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The Application and Usefulness of Economic Analyses for Water Quality Management in Coastal Areas

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1. INTRODUCTION

In managing water quality in U.S. estuaries, as well as throughout ocean and coastal governance, there is an increasing call for economic research to communicate the values of environmental resources to local communities, policy makers, and other stakeholders. Watershed managers implement economic studies to: 1) better communicate the value of estuarine resources to the wider community, 2) determine the most cost-effective management actions, and 3) compare the costs and benefits of actions to improve water quality. In order to better understand how economic studies are applied and their usefulness in coastal management, we interviewed managers from six National Estuary Programs (NEPs) and two watershed organizations that have undertaken economic studies, focusing on the lessons learned from the use of those studies.

Economic studies can provide insights to managers and stakeholders about the implications of management actions or lack of action. Although economic research can offer a common language and framework, estimating economic values of policy changes to estuaries is a complex process requiring careful implementation in terms of methodology and scale as well as in the presentation and application of findings (Pendleton 2010). The findings from our interviews highlight the utility and limitations of economic analyses for coastal management and may help coastal managers to determine the most appropriate economic approaches to suit their needs and to avoid some of the pitfalls faced by other managers in conducting and communicating economic analyses. Additionally, our findings may help economists understand the needs of estuary managers, and help them better provide economic research that can contribute effectively to coastal management.

2. METHODS

This study identified participants that were engaged in managing water quality in coastal ecosystems and had conducted, or were in the process of conducting, economic analyses. Eight semi-structured phone interviews (Patton 2002) were conducted with coastal managers. Six of the nine National Estuary Programs that had conducted, or were in the process of conducting, economic analyses at the time of this research participated (see Jewhurst and Mazzotta 2016 for additional details). The reports for each of these analyses were also reviewed. Two additional

interviews were carried out with county-level organizations that are using economic analyses.

Identification of participants was limited to those familiar to the EPA's National Estuary Program (NEP) staff, who administer the 28 NEPs nationwide. EPA Regional offices as well as EPA Headquarters were contacted and asked to submit suggestions for eligible participants, and nine NEPs were identified. Of the nine, we reached out to eight. One was not contacted because its analysis was a review of other economic studies. Seven of eight responded and six were used. One did not respond, and one helped pilot discussion questions. The pilot responses were excluded from the results because researchers in this study conducted that NEP's economic analysis and/or currently work with that NEP, which may have influenced its responses. The two county-level participants were chosen because they have robust programs actively working to restore coastal waters, and could provide direct insights about the type of economic information watershed managers currently need.

Of the eight interview participants, six were from NEP organizations that have coordination and facilitation roles and two were from county organizations that have regulatory authority. All of the estuaries are located in the eastern United States, including the Atlantic and Gulf of Mexico; the watersheds studied range from 19.5 mi^2 to 16,246 mi^2. The economic analyses of these organizations represented a breadth of initial goals, including justifying investments in water quality protection, understanding the costs of restoration versus the benefits of ecosystem services, providing insight to elected officials and communities on the value of ecosystems, and promoting a feeling of worth of local waters. They were conducted from 2008 to 2015 through the assistance of contractors or universities, or using in-house expertise.

While the results and experiences included here are drawn from a relatively small sample when considering the breadth of coastal water quality management entities nationwide, they are intended to be a starting point for those considering economic analyses in the future and to provide some lessons learned for the benefit of other coastal managers.

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3. RESULTS AND DISCUSSION

Seven of the eight organizations we interviewed conducted or commissioned studies between 2008 and 2015; two groups had two studies each (Table 1). In general, the economic studies commissioned by the NEPs and watershed organizations were intended to further the understanding of their estuary in terms of one or more of the following perspectives:

1. Economic impacts and contributions to the local economy from the estuary,
2. The economic value (i.e., the maximum amount a person is willing to pay or give up for something) of tradeoffs among management costs, potential changes in water quality and habitat quality and subsequent effects on ecosystem services, or
3. "Total asset value" (i.e., the value of the total stream of benefits provided by a natural system) overviews.

