A Method for Economic Valuation of Nutrient Monitoring

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Introduction

One of the potential economic benefits of water quality monitoring is a reduction in pollution control costs achieved through greater certainty about the success of pollution controls in improving water quality. Increased monitoring leads to measurably smaller errors in water quality model predictions which, in time, reduces the "margin-of-safety" required of pollution control programs to meet water quality goals with a desired level of reliability.

Nutrient trading programs account for uncertainty in the effects of controls by imposing a trading ratio on purchasers of pollution credits to cover the risk of not meeting water quality goals. Currently, uncertainty ratios in nutrient trading range from 2:1 to 5:1 (Ribaudo and Gottlieb, 2011), implying low confidence in the ability of models to predict the effects of reducing nutrient sources in watersheds. Increased monitoring could significantly increase confidence in such models and effectively lower the cost of pollution control.

In this modeling study, we attempt to quantify the potential value of increased monitoring by estimating its effects on the marginal cost of control programs designed to reduce the export of reactive nitrogen (N_R) from US watersheds with a specified reliability level.

Procedure

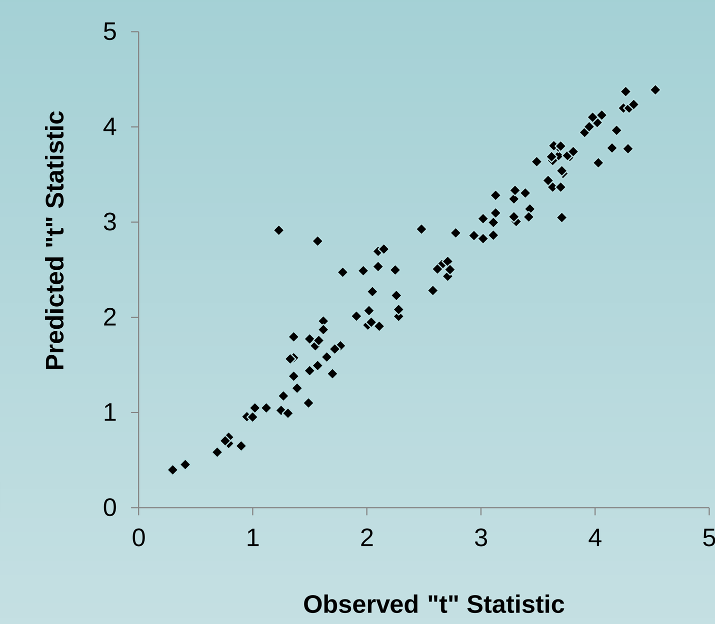
1. Randomly select "networks" of from 50 to 350 monitoring stations from a national database of 379 stations.
2. Recalibrate a national SPARROW N_R model (Alexander, et al, 2000) for each network of stations.
3. Regress the fertilizer-nitrogen "t" statistics from the calibrated models on the number of monitoring stations used in a calibration and the calibrated fertilizer-nitrogen coefficient (see results in Figure 1).
4. Based on the mean fertilizer-nitrogen coefficient, the predicted "t" statistic, and the standard "t" distribution, determine the lower 10th-percentile coefficient value for each calibrated model. The 10th-percentile coefficient indicates the estimated minimum (90-percent confidence) amount of reduction in watershed N_R export that would result from a unit reduction in fertilizer-nitrogen input.
5. Based on the average marginal cost of cropland nitrogen control ($4.00 per kg; Chesapeake Bay Program Office, 2003) and the 10th-percentile coefficient value, determine the marginal cost of reducing watershed N_R export by 1 kg with 90% confidence. Plot marginal cost against number of stations (Figure 2).
6. Determine the marginal value of adding a station to a network from the slope of the marginal cost curve developed in step 5. Plot marginal value against number of stations (Figure 3).
7. Estimate the total value of an additional station for a set of representative US river basins by multiplying the marginal value of a station by a "desired" level of water quality improvement. Assume a baseline network of 379 stations (the national database used in this study).

