

Short communication

Nitrate-N load reduction measured in a central Iowa restored oxbow

Keith E. Schilling^{a,*}, Keegan Kult^b, Anthony Seemon^b, Karen Wilke^c, Christopher S. Jones^d^a Iowa Geological Survey, Trowbridge Hall, University of Iowa, Iowa City, IA, United States^b Iowa Soybean Association, Ankeny, IA, United States^c The Nature Conservancy, Des Moines, IA, United States^d IHR Hydroscience and Engineering, University of Iowa, Iowa City, IA, United States

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ABSTRACT

This short communication presents new data collected from a tile-fed oxbow site in north-central Iowa and reports on the quantification of NO₃-N load reductions using a mass balance approach. Using improved monitoring equipment deployed at the site in 2017, including a continuously-reading nitrate sensor, a NO₃-N budget for the oxbow was developed to estimate annual and monthly load reductions occurring in the reconstructed oxbow. Daily NO₃-N input was primarily from two drainage tiles and concentrations in the oxbow ranged from < 0.2 to 3.5 mg/l. Based on daily mass balance, the oxbow retained 42.3 kg of NO₃-N, or 0.21 g N m⁻² d⁻¹, and the NO₃-N retention efficiency was 35.4%. Removal efficiencies in early spring and late summer and fall were much higher than late spring and early summer. Based on mass load reductions, the effectiveness of oxbows for N load reductions is greatest when oxbows receive greater N loads from tile drainage compared to N loads delivered from flood pulses.

1. Introduction

Floodplain oxbows formed when stream meanders are cut off through bank erosion or artificial straightening (Ward et al., 2002) will often accumulate sediment and organic material over time and transition from lentic to terrestrial habitat (Constantine et al., 2010). Removing the oxbow fill material to restore the lentic habitat has been proven to be viable strategy to improve habitat for fishes, including the federally endangered Topeka shiner (*Notropis topeka*) (Bakevich et al., 2013) and waterfowl (LaGrange and Dinsmore, 1989). Recent work in Iowa is focusing on quantifying the nitrate-nitrogen (NO₃-N) reduction benefits of reconstructed oxbows.

Jones et al. (2015) compared mean NO₃-N concentrations in three restored oxbows to inlet tile water and found a 45–61% reduction in concentration. Kalkhoff et al. (2016) reported on a two-year study comparing a restored oxbow to an unrestored oxbow in north-central Iowa and found that the restored oxbow reduced nitrate concentrations approximately 54% compared to the incoming flows from a field tile. At a central Iowa site located in the recently glaciated Des Moines Lobe (DML) of Iowa, Schilling et al. (2017) used N:Cl ratios to quantify NO₃-N retention efficiency of a reconstructed oxbow fed by tile drainage and reported retention to range from 44% to 47% from May to September. At an eastern Iowa site located off the DML, Schilling et al. (2018) quantified NO₃-N retention during a spring storm water runoff event in

a newly reconstructed oxbow (< 1 year old) in eastern Iowa. They deployed a continuously-reading N-sensor to show oxbow NO₃-N concentrations decreasing from 5.3 mg/l after the flood event to background conditions over 21 days.

NO₃-N concentration reductions in restored oxbows have been more easily documented than mass load reductions. At the eastern Iowa oxbow site, Schilling et al. (2018) used a N mass balance approach to report that the new reconstructed oxbow processed ~14.7 kg of flood-derived NO₃-N over a three-week period, equivalent to a NO₃-N retention rate of 0.30 g N m² d⁻¹ and a retention efficiency of 74%. However, since the oxbow in this case was only connected to the stream for a short period during the flood, the oxbow did not actually intercept much of the stream N load (approximately 0.14% of the total NO₃-N load for the event) and the retention of ~15 kg of NO₃-N in the oxbow was largely negligible against the backdrop of high loading rates during the flood. In contrast to limited flood-derived N delivery, oxbows that capture tile-fed NO₃-N have the potential to intercept much greater agricultural N loads. For example, a tile-fed oxbow in central Iowa received approximately 220–450 kg of NO₃-N per year, as much as 30-times the amount of load delivered from a flood. Unfortunately, Schilling et al. (2017) were unable to close the N balance to quantify N mass reduction at the tile-fed oxbow site due to limitations in monitoring.

This short communication revisits the tile-fed oxbow site in north-

* Corresponding author.