The intended users of the studies were watershed decision makers (policy makers, board members, and managers), other NEP managers and employees, and the broader public. Most studies included more than one of these perspectives. Appendix 1 includes the specific geographic areas, study names, year of publication, and links.

Table 1. Summary of Economic Studies.

Number of estuaries	7
Number of studies	9
Estuaries with 2 studies	2
Year of publication	
2008	1
2011	1
2012	2
2013	1
2014	2
2015	2
Size of watershed (mi^2)	
minimum	19.5
maximum	16,246
mean	3,926
Type of value estimated:	
Economic impacts or contributions	6

Economic values to inform tradeoffs	5
Total asset value based on value per acre	3
Conducted surveys	2
Hedonic property value studies	2
Attempted to value water quality	5
Attempted to value water quality in terms of changes in nitrogen	2

In our review of the coastal economic analyses, six of the nine studies included analysis of economic impacts or economic contributions to the local economy, which measure local or regional economic activity associated with the estuary (Watson et al. 2007). This was evaluated through several different mechanisms, such as spending by tourists or revenues from businesses that are dependent upon the estuary or the natural capital of its watershed. Most of these studies used standard input-output modeling (either IMPLAN or REMI[1]) to capture multiplier, or secondary, effects of spending; two studies selected multipliers from the literature rather than modeling multipliers for their specific locations.

Economic values of tradeoffs (Lipton et al. 1995, Pendleton 2010) were generally evaluated using micro-economic approaches to estimate marginal values—the value of a small, policy-relevant change—of potential changes in water and habitat quality effects on ecosystem services. Five studies applied standard environmental economic approaches for evaluating tradeoffs among various aspects of estuary or watershed environmental quality or ecosystem services. Two studies collected primary data using surveys, and two conducted hedonic analyses; the remainder applied benefit transfers, which use values from existing studies to estimate values in another location or context.

Three of the nine studies conducted broader economic overviews of total asset value, typically measured as dollars per acre for different land cover types, focused on generating an annual value provided by the whole estuarine ecosystem (see, e.g., Liu et al. 2010). In our interviews, we found that some managers were not aware that this approach does not provide values that can be used in benefit-cost analysis, and that such methods are controversial among economists. Yet, managers found

[1] www.implan.com; www.remi.com

that the total asset values resonated with constituents and therefore provided a useful communication tool.

We asked those managers about the economic information they currently need. Because the major pollutant of concern for many coastal ecosystems is nitrogen, all groups participating in this study are working to manage nitrogen in various ways. Nitrogen management, like many coastal issues, is extremely complex, with both point and non-point sources interacting within multiple interconnected natural and human systems (Howarth 2008). There are a number of options for managing nitrogen pollution (U.S. EPA 2011). Determining the best combination of potential management alternatives, given the diversity of nitrogen sources within a watershed, is difficult. All of the options are costly to varying degrees to design and implement. Given the complexity and costliness of managing nitrogen, responses from the coastal watershed managers about using economic analyses primarily focused on nitrogen issues.

Although the managers interviewed stressed the importance of evaluating changes in water quality, particularly those related to nitrogen loading to the estuary, only five of the studies addressed water quality at all and only two of those attempted to value changes in nitrogen. One of the studies that addressed nitrogen used the hedonic valuation method to estimate property value impacts of variations in nitrogen concentrations; the other used an avoided-cost approach to evaluate the nitrogen-removal service of coastal wetlands. Two of the other three studies that attempted to incorporate water quality used benefit transfer methods that did not value specific measurable changes in water quality, and the third used a stated preference survey that also did not value specific measurable changes in water quality.

3.1 Satisfaction with the Research

The interview participants were largely satisfied with the information provided through the economic studies and believed the analyses were useful tools. In particular, they noted the studies were useful for communicating the tangible benefits of the estuaries to the community and economy. The studies were also seen as helpful for improving support of both decision-makers and the public for investments in water quality improvements.

