NUTRIENT CONCENTRATION GRADIENTS AND BIOLOGICAL RESPONSE IN CENTRAL NEBRASKA STREAMS

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ABSTRACT: Nutrients and excessive algal productivity are leading causes of water-quality degradation in streams and rivers draining agricultural regions. Federal guidance for establishing regional nutrient criteria are being developed for use in stream eutrophication monitoring and management programs. The development of nutrient criteria will be aided by a national study the U.S. Geological Survey is conducting to document how biological communities and stream metabolism respond to a gradient of nutrient conditions among streams draining agricultural areas or land uses. The primary objectives of this study are to determine (1) relations between nutrients and biological community structure, (2) relations between nutrients and stream metabolism, and (3) how these relations vary within and between different environmental settings across the United States. Sixty candidate stream reaches in central Nebraska were selected using digital map data for streams, basin-landscape features, and estimated nutrient inputs derived from county-level fertilizer sales, atmospheric deposition, and livestock data. A field reconnaissance of the streams was conducted during summer 2002 to define an expected range of nitrate and orthophosphate concentrations during low-flow conditions. Although agricultural production in the region is uniformly intensive, nitrate concentrations during the stream reconnaissance ranged from <0.1 to 6.2 mg/L as nitrogen and orthophosphate concentrations ranged from <0.02 to 6.3 mg/L as orthophosphate. During summer 2003, water chemistry, stream and riparian habitat, algal and macroinvertebrate communities, and stream metabolism will be sampled at 28 streams in central Nebraska, as well as in other agricultural regions of the United States.
KEY TERMS: nutrients; streams; productivity; aquatic communities; eutrophication; Nebraska

INTRODUCTION

Since 1991, scientists with the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program have been collecting and analyzing data in more than 50 major river basins and aquifers across the Nation with the goal of developing consistent and comparable long-term information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions (Gilliom and others, 2001). In 2001, the NAWQA Program began its second cycle of assessments by returning to 14 of the river basins and aquifer systems to build on initial assessments and increase the understanding of long-term trends and factors affecting water quality. During this decade of assessments, an increased focus will be placed on understanding the key processes that control water-quality conditions and the potential effects of contaminants and other disturbances on humans and aquatic ecosystems through topical studies (Gilliom and others, 2001). Among the national priority issues identified for study for the program is understanding the effects of nutrient enrichment on stream ecological systems.

Although eutrophication has long been identified as an important water-quality issue, the U.S. Environmental Protection Agency (EPA) has focused recently on developing regional nutrient criteria, with the goal of reducing and preventing eutrophication nationally as required by the Clean Water Act (U.S. Environmental Protection Agency, 2001). In response to the recently increased interest in the effects of nutrient enrichment, several NAWQA study units most affected by nutrient enrichment will address the key question for this topical study: How do biological communities and associated processes respond to varying levels of nutrient enrichment among agricultural streams in different environmental settings (Gilliom and others, 2001)? To answer this question, streams from contrasting agricultural settings in the Nation across a range of nutrient conditions will be studied. The scope of the study includes water chemistry, stream and riparian habitat, algal and macroinvertebrate communities, and stream metabolism, with sampling beginning in the summer of 2003. To confirm the presence of nutrient concentration gradients in each of the initial agricultural settings to be studied, field reconnaissance of candidate sites was conducted in 2002. This paper describes the methods used to identify the independent candidate streams, the agricultural settings of interest, and theoretical gradient in nutrient inputs to the basins in the settings. It also describes the reconnaissance activities, and presents the preliminary results from the reconnaissance nutrient sampling conducted in the Central Nebraska Basins (CNBR) study unit.

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STUDY AREA

The nutrient enrichment topical study currently involves five NAWQA study units selected to represent contrasting agricultural settings. The location of the selected study units (Figure 1) makes it possible to compare by region (arid west; semi-humid Midwest; and humid east), as well as nationally and by study unit. The CNBR study unit includes the area drained by the Platte River downstream of the confluence of the North and South Platte River channels near North Platte, Nebraska (Figure 1). This roughly 78,000-km^2 study area includes the Loup, Cedar, and Elkhorn River drainages.

