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Evaluating the effectiveness of restored wetlands for reducing nutrient losses from agricultural watersheds

Abstract: Scientists examined the effectiveness of recent wetland restorations and land use conversions (set-asides) for reducing nutrients in agricultural runoff into the Iowa Great Lakes.

Question & Answer

Q: What are the results when scientists monitor nutrient concentrations in the inputs and outputs of restored wetlands and also monitor nutrient concentrations in the outflows of sub-watersheds differing in number of restored wetlands and acreage in set-aside programs?

A: Although 278 wetlands have been restored, runoff from only 20 percent of the upland areas in the Iowa Great Lakes watershed passes through these wetlands before it reaches the lakes. Wetland restorations were concentrated in areas that are no longer cultivated and consequently, most restored wetlands do not receive agricultural runoff. Where they do, restored wetlands were effective sinks for total nitrogen (TN), but their effectiveness as sinks for total phosphorous (TP) is less clear. Although the vegetation of restored wetlands is not as abundant as that in natural wetlands, this does not seem to affect their nutrient removal capacities. Concentrations of total nitrogen in outflows from sub-watersheds with the highest number of restored wetlands and most land in set-aside programs were significantly lower than from those that were mostly crop fields. Total phosphorus concentrations in outflows, however, were highly variable, and more detailed studies are needed to determine how effective restored wetlands and set-aside programs are for reducing phosphorus in outflows.

Background

Reduction of nonpoint source pollution due to agricultural runoff in lakes and rivers will require a combination of on-field best management practices and off-field modifications in land use such as buffer strips, grassed waterways, and wetlands. In the Upper Midwest, strategically placed wetlands with their denitrification capacity seem to be the simplest and cheapest means of removing nitrates from drainage water.

Yet, water quality data from the Iowa Great Lakes indicate that concentrations of nutrients in these lakes have not declined as a result of the restoration of hundreds of wetlands in the watershed. The project focused on learning why the restoration of wetlands has not lowered the nutrient content in the region. Two possible reasons considered in this study are that restored wetlands may not yet have the nutrient removal capacity of natural wetlands or the restored wetlands may not intercept sufficient nutrient to significantly impact overall nutrient inputs to the lakes. Another reason (not covered in this study) may be that the wetlands are not been located in places where they can intercept runoff adequately.

The specific objectives of the study were to:

1. Determine the number, location, and size of restored wetlands in the Iowa Great Lakes Watershed;
2. Determine the composition, abundance, and distribution of the vegetation and biomass of living and dead vegetation in selected restored wetlands;

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3. Estimate the nutrient removal capacity of selected restored wetlands by measuring nutrient input and output concentrations; and
4. Measure the nutrient losses from sub-watersheds primarily in row crops with and without restored wetlands.

Approach and methods

In the summer of 2000, all restored wetlands in the agriculture-dominated sub-watersheds of the Iowa Great Lakes Watershed (IGLW) were evaluated as potential study sites. Using information from the Natural Resources Conservation Service (NRCS), the investigators selected sub-watersheds with suitable restored wetlands and without restored wetlands. Only sub-watersheds with a single surface outlet were used in this study.

Agricultural runoff into these restored wetlands comes from drainage tiles that have been diverted into them. Likewise, the only surface outlet of water from these restored wetlands is a standpipe or dam spillway that allows water to flow back into the drainage tile systems when water levels reach a certain point. Standard methods were used to collect and analyze water samples at weekly intervals when there was flow. Testing was conducted for total phosphorus (P) and nitrogen (N) content.

The vegetation and litter compartments of each restored wetland were sampled using standard techniques in 2001 and 2002. Each restored wetland was divided into 10 zones. Randomly placed quadrants in each zone were sampled in either late July or early August. The abundance of each plant species in each quadrant was estimated using a cover-abundance scale. Plant material from each quadrant was harvested and weighed.

Results and discussion

Restored wetland inventory. Digitized land-use and topographic maps of the watershed were used to collect data on the location, area, and catchment size of each restored wetland. For the most part, the restored wetlands were found in clusters or complexes on large tracts of public land managed by the Iowa Department of Natural Resources. Most are on row cropland that has been converted to perennial grassland and the total area covered by these restored wetlands is only 360 ha. Consequently, most of these wetlands do not intercept significant amounts of agricultural runoff.

Vegetation of restored wetlands. Five restored wetlands were selected for monitoring and detailed sampling of their vegetation. Finding suitable wetlands whose nutrient inputs and outputs could be monitored proved difficult. Only about 30 of the 278 sites examined were deemed to have potential as study sites and five that could be most reliably sampled were selected. Sampling of vegetation and standing crop began in summer 2001. In general, the five sites had similar vegetation that was dominated by a small number of common wetland species. Four of the five wetlands were dominated by reed canarygrass and cattail. The fifth wetland, which was a damned-up stream and deeper than the other sites, was dominated by pondweeds. The vegetation on the five selected sites was not as dense or species rich as that found around comparable existing prairie potholes in northwest Iowa.