Managers identified the studies as useful in demonstrating that costly management projects were worth investing in because of the economic significance of water resources to the community. One participant said that proponents of water quality and habitat restoration projects used the economic information to increase the wider community's level of comfort with projects, by showing that the projects are not only environmentally, but also economically, important. Another hoped that residents living along tidal creeks would be encouraged to make lifestyle changes that benefit water quality, because the economic data show that improving the environment will pay off.

Economic information demonstrating clean water's contribution to the local economy was used in Florida to introduce new legislation and rank projects based on nitrogen and phosphorous removal. In New England, economic data were used to illustrate the impact of nitrogen on home values, helping the public relate to what might otherwise seem like an abstract problem by providing a concrete and salient example. Elsewhere, the studies have helped facilitate discussions with a broader range of funding partners, spark interest in further economic studies, garner public attention for improving water quality, and encourage behavioral change among watershed residents.

Several participants highlighted the usefulness of simply having a monetary value to point to when discussing the coastal environment. For them, monetary values provided a communication tool by quantifying the value of resources in terms meaningful to those who may not usually consider the benefits of water resources. For example, a participant mentioned that their analysis demonstrated their bay is the economic tax base of the area by showing the expenditures of regional money related to bay resources. The study resulted in increased interest from the business community, many of whom were not engaged in management efforts prior to the release of the findings. The participants also saw these values as useful when applying for grants and other types of funding. Watershed managers found that even studies that used methods that may not be considered appropriate by many economists were still useful as communication tools. They felt that, even if the values themselves are uncertain or not appropriate for benefit-cost analysis, simply having monetized values is helpful.

3.2 Perceived Limitations of Economic Studies

Although the economic studies were generally seen as beneficial for management of their watersheds, participants noted a number of limitations in their usefulness. Thorough economic analyses can be costly (NOAA Coastal Services Center 2009); as a result, the scope of studies was often determined by available funding and by types of expertise that were readily available and affordable, rather than by management priorities. This can lead to a mismatch between the desired economic information and data and what is actually provided by economic studies.

While many of the interview subjects would have liked to be able to do a detailed benefit-cost or cost-effectiveness analysis for specific actions in their watershed, particularly with respect to nitrogen impacts, the necessary economic information and studies were beyond their ability to fund. This does not mean the findings from the studies are not useful or that managers should be discouraged from pursuing the funding of economic studies using available expertise, but rather that an emphasis should be placed on specifying management priorities and identifying relevant economic information before undertaking a study.

As with many other analyses for environmental management (e.g., Koontz and Thomas 2006), data limitations were a real concern for the conduct of economic analyses. A relative dearth in availability of localized economic data or relevant data for benefit transfer limited the methodologies applicable at appropriate geographic scales. For example, one economic impact study was conducted because of the ready availability of data on the local economy. A full economic valuation for benefit-cost analysis, while desired, was not possible because required data were not available within the group's timeframe and budget. While the economic impact study proved useful for communicating the estuary's importance to the local economy, it only presented one piece of the picture and could not support analysis of management options. This is an example of how data and funding limitations influence the type of economic analysis chosen. Those commissioning studies must be careful to appropriately communicate and apply the results of economic studies, bearing in mind the data limitations and the economic analysis method and its limitations.

Interview participants stressed the benefits of, and need for, more localized economic studies to better communicate impacts on a specific geographic area to local decision makers. These studies require locally-appropriate data, both

ecological and economic, that do not always exist or are difficult to compile. One participant mentioned that their program would like to provide results that are more specific to their local communities, to encourage them to invest in environmental projects. They discussed the lack of data at the appropriate scale to support effective targeting of specific groups. For another group, the appropriate data existed but were not readily available. Data were dispersed among multiple sources, requiring an in-depth data collection and organization effort. This indicates a need for a more centralized repository for localized data at a watershed level, as well as more targeted socio-economic data collection. These data limitations are by no means unique to economic analyses in estuaries (see a broad description for limitations in social sciences in Rae and Singleton (2015)), but remain important, as the difficulty of locating and compiling necessary data increases the costs and time spent on analyses.

