Ecosystem services impacts associated with environmental reactive nitrogen release in the United States

Jana E. Compton[1], Daniel J. Sobota[2], Jiajia Lin[3], and Mario Sengco[4]

[1]U.S. EPA Office of Research and Development, Western Ecology Division, Corvallis OR 97333
[2] Environmental Solutions Division, Oregon Department of Environmental Quality, 811 SW 6th Avenue, Portland OR
[3] National Research Council, National Academies of Science, Washington DC 20001, based at US EPA Western Ecology Division
[4] U.S. EPA Office of Water, Office of Science and Technology, Washington DC 20460

Abstract

Nitrogen (N) release to the environment from human activities can have important and costly impacts on human health, recreation, transportation, fisheries, and ecosystem health. Recent efforts to quantify these damage costs have identified annual damages associated with reactive N release to the EU and US in the hundreds of billions of US dollars (USD). The general approach used to estimate these damages associated with reactive N are derived from a variety of methods to estimate economic damages, for example, impacts to human respiratory health in terms of hospital visits and mortality, willingness to pay to improve a water body and costs to replace or treat drinking water systems affected by nitrate or cyanotoxin contamination. These values are then extrapolated to other areas to develop the damage cost estimates that are probably best seen as potential damage costs, particularly for aquatic ecosystems. We seek to provide an additional verification of these potential damages using data assembled by the US EPA for case studies of measured costs of nutrient impacts across the US from 2000-2012. We compare the spatial distribution and the magnitude of these costs with the spatial distribution and magnitude of costs from HUC8 watershed units across the US by Sobota et al. (2015). We anticipate that this analysis will provide a ground truthing of existing damage cost estimates, and continue to support the incorporation of cost and benefit information into communication, outreach, and decision-making related to nutrient pollution.

Key Words
Ecosystem services, air quality, water quality, drinking water, treatment costs, human health

Introduction

Recent assessments of the costs and benefits of reactive N uses illustrate substantial impacts of N release to the environment on human health, recreation, tourism, fisheries and property values. The EU N assessment estimated that the annual costs of N release range from $97-625 billion USD (van Grinsven et al. 2013), and a similar range of values were estimated for the conterminous US ($81-441 billion USD; Sobota et al. 2015). These assessments connect the magnitude of N release from different sources, and tied these to specific estimates of damages associated with different forms and media by using the common metric of $\$ \text{ kg}^{-1}$ N. However, these approaches are best viewed as estimating the potential damages from nutrients because for many of the damages, in particular the aquatic damages, since they generally extrapolate cost functions developed for one area across a larger area. We use information presented in a recent EPA report that assembled data on the documented costs associated with nutrient pollution in the US (US EPA 2015), and compare these actual costs with the potential costs estimated for HUC8 watersheds across the US by Sobota et al. (2015). This ground truthing of the cost data with actual measured costs for damages will allow us to compare these results spatially and allow us to determine whether hot spots for potential damages line up with the actual damages quantified in the EPA report. Decision makers use cost benefit analyses to evaluate the impacts of alternative policy choices and decisions, and improving the information base that contributes to these analyses can better inform the decision-making process.

Methods

Estimation of potential and actual damages
Potential damages were estimated using the approach of Birch et al. (2010) and van Grinsven et al. (2013), which connects specific forms of N to the damage costs associated with that N form in a particular setting. Every form has a \$ kg^{-1} N associated with it. Some of these per unit N damage costs are widely applicable. For example, the exposure-based impacts of N-derived ozone or particulates on human respiratory health impacts such as mortality, morbidity and lost work, are generally similar across the US. In contrast, N effects on streams, lakes and coastal ecosystems are not the same across the US, and depend upon local factors and climate drivers in addition to N inputs.

Comparison of potential and actual damages
Data on the actual costs of nutrients to freshwater and coastal ecosystems as well as drinking water systems is largely based on a recent EPA report that assembled data on the documented costs associated with nutrient pollution in the US from 2000 through 2012 (US EPA 2015). The EPA report presents data on the external costs associated related to nutrient impacts as well as the costs associated with reducing nutrient release (Table 1). Each of the place-based examples of external costs will be assigned to a given HUC8 watershed, and then we compare the value of these actual costs with the potential costs estimated for HUC8 watersheds across the US by Sobota et al. (2015; Figure 1). This ground verification of the cost data with actual measured costs for damages will allow us to compare these results spatially and allow us to determine whether hot spots for potential damages line up with the actual damages quantified in the EPA report.

Table 1. Sectors and types of impacts used for economic cost data.