Restored wetland nutrient inputs and outputs. All of the water samples collected from the wetlands were analyzed for total nitrogen (TN) and total phosphorus (TP). The overall mean input concentration of TN for all five wetlands over both years was 19.0 mg/l, while the mean annual output concentration was 2.93 mg/l, which is an 85 percent mean reduction in TN concentration. However, wetland catchments were too small and flows were too low and variable to estimate nutrient mass loadings or inputs to the wetlands. Consequently, it was not possible to make reliable estimates of mass reductions of phosphorus by these wetlands during the study period. (Mass reduction, i.e., the total amount (mass) of a nutrient retained is the only reliable well to determine how effective a wetland or other body of water is at removing a given nutrient.) It was clear that all five wetlands reduced TN mass significantly over both years, although it is not clear whether they significantly affected TP mass. The overall mean TP concentration in the inputs of these five restored wetlands was 0.189 mg/l and the overall mean concentration in the outputs was 0.108 mg/l. However, inflow and outflow TP concentrations were too variable to draw any conclusions regarding mass reductions. There was no correlation between nutrient reduction and either living or dead biomass.

Sub-watershed nutrient outputs. In 2000, 2001, and 2002, grab samples were collected at outflows from 10 selected sub-watersheds, differing in predominant land use and in extent of restored wetlands. All samples were analyzed for total nitrogen (TN) and total phosphorus (TP). Nitrate concentrations were related closely to sub-watershed land use, being highest in sub-watersheds that were predominately cropland and falling to near detection limits in sub-watersheds with extensive wetland restoration and set-aside. In general, concentrations of TN were lower in outflows from sub-watersheds with extensive wetland restoration and conversion of cropland to set-aside. However, the relative contribution of wetland restoration and set-aside programs is obscured by the correlation of these land use changes. Sub-watersheds with extensive wetland restoration tended to have extensive cropland conversion.

TP concentrations displayed more short-term variability than TN concentrations, and were less clearly related to sub-watershed land use. A comparison of long-term patterns in TP concentrations illustrates considerable overlap in TP concentrations across sub-watersheds with land use ranging from extensive cropland (40) through intermediate amounts of cropland (48) to no significant cropland (47). Sub-watersheds with extensive set-aside and restored wetlands did not have consistently lower TP concentrations in their outflows than those consisting predominantly of row crops and without restored wetlands.

Although TN concentration varies significantly in outflows from one sub-watershed to another, as expected, restored wetlands and land set-aside programs are effective in reducing nitrate losses from sub-watersheds. For TP, thought to be the major nutrient responsible for algal blooms in most lakes, the outcome is less clear. The results from the sub-watershed studies parallel those from the restored wetland studies. In both cases, TN concentrations are reduced consistently while TP levels vary much more, both spatially and temporally.

Conclusions

Although nearly 280 wetlands have been restored in Iowa's Great Lakes Watershed, these wetlands intercept runoff from about 20 percent of the uplands in the watershed. For TN (assuming 75 percent removal efficiency), this suggests that nitrogen inputs to the Great Lakes would have been reduced by less than 1 percent. For TP (assuming 50 percent removal efficiency), they would be reduced less than 10 percent. Consequently, it is not surprising that nutrient concentrations in the Iowa Great Lakes have not begun to decline. When all sources of nutrients (dry fallout, wet fallout, internal loadings, urban runoff, etc.) are taken into consideration, the effects of current wetland and upland restorations on reducing nutrient levels in the lakes remain too small to be detectable.

Impact of results

These results indicate that improvement of water quality by using wetland and set-aside programs may be more complex than was previously thought, especially for phosphorus. However, this study was done during a drought when there was very little flow. Studies such as this one need to be extended to cover periods of normal and above normal flow. The data for phosphorus indicate that continuous sampling of storm events is needed to obtain realistic estimates of phosphorus in outputs from sub-watersheds. To gain better phosphorus data, automatic samplers were deployed in a series of sub-watersheds during the last year of the study. Regrettably, the lack of flow during this study period made it impossible to collect much data with these samplers. Although the effectiveness of nitrogen removal in agricultural runoff could be increased by improved siting of restored wetlands, it is unclear whether this would significantly improve phosphorus removal.

Education and outreach

A presentation on some of the preliminary results from the study was made at the Midwest Limnology Conference. A thesis and additional papers are being written now that the research has been completed.

For more information, contact
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