E-mail address: keith-schilling@uiowa.edu (K.E. Schilling).

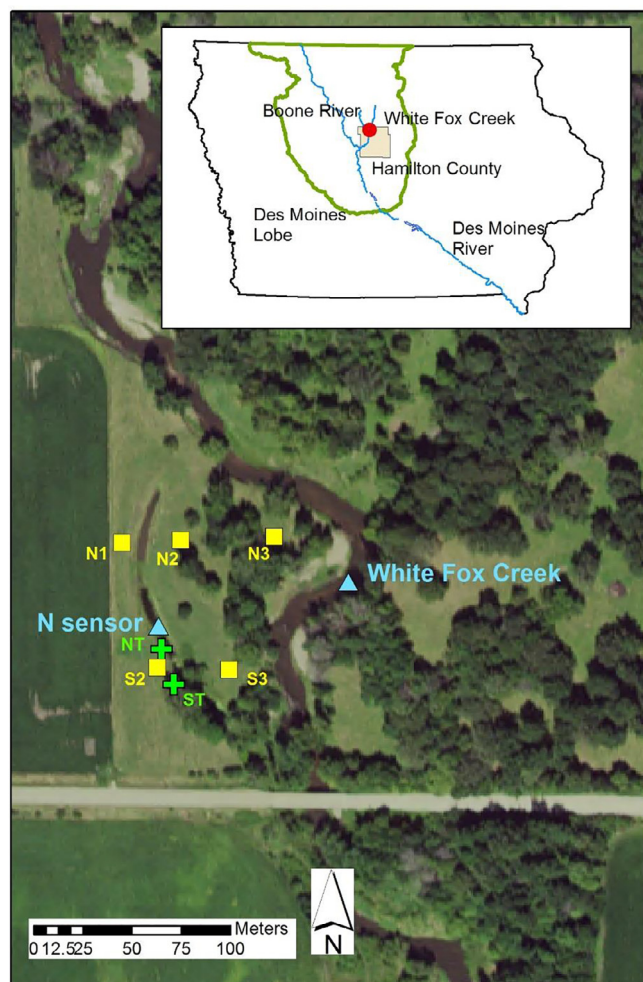


Fig. 1. Location of Frye oxbow site in north-central Iowa and oxbow sampling sites, including wells (N1, N2, N3, S2, S3) and tiles (NT and ST).

central Iowa and reports on the quantification of $\text{NO}_3\text{-N}$ load reductions using a mass balance approach. Using new monitoring equipment deployed at the site in 2017, including a continuously-reading nitrate sensor, we were able to close the $\text{NO}_3\text{-N}$ budget and estimate annual and monthly load reductions occurring in the reconstructed oxbow.

2. Methods and materials

Site description, oxbow construction details and field and analytical methodologies were provided in Schilling et al. (2017) and pertinent details are presented herein. The Frye oxbow was constructed in the floodplain of White Fox Creek (Fig. 1) in fall 2012 by excavating approximately 2071 m^3 of post-settlement alluvium to a depth of approximately 1.8–2.2 m. The oxbow consisted of two 0.08 ha oxbow cells connected by a 2.4 m long, 0.4 m deep connective channel and the oxbow outlet is connected to the channel of White Fox Creek during high flow events. The total surface water area of the oxbow is approximately 825 m^2 . Two 15 cm diameter tile lines drain into the oxbow (north tile (NT) and south tile (ST); Fig. 1) from an adjacent agricultural field (Fig. 1). Five shallow (4.5 m deep) monitoring wells were utilized in this study (N1, N2, N3, S2, S3) (Schilling et al., 2017).

Tile discharge into the oxbow was measured by Teledyne ISCO 2150 Area Velocity (AV) Flow Modules. AV sensors were secured to expansion rings placed approximately 0.3 m into the tiles from the outlet. Discharge from the oxbow into White Fox Creek was measured by placing a 0.25 M modified HXL flume into the channel to give a defined

geometry and placing an ISCO 2150 AV in the middle of the approach.

