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July 2011



ARKANSAS WATER RESOURCES CENTER ANNUAL
TECHNICAL REPORT FY 2010

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Arkansas Water Resources Center Annual Technical Report FY 2010

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This publication serves as the annual report to the U.S. Geological Survey regarding the projects and activities of the Arkansas Water Resources Center for FY 2010. This document provides summary information for each of the 104B projects funded: 1) Determination of the magnitude of mercury methylation in the water column of a high organic carbon river, lower Ouachita River, Union and Ashley Counties, Arkansas; 2) Assessment of water quality and stream bank stability following BMP implantation on the upper Strawberry River watershed; and 3) Denitrification, internal N cycling, and N retention in river impoundment reservoirs. This publication also summarizes the Arkansas Water Resources Center's information transfer program, student involvement, notable awards and achievements, and publications of previous 104B projects.

Keywords: Arkansas Water Resources Center, 104B Program Funding, Information Transfer, Water Quality

Introduction

The Arkansas Water Resources Center located at the University of Arkansas, Fayetteville, Arkansas is part of the network of 54 water institutes established by the Water Resources Research Act of 1964. Since its formation, the Arkansas Water Resources Center (AWRC) program in cooperation with the US ecological Survey and the National Institute for Water Resources has focused on helping local, state and federal agencies understand, manage and protect water resources within Arkansas. AWRC has contributed substantially to the understanding and management of water resources through scientific research and training of students. Center projects have focused on topics concerned with water quality of surface water and ground water, especially non-point source pollution and sensitive ecosystems. AWRC helps organize research to insure good water quality for Arkansas today and in the future.

The AWRC focuses its research on providing local, state and federal agencies with scientific data and information necessary to understand, manage and protect water resources within Arkansas. AWRC cooperates closely with colleges, universities and other organizations in Arkansas to address the state's water and land-related issues, promote the dissemination and application of research results, and provide for the training of scientists in water resources. Each year, several research faculty participate in AWRC projects with the help of students who gain valuable experience doing environmentally related work across the state. AWRC research projects have studied irrigation and runoff, innovative domestic wastewater disposal systems, ground water modeling and landuse mapping, erosion and pollution, water quality and ecosystem functions.

The Center provides support to the State's water research by acting as a liaison between funding groups and the scientists, and then coordinates and administers grants once they are funded. Accounting, reporting and water analyses are major areas of support offered to principal investigators. The AWRC has historically archived reports of water resource studies funded by the 104B program or through the Center on its website.

In addition, the AWRC sponsors an annual water conference held in Fayetteville, Arkansas each spring, drawing over 100 researchers, students, agency personnel and interested citizens to hear about results of current research and hot topics in water resources throughout the state. AWRC also co-sponsors short courses and other water-related conferences in the state and region. In addition, AWRC maintains a technical library containing over 900 titles, many of which are online. This valuable resource is utilized by a variety of user groups including researchers, regulators, planners, lawyers and citizens.

The AWRC also maintains a modern water quality laboratory that provides water analyses for researchers, municipal facilities, and watershed stakeholders; farmers and other citizens submit samples through the cooperative extension service. This laboratory is certified through the Arkansas Department of Environmental Quality for the analysis of surface and ground water samples.

The AWRC has a technical advisory committee made up of professionals from educational institutions, environmental organization, water supply districts, and government agencies throughout Arkansas. This committee has the opportunity to evaluate proposals submitted annually to the USGS 104B program, to recommend session topics included in the annual research conference, and to provide general advice to the AWRC Director and staff.

Research Program Introduction

Each year, several researchers participate in 104B projects funded through the Arkansas Water Resources Center (AWRC), and these projects are completed with the help of students in water and environmentally related fields. The research projects funded through the AWRC have studied a broad range of environmental and water issues facing Arkansas, including irrigation and rainfall–runoff, innovated domestic wastewater disposal, groundwater modeling and land use mapping, erosion and nonpoint source pollution, water quality and