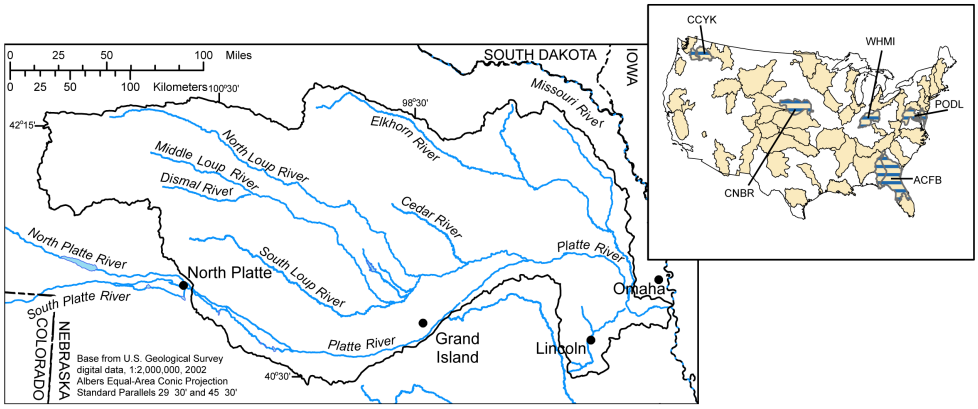

Figure 1. Location of the Central Nebraska Basins study unit and other National Water-Quality Assessment study units participating in the nutrient enrichment topical study.

SITE SELECTION METHODS

Given the distribution of study units across the Nation, consistent methods for selecting sampling sites were necessary to reduce variability in characteristics such as stream size, discharge rates, and stream habitat. National datasets were used to identify nutrient ecoregions and candidate stream reaches, and to estimate nutrient inputs.

Elevation Derivatives for National Applications (EDNA) data, generated as a result of an interagency effort to develop a hydrologically correct version of the National Elevation Dataset, were used to delineate stream basins and reaches. An EDNA database was prepared for each study unit that included basin and reach coverages, and a series of variables identified as useful for site selection. These variables include: soil characteristics, potential evapotranspiration, hydrologic landscape region, basin elevation, base-flow index, precipitation, land use, ecoregion, and estimated nutrient inputs. National-scale analysis of the NAWQA data has demonstrated that nitrogen loading to the land surface was significantly related to nitrogen yields to streams (Fuhrer and others, 1999) and possibly could be used as a surrogate for nutrient concentration in streams with sparse water-quality data. The nutrient input estimates used during this analysis were derived from county-level fertilizer sales, atmospheric deposition, and livestock data.

Because recent data indicates that small streams and rivers are most effective in nitrogen processing, transformation, and retention (Alexander and others, 2000; Peterson and others 2001), the selection of candidate sites was focused on small streams. Although streamflow data would be a more accurate indicator of stream size, such data were not available for the majority of the candidate sites. As a surrogate for streamflow data, the area of each drainage basin was used to stratify sites by size, with basins initially limited to areas between 100 and 400 km^2. In the CNBR study unit, the size range of the candidate basins was expanded to 2,500 km^2 because many small streams were dry as a result of drought conditions in 2002.

Recognizing that nutrient levels leading to eutrophication vary regionally because of geographical variations in geology, climate, and soil types (U.S. Environmental Protection Agency, 2001), the EPA is using aggregations of Level III ecoregions to define regional nutrient criteria (nutrient ecoregions). Although some studies have indicated ecoregions may not adequately describe the variability in some water-quality constituents, especially in reference conditions (Robertson and others, 2001), this scheme may still be valid to examine the range in responses of biological communities to different nutrient conditions, and the NAWQA nutrient-enrichment study will use nutrient ecoregions as its primary regionalization method. Which may facilitate the use of NAWQA findings by other Federal and State agencies. For every nutrient ecoregion in a study unit, frequency plots showing the number of candidate streams and the nutrient input estimates (nitrogen and phosphorus) in kilograms per square kilometer for each basin indicated which agriculturally influenced ecoregions contained sufficient candidate streams with an adequate range in nutrient conditions. As site selection was not limited to basins with existing water-quality sampling stations, little water-quality data were available for candidate streams.

Three nutrient ecoregions and approximately 85 candidate stream reaches exist in the CNBR study unit (Figure 2). Based on the nutrient input estimates, the greatest range in nutrient concentrations in streams was expected in the Central

Cultivated Great Plains ecoregion (Figure 3).