Results

Predicting Coefficient Error from Number of Monitoring Stations

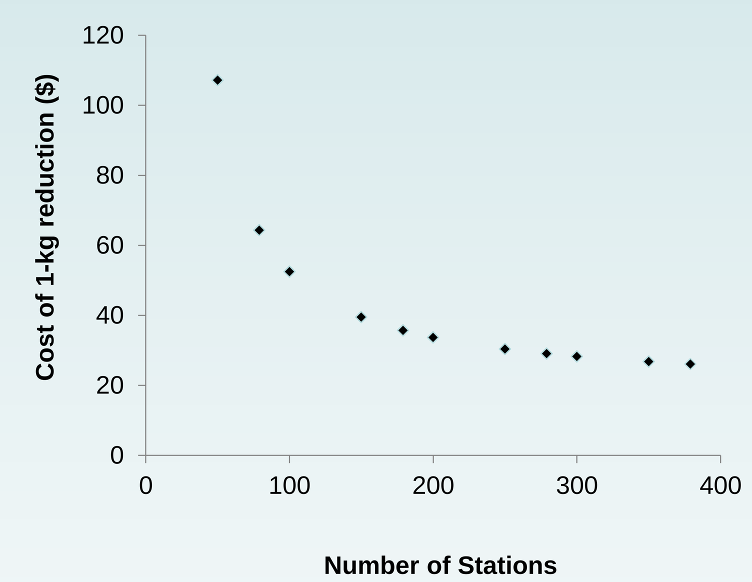
Figure 1 Regression results: Predicted vs observed "t" statistics for the fertilizer-nitrogen coefficient in 131 SPARROW models. The SPARROW models were calibrated with varying numbers of monitoring records randomly drawn from a national network of 379 stations. Equation:

Predicted "t" = - 0.032 + 0.0086 [no. stations] + 5.31 [mean coeff.]
R-square = 0.92



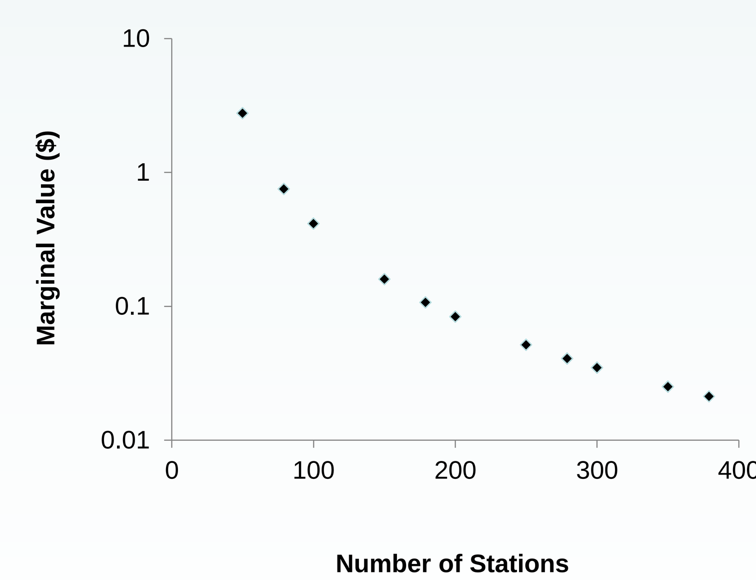
Marginal Cost of 90%-Certain Nutrient Controls

Figure 2. Marginal cost of reducing watershed nitrogen export by 1 kg with 90% confidence *vs.* number of monitoring records used to calibrate a SPARROW model used to predict the effects of cropland nitrogen control. The curve shows how the predicted cost of achieving high reliability in a control program decreases with an increase in the amount of monitoring data that is available for watershed model calibration.



Marginal Value of a Monitoring Station Due to Reduced Model Error

Figure 3. Estimated marginal value of an additional monitoring station (i.e. slope of the curve in Figure 2) *vs.* number of monitoring stations. The marginal value of an additional monitoring station decreases to less than $0.10 per kg of reduction in watershed nitrogen export when the number of monitoring station records exceeds about 200.



Application

Total Value of an Added Station in Representative River Basins

Basin	Cropland Nitrogen Input (10^6 kg/yr)	Assumed Nitrogen Reduction (%)	Value of Additional Monitoring Station (per year)
Neuse River (NC)	29.1	40	$50,500
Potomac River (MD)	29.9	40	$51,900
Brazos River (TX)	173	40	$300,300
Willamette River (OR)	415	40	$720,400

Table 1. Estimated total value of a monitoring station in four US river basins. The estimates assume a water quality goal of reducing watershed nitrogen export by 40 %, and a baseline monitoring network of 379 stations (the number used for this study). Estimates of total value are determined by multiplying the marginal value in Figure 3 by the desired reduction in watershed nitrogen export in kg/year. The marginal value of a station in a 379-station network is $0.021 per kg N_R exported.

Conclusions

1. One of the potential economic benefits of water quality monitoring is a reduction in pollution control costs achieved through greater certainty about the success of pollution controls in improving water quality.
2. The accuracy of model predictions of the effects of nutrient reduction on watershed N_R export is highly correlated with the number of monitoring station records available for calibrating the model.
3. The total estimated value of an additional monitoring station in the four basins examined here ranges from about $50K per year to more than $700K per year, about 0.05% of the total cost of reducing N_R export in those basins by 40%.

References

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