Water samples from the wells, tile lines, oxbow and White Fox Creek were collected approximately bi-monthly from March 22 to November 11, 2017 using methods described previously (Schilling et al., 2017) and analyzed for $\text{NO}_3\text{-N}$ and Cl at the Iowa Soybean Association certified testing laboratory in Ankeny, Iowa. Samples were analyzed on the day of collection using Environmental Protection Agency method 300.0 (National Environmental Methods Index 2008a). On April 18, 2017, a Hach Nitratax SC plus, 2-mm path length (Hach Company, 2011) was installed in the oxbow to monitor $\text{NO}_3\text{-N}$ concentrations. A CR1000 data logger continuously recorded $\text{NO}_3\text{-N}$ concentration and water temperature at a 5-min interval (Campbell Scientific Inc.).

A daily $\text{NO}_3\text{-N}$ mass balance for the oxbow was developed for the March to November 2017 period. Daily inflow $\text{NO}_3\text{-N}$ was the sum of the daily tile loads from the north and south tiles and groundwater seepage and outflow was the product of the oxbow concentration and daily discharge from the oxbow into White Fox Creek:

$$\text{NO}_3\text{-N retention (kg)} = \sum [\text{NO}_3\text{-N}_{(\text{kg})}]_{\text{in}} - [\text{NO}_3\text{-N}_{(\text{kg})}]_{\text{out}} \quad (1)$$

Previous assessment of the oxbow site indicated that $\text{NO}_3\text{-N}$ delivered via groundwater seepage was insignificant relative to the tile flow ($< 0.1\%$). Hence for the $\text{NO}_3\text{-N}$ mass balance we rounded up the contribution of groundwater inflow $\text{NO}_3\text{-N}$ to 0.001 kg/day based on previous monitoring.

3. Results

Precipitation measured nearby in Webster City, Iowa, was 719 mm for the March to November monitoring period (Fig. 2a). Monthly rainfall ranged from 81 to 84 mm in March, April and June, and exceeded 120 mm in May, August and October 2017. Lowest monthly precipitation was recorded in July when only 18 mm fell on the ground.

Water samples collected from tiles, groundwater wells, oxbow and White Fox Creek showed variable nitrate and chloride concentrations in 2017 (Table 1). Highest $\text{NO}_3\text{-N}$ concentrations were detected in White Fox Creek (up to 16 mg/l) whereas tile and upgradient groundwater concentrations were similar (2–4 mg/l) (Fig. 2b). Continuous $\text{NO}_3\text{-N}$ concentrations measured in the oxbow using a Nitratax sensor showed considerable variability, varying from < 0.2 to 3.5 mg/l (Fig. 2a). $\text{NO}_3\text{-N}$ concentrations in the oxbow peaked on June 29 (3.5 mg/l) following approximately 70 mm of accumulated rainfall during the previous two week period, and then rapidly declined to < 0.2 over the next 25 days. $\text{NO}_3\text{-N}$ concentrations in the oxbow peaked again on October 9 (2.5 mg/l) following another extended period of rainfall (125 mm in 15 days) and subsequently decreased thereafter.

$\text{NO}_3\text{-N}$ loads into the oxbow were dominated by tile discharge and daily input tile loads ranged from 0 (tiles not flowing) to 2.8 kg/day and averaged 0.49 ± 0.56 kg/day from April 2 to October 31, 2017 (Fig. 2c). Tile loads were greater than 1–2 kg/day on several occasions in the spring and early summer before the last occurrence on June 29, and then were observed to decrease to < 0.1 kg/day from mid-July to October 9. Following early October rainfall, the tiles resumed discharging approximately 0.2–0.4 kg N per day, causing the increasing spike in October $\text{NO}_3\text{-N}$ concentrations in the oxbow. Total cumulative loads from both tiles was 119.4 kg, whereas total input load from groundwater was approximately 0.24 kg.

In contrast, daily $\text{NO}_3\text{-N}$ discharge from the oxbow ranged from 0 (no oxbow discharge to White Fox Creek) to 6.8 kg/day and averaged 0.37 ± 0.71 kg/day (Fig. 2c). The greatest single day discharge of $\text{NO}_3\text{-N}$ from the oxbow occurred on June 30 when approximately 4.9 kg of $\text{NO}_3\text{-N}$ was exported from the oxbow than was input from tiles and groundwater. Overall, total cumulative $\text{NO}_3\text{-N}$ loads discharged from the oxbow in 2017 was 77.3 kg. During the monitoring period, there were no occurrences of surface water backflow from the creek into the oxbow. Based on daily $\text{NO}_3\text{-N}$ balance in the oxbow, (Eq. (1)), the

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