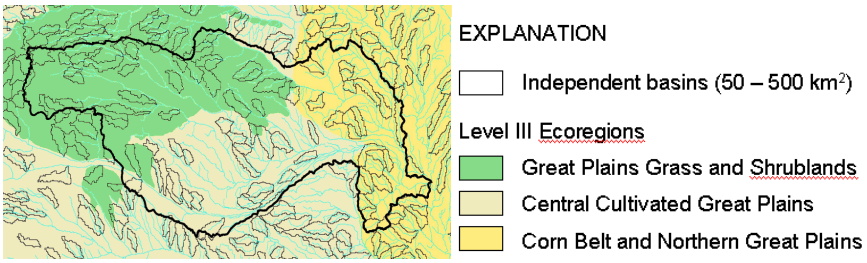

Figure 2. Location of independent stream reaches by U.S. Environmental Protection Agency's nutrient ecoregions in the Central Nebraska Basins study area, Nebraska.

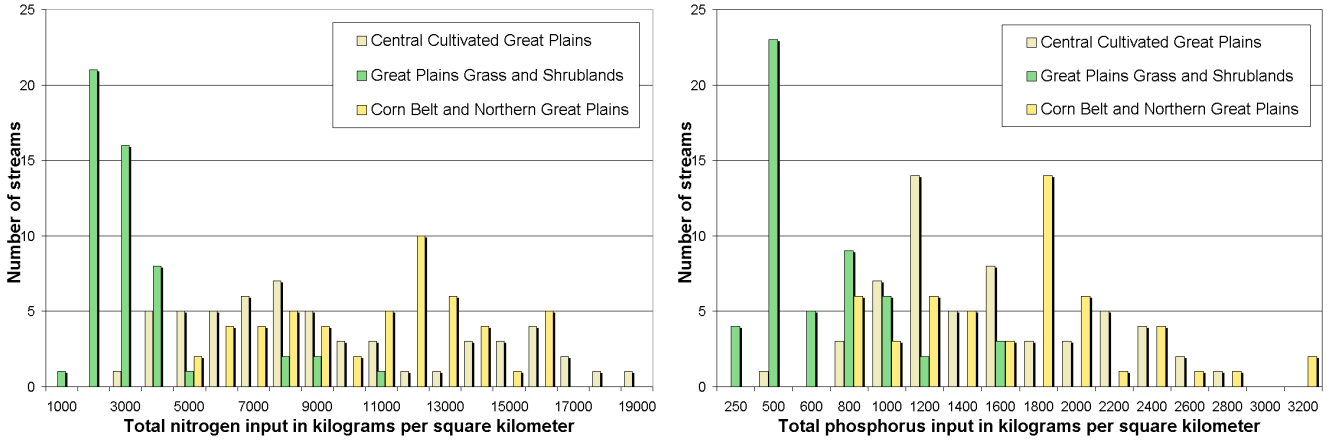

Figure 3. Distribution by nutrient ecoregion of estimated nutrient input (nitrogen and phosphorus) to the land surface, Central Nebraska Basins.

FIELD RECONNAISSANCE

Field reconnaissance was conducted in late summer to early fall 2002 during low-flow conditions. Reconnaissance of each site consisted of locating a reach of the candidate stream that had adequate streamflow, was accessible, and was not affected by obvious upstream point sources. Data collected during the field reconnaissance included: field measurements of specific conductance, pH, water temperature, and dissolved oxygen; estimates of average channel width, depth, and canopy cover; and observations of stream habitat types, riparian buffer width, and adjacent land use. To determine nutrient concentrations, a grab sample was collected and analyzed in the field for nitrate and orthophosphate concentrations using a Hach Model DR/2400 portable spectrophotometer[1].