Uncertainty is often discussed as a limitation in using study results for decision-making (e.g. Young 2001). Although we hypothesized that uncertainty of findings, with regard to precision of the estimated economic values and their applicability to specific locations and context (e.g., benefit transfer errors of various types), would affect the perceived usefulness of the studies, most of the participants indicated otherwise and did not note uncertainty as a major issue. Two participants responded that their studies were not being used at such a localized scale where uncertainty in the form of transfer error would become a major issue. Two other participants responded that the supporting data and methods from their studies were readily available yet they received little comment on them, leading them to believe that stakeholders were not concerned about technical details of the analyses. Because the studies investigated in this research were not intended to be the primary basis to guide specific regulations or decisions, participants found the level of uncertainty to be acceptable or did not note this as a concern. However, one participant did receive criticism of the methods used in its analysis, and therefore felt hesitant to use the results. In that case, uncertainty of estimates did have an influence on the perceived usefulness of the analysis.

Similar to many other types of studies solicited for use in management applications, interview participants stressed that the results of economic studies need to be presented in a more accessible format and through user-friendly applications (see, for example, Landry 2011, Tribbia and Moser 2008, Dabelko 2005 for discussion of this across other fields). For example, participants suggested

that approachable executive summaries for their reports should be provided. This would help the managers as well as interested community members and stakeholders to better understand the implications of the study. Economic studies are often written in a complex academic style that is inaccessible to non-experts, and participants called for the co-production of summaries using plain language to increase the usefulness of the work through accessibility to a wider audience.

3.3 Identified Economic Research Needs

While this work targeted a number of different existing or ongoing economic studies, we also asked participants to identify their most salient unmet economic research needs for management, particularly with regard to nitrogen, in their watersheds. The responses, grouped in Table 2 as questions, identified diverse needs that can be met using a range of economic studies, from relatively basic analyses to projects that would require intense interdisciplinary and outreach work. The identified research questions can be used by research economists seeking to apply their work to ongoing coastal management needs, and the appropriate methods listed can assist managers who are considering commissioning a study to select the most useful approaches.

Each of these questions points to a particular appropriate method or methods (Jewhurst and Mazzotta 2016), which are included in Table 2 under "Question Context." The selection of relevant method(s) will be influenced by the availability of data or the ability to collect new data, the intended use of the results, and the type of question being asked. Relevant economic methods include, but are not limited to:

1) Cost-Effectiveness Analysis: The identification of the least costly way to achieve an already-established goal (Balana et al. 2011).
2) Economic Contribution Analysis: The measurement of the level of economic activity associated with a particular policy, event, or industry for an area (Watson et al. 2007).
3) Economic Impact Analysis: The estimate of money flowing into a region from a specific amenity (e.g., an estuary; Watson et al. 2007).
4) Economic Benefits Analysis (economic valuation): The estimate of the economic value of a resource to individuals, with the individual values often summed to calculate a societal benefit (Lipton et al. 1995).

5) Benefit-cost Analysis: A multi-step analysis that evaluates the value of the difference between a defined baseline condition and an expected condition after a management action, comparing total benefits to total costs (Barbier et al. 2011).

Collectively, these questions show a broad need for economic analyses and collaboration between watershed managers and economists in method selection and presentation of results in appropriate ways.

3.4 Best Practices for Applied Economic Research

Although interview participants were largely satisfied with the economic analyses, and study results were widely seen as effective communication tools, in practice, because of data and funding limitations and the complexity of management issues, options for economic analysis will often be limited. When conducting economic studies, managers should work with trained economists to identify appropriate methods, implement the research properly, and apply and communicate the results correctly.

Given the practical realities, particular care should be taken to use the results of feasible economic analyses only within the context for which the original study was intended and to avoid extrapolating the results beyond the appropriate context. For example, generalizing the values from a single site-specific economic study to overall values for society, or using economic impacts in benefit-cost analysis, while tempting, is generally not an appropriate use of the findings. The inappropriate use of study results is one of the common concerns in the application of "total asset value" studies that attempt to estimate the total flow of ecosystem services from a system to quantify the value of the ecosystem. Although some of the managers we spoke with have used results of "total asset value" studies and found them to be effective communication tools for demonstrating the potential magnitude of economic value of seemingly abstract assets, conventional economic practices would not generally recommend this approach (Plummer 2009, Bockstael et al. 2000, Toman 1998).