Sector	Economic Impact
Tourism-related Industries	Lost revenue
Commercial Fisheries	Lost revenue
Households	Decreased property value
	Cost of illness
Other Industry	Increased operational costs
Municipalities	Increased cost of drinking water treatment

Results

Excess nutrient loading to freshwater and coastal ecosystems can cause algal blooms, decreased water clarity, low dissolved oxygen levels, accumulation of cyanotoxins in shellfish, and odor, taste, cyanotoxin and nitrate contamination of drinking water supplies. Often algal blooms are driven by phosphorus as well, although we do not include phosphorus in this initial analysis. The consequences of excess nutrient loading are seen as reduced revenues in tourism, recreation, and fishing, human health issues, increased water treatment costs and other impacts (Table 1). For example algal blooms in an Ohio lake caused \$37-\$47 million in damages due to lost tourism revenues in the local area over two years. The city of Toledo, OH, lost their main water supply for several days due to contamination with cyanotoxins due to harmful algal blooms, and the cities of Columbus, OH, and Des Moines, IA, regularly require expensive treatment of their intake water because of nitrate contamination above the US EPA drinking water maximum contaminant level of 10 mg nitrate-N L^{-1}. For Des Moines, the costs are greater than \$1 million per year and those costs are passed on to the customers of the drinking water supply system. Drinking water contamination with nitrate in California's Central Valley is a very substantial problem, and scientists are only beginning to quantify the damages associated with treatment costs and human health impacts. Potential estimates of freshwater damage costs are high in Ohio, around the

Great Lakes, Chesapeake Bay, the upper Midwest, and California's Central Valley, which suggests a strong spatial correlation between the potential and actual damage costs. The magnitude of the actual, measured damages does not appear to be as large as the potential estimates, but a more complete analysis of the data, including gaps, is needed to fully address this relationship.

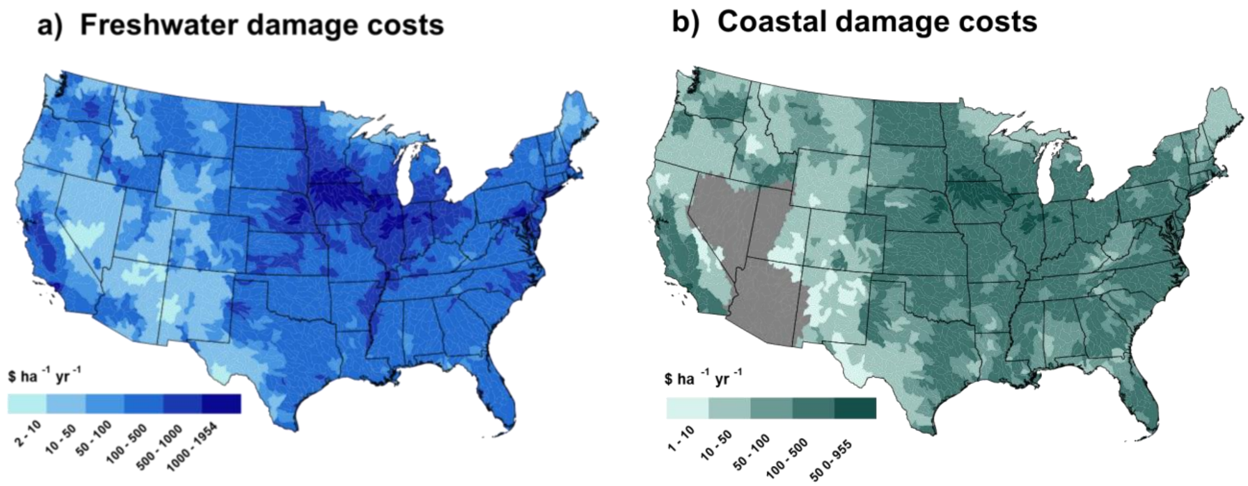

Figure 1. Distribution of potential damage costs to a) freshwater and b) coastal ecosystems in the conterminous United States caused by anthropogenic N leaked to the environment from a given HUC8-scale watershed unit, early 2000s. Grey areas do not drain to the coast. (from Sobota et al. 2015)

Summary

This comparison of potential and actual costs will allow us to assign ground truthed values based on the actual measured damages associated with nutrient releases to the environment. We also plan to refine our estimates of the damage costs to N in the US in a new way. Currently, we are at the stage of tracking newspaper articles and anecdotal evidence, with limited publications on this topic. Ideally, there would be a national tracking system for algal blooms and drinking water systems that would gather and store this type of information so that we can periodically assess the effects of nutrients on the economy. We will address this topic and highlight some of the important data needs that such a tracking system might provide.

References

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