In the CNBR study area, 60 streams sites in the Central Cultivated Great Plains nutrient ecoregion were included in the field reconnaissance. Because of drought conditions in the study area, only 24 of the 60 sites visited in 2002 had sufficient flow for collecting nutrient samples. The remaining 36 streams were dry, had water that was ponded, or were in backwater conditions caused by a confluence with a larger stream and will be revisited and sampled, if possible, during additional reconnaissance activities in the spring 2003. Although agricultural land use is uniformly intensive in this region, nitrate concentrations measured during the field reconnaissance ranged from <0.1 to 6.2 mg/L as nitrogen, and orthophosphate concentrations ranged from <0.02 to 6.3 mg/L as orthophosphate (Table 1). The reconnaissance results confirmed the presence of a substantial range in nutrient concentrations. The estimated nitrogen input was moderately related to measured nitrate concentrations ($r^2 = 0.30$). The estimated phosphorus input was poorly related to the measured orthophosphate concentrations ($r^2 = 0.05$) as indicated by the negative slope of the orthophosphate concentration and phosphorus input (Figure 4). These results are consistent with the national NAWQA nutrient data in which a greater proportion of nitrogen than phosphorus loading to the basin was lost to the stream, likely because of the tendency of nitrate to be transported with runoff or streamflow, while phosphorus attaches to soil particles and is less likely to be transported and detected during low-flow conditions (Fuhrer and others, 1999).

[1] Any use of trade, product, or firm name is for descriptive purposes only and does not imply endorsement by the U.S. Government

Table 1. Summary statistics for nutrient concentrations measured in the Central Cultivated Great Plains ecoregion during field reconnaissance activities in central Nebraska [mg/L, milligrams per liter}.

Nitrate		*Orthophosphate*	
Mean (mg/L)	1.45	Mean (mg/L)	2.62
Standard error	0.363	Standard error	0.373
Median (mg/L)	0.9	Median (mg/L)	2.25
Mode	0.05	Mode	0.01
Standard deviation	1.78	Standard deviation	1.83
Sample variance	3.16	Sample variance	3.35
Kurtosis	1.73	Kurtosis	-0.807
Skewness	1.68	Skewness	0.398
Minimum (mg/L)	<0.1	Minimum (mg/L)	<0.02
Maximum (mg/L)	6.2	Maximum (mg/L)	6.3
Sample size	24	Sample size	24

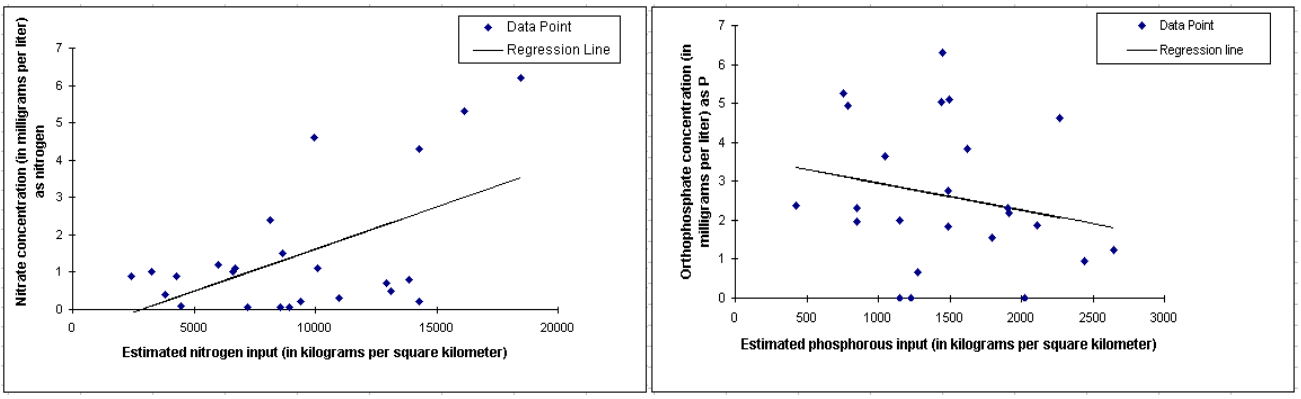

Figure 4. Regression of nutrient concentrations measured during field reconnaissance sampling and estimated nutrient input to the drainage basin.

FUTURE ACTIVITIES

During the summers of 2003 and 2004, water chemistry, algal and macroinvertebrate communities, and rates of stream metabolism are planned to be sampled at 28 streams in central Nebraska, and similar numbers of streams in four other agricultural ecoregions of the United States. Additional study units are planned to be added to the nutrient enrichment topical study in 2004 and 2007. Combined with the results from the four initial study areas, the findings of these studies will aid in evaluating the effectiveness of existing, and development of new, water-quality management strategies.

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