Table 2. Identified Research Questions.

These questions were identified by interview participants as salient economic research questions for managing nitrogen within their estuaries.

Identified Economic Research Questions for Water Quality and Nitrogen Management	
Question	**Question Context**
How do we use economic information as a communication tool to illustrate the importance of water quality improvements to a wider audience?	This is a broad question, asked by many managers. It does not directly lead to any one type of analysis.
How do we impress upon the local community the tangible economic values related to water quality, in the form of money circulating through the community?	This question would be addressed using economic impact or economic contribution analysis.
How do we link the benefits of water quality improvements to business revenues, jobs, and other measures that resonate with residents, the business community, and broader stakeholder groups?	This question focuses on money flowing through the local economy, and would be addressed using either economic impact analysis or economic contribution analysis.
What is the cost per pound of nitrogen removed for a given management practice?	This question must be answered to perform either cost-effectiveness or cost-benefit analysis. It requires coordination among economists, nitrogen modelers, engineers, and other technical experts.
What is the most cost-effective way to implement nitrogen management practices in order to meet a total maximum daily load (TMDL) or another predetermined endpoint?	This question would be addressed through the methods of cost-effectiveness analysis.
Using decision support tools, how can we convert environmental and cost-effectiveness data into actionable information for decision makers and the public?	This question addresses how to best apply the results of cost-effectiveness analysis.
How do we evaluate the social benefits of protecting water quality in the community in a way that can be compared to other social programs or actions?	This question would be addressed using economic benefits analysis.
What are the benefits of nitrogen management and the associated environmental improvement, compared to the costs of implementing nitrogen management practices? If we spend a given number of dollars for a given level of treatment, what is the return on investment and increase in benefits to society?	These questions are two different ways of framing the benefit-cost question. To answer these questions, a full benefit-cost analysis is required.

Several managers expressed a desire for benefit-cost analysis in particular, but evaluating the complete suite of economic benefits and costs for systems as complex as estuaries is extremely challenging, time consuming, and expensive (NOAA Coastal Services Center 2009), and none of the groups interviewed had attempted a benefit-cost or even a cost-effectiveness study. Many of the benefits and costs cannot be easily quantified, as it is difficult to determine society's willingness to pay for many ecosystem services and estimates of costs per unit of nitrogen removed are often highly uncertain. In many instances, methods that rely on the logic of economics but do not monetize benefits may be as effective as full benefit-cost analysis for demonstrating that estuaries provide important services. For example, even the simple identification of benefits streams, or the use of non-monetary benefit indicators that focus qualitatively on who benefits and by how much, can demonstrate an estuary's assets and positive impact for society (Mazzotta et al. 2016, Schuster and Doerr 2015). These types of analyses are simpler to apply than attempts to monetize all of the benefits and costs for a full-scale analysis, but can still provide valuable insights about the benefits of estuaries.

Given the limitations of data availability and accepted methodology, an economic analysis may not show net economic gains to a community despite the ecological or social significance of affected resources. This may be because economic benefits are small relative to costs; but may often result from the inability to accurately measure the changes in valued endpoints that result from a specific, and sometimes very small, change in conditions. Solutions to environmental problems can be extremely costly in terms of infrastructure, monitoring, enforcement, and more. While costs are often relatively easy to measure, particularly if they involve installation and maintenance of technological solutions, benefits can be difficult to predict and measure, both from the biophysical side and in terms of economic values (Bruins et al. 2017, Iovanna and Griffiths 2006, Kline et al. 2013).

