront owners exhibit a strong willingness to pay for reducing concentrations of fecal coliform bacteria.

Contingent Valuation Example: The Economic Value of Water Quality in the Catawba River Basin

A Duke University study used the contingent valuation method to estimate the economic value of protecting water quality in the Catawba River basin at its current level (Kramer and Eisen-Hecht, 2002; Eisen-Hecht and Kramer, 2002). Telephone interviews were conducted with 1085 randomly selected households in 16 counties within the Catawba River basin in North and South Carolina. Before the interviews, the survey respondents were mailed a short information booklet that described a water quality management plan (summarized in Box 1). Respondents were then asked if they would support the management plan. The management plan was offered to respondents at one of eight different price levels ranging from $5 to $250 per year for five years (Box 2). The contingent valuation scenario was developed through reviews of other studies and refined during focus groups and pretests.

The survey results indicated that, besides showing a high level of concern about water quality, area residents place a significant monetary value on protecting water quality in the Catawba basin. Two-thirds of the respondents expressed a willingness to pay, through an increase in state income taxes, for the management plan described in the pre-survey booklet. The willingness to pay expressed by respondents puts a dollar value on the well-being they receive from the protection of water quality in their region. This well-being translates into an annual economic benefit of $139 per Catawba River basin taxpayer and more than $75 million for all taxpayers in Catawba basin counties. Table 2 shows a distribution of willingness to pay values. South Carolina residents, living near the more polluted downstream portion of the river, were willing to pay more than North Carolina residents were. For residents in both states, willingness to pay rose with household income.

Box 1: Summary of Water Quality Management Plan Presented to Catawba Basin Survey Respondents

This management plan addresses the main water pollution problems in the basin: sediment and nutrients. It also continues to manage related problems such as pollution by toxic substances and bacteria and viruses. While this specific management plan has not been proposed by state governmental agencies, it is drawn from their best available information. This includes information on the condition of the basin and how to best manage the problems.

This potential management plan includes the following components:

1. Construction and use of best management practices (BMPs) within the basin. These include buffer strips and holding ponds for farms, construction sites and residential areas.
2. Development of a basinwide land use plan. This would encourage land uses in the basin that are consistent with the goals for water quality in the basin. Government agencies could use this land use plan to make decisions that would affect water quality.
3. Improving and increasing the capacity of sewage treatment plants in cities within the basin.
4. Purchasing and setting aside of tracts of land that have been determined as critical to the protection of water quality.

Box 2: Contingent Valuation Question for Valuing Water Quality Management Plan

Now, assume a vote is being held today to approve or reject this management plan. Your payment for this plan would be collected through an increase in your usual state income taxes. All residents in counties within the Catawba River basin would make identical payments. This money would only be used for implementing this management plan for the Catawba River basin. If a majority of Catawba basin county residents vote in favor of this management plan, it will go into effect. Before you answer the following question, please consider your current income, as well as your expenses.

Suppose that this management plan would cost you $____ (5, 10, 25, 50, 100, 150, 200, 250) each year for the next five years in increased state income taxes. Would you vote in favor of the management plan?

After the contingent valuation question, the survey questionnaire contained various questions designed to elicit additional information from respondents regarding their votes on the management plan. One of these questions sought to uncover the most important reasons why respondents might value the management plan. The highest-rated reason was quality of area drinking water, followed by the knowledge that the waters in the basin were being protected, regardless of respondents' use of them. These results shows that their willingness to pay was a function of both use and nonuse values.

Table 2: Willingness to Pay to Protect Catawba River Water Quality

Respondent Group	Mean Willingness To Pay
Total Sample	$139
Comparison across states	
North Carolina residents	$135
South Carolina residents	$150
Comparison across income levels	
Household income $30,000 and under	$116
Household income between $30,001 and $75,000	$157
Household income above $75,000	$180

The annual benefits from the CVM survey were used as part of a cost-benefit analysis of implementing the water management plan (Table 3). Detailed costs were estimated for each component of the management plan. The results showed a net present value of $95 million that would result from implementing the plan, indicating that benefits far outweighed the costs.

Table 3: Benefit-Cost Analysis of Implementing the Catawba Basin Management Plan

Net Present Value of Benefits over time	$340 million
Net Present Value of Costs over time	$245 million
Benefits minus Costs	$95 million

3. Implications for Improved Water Management

Why should we worry about the economic valuation of water ecosystems? In part, because there will always be competing needs for public funding and there will often be competing demands for the use of water resources. Benefit-cost analysis has proven to be a useful tool to guide public decision making in the face of competing interests. Environmental organizations and other public interest groups may find it useful to turn to benefit-cost analysis, including the analysis of non-market values, to advocate for a complete accounting of the impacts of water policies. Those concerned about fiscal responsibility of public investments in water resources may find that the discipline provided by impartial weighing of benefits and costs can contribute to a wiser use of public funds. Because many of the services provided by freshwater and estuarine ecosystems are outside the realm of market transactions, the value of these service flows is best evaluated with nonmarket methods developed by environmental economists. It is important for environmental professionals to be better informed about these methods, when they are called for, and their strengths and weaknesses (Braden 2000). Environmental valuation is a mature and rapidly growing enterprise, with thousands of applications now complete, many of them applied to water resources. Research in this field has documented a large willingness to pay for improvements in water quality, for conservation and restoration of rivers and wetlands, and provision of irrigation and floodplain services and a variety of other water related ecosystem services.

This research activity is unlikely to slow down in the future. As environmental economist Kerry Smith (1993) notes in his appraisal of non-market valuation methods, "Environmental resources are increasingly recognized as assets providing services that are no longer readily available. Indeed, demands to measure their values and incorporate them into our decisions is precisely what we would expect at their scarcity increases (p. 1)."

Our expanding knowledge about how to quantify water ecosystem services provides opportunities for improved policy formulation regarding the management of those resources. Obviously, the valuation studies will not be the only factor when decisions are being made that will affect a watershed. But in cases where political decisions are relatively "close calls," estimates of non-market values as part of a benefit-cost analysis of policy alternatives may be influential (Bennett, 2003).

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