Most of the interview participants noted that they lacked the ecological data, such as the environmental response that would result from a given amount of pollution reduction, and studies needed to quantify benefits of nitrogen management. Many key ecosystem services have not been valued reliably in any context or values may vary spatially or temporally in ways that are difficult to capture for a given study (Barbier et al. 2011, Compton et al 2011, Turner et al. 2000). As a result, benefits are often quantified based on a limited number of use

values (value derived from actual use through commercial or recreational activities or other direct interactions with the estuary), excluding many other cultural and nonuse values (e.g., values people place on a component of the estuary that they may never use).

4. CONCLUSIONS

Existing and ongoing economic studies are seen by estuary and watershed managers as useful tools for improving nitrogen management and other water quality impairments in their complex ecosystems. Studies have been used by managers to support management decisions, facilitate communication, and engage with more diverse stakeholders. While past studies have been received positively and have proven useful, some of the methods used, or applications of methods, were not fully consistent with the best practices in economics. Others did not address some of the most pressing questions posed by managers. Environmental economics is a complicated field that requires detailed information about the affected communities and ecosystems, and future studies need to be developed, conducted, and applied with fastidious attention by experts, based on clearly-expressed needs of managers. The use of economic analyses in watershed management also necessitates effective communication of approaches and findings that are accessible to practitioners who may not have any economic background. Interview participants identified a number of management questions that would greatly benefit from economic analyses. It is important for managers and researchers to work collaboratively to improve the usefulness of their investigations.

APPENDIX 1: REPORTS EXAMINED

Geographic Area	Authors	Year	Title	URL
Barnegat Bay Watershed	Kauffman, G.J., and Cruz-Ortiz, C.	2012	Economic Value of Barnegat Bay Watershed	http://www.ipa.udel.edu/publications/BarnegatBay_report.pdf
Delaware Estuary Watershed	Kauffman, G.J., Homsey, A., Chatterson, S., McVay, E., and Mack, S.	2011	Economic Value of the Delaware Estuary Watershed	http://dspace.udel.edu/bitstream/handle/19716/9773/DelEstuaryValueReport.pdf?sequence=1
Indian River Lagoon and tributaries; 5 counties surrounding the lagoon	Hazen and Sawyer, P.C.	2008	Indian River Lagoon Economic Assessment and Analysis Update	https://onelagoon.net/wp-content/uploads/irl_economic_assessment_2007.pdf
Long Island Sound Basin	Kocian, M., Fletcher, A., Schundler, G., Batker, D., Schwartz, A., Briceno, T.	2015	The Trillion Dollar Asset: The Economic Value of the Long Island Sound Basin	http://www.eartheconomics.org/publications-archive/
Sarasota Bay Estuary and adjacent barrier islands	Hindsley, P.R., Debure, K.R., and Morgan, O.A.	2012	The Sarasota Bay Economic Valuation Project: Phase I	https://sarasotabay.org/wp-content/uploads/2012-09-SarasotaBay_ValuationP1.pdf
Sarasota Bay Estuary and adjacent barrier islands	Hindsley, P.R., and Morgan, O.A.	2014	The Sarasota Bay Economic Valuation Project: Phase II	https://sarasotabay.org/wp-content/uploads/SBEP_SarasotaBay_EconomicValuation_PhaseII.pdf

Geographic Area	Authors	Year	Title	URL
Tampa Bay and Watershed	Tampa Bay Estuary Program and Tampa Bay Regional Planning Council	2014	Economic Valuation of Tampa Bay	http://www.tbrpc.org/eap/pdfs/Economic_Valuation_of_Tampa_Bay_Estuary_July2014.pdf
Tampa Bay and Watershed	Russell, M. and Greening, H.	2013	Estimating Benefits in a Recovering Estuary: Tampa Bay, Florida	https://link.springer.com/article/10.1007%2Fs12237-013-9662-8
Three Bays Watershed, Barnstable, MA	Ramachandran, M.	2015	Water Quality and Cape Cod's Economic Future: Nitrogen Pollution's Economic Impact on Homes and Communities: An analysis of the effect of impaired water quality due to nitrogen pollution on Cape Cod's housing market	http://www.capecodcommission.org/3bays/assets/three_bays_study_full_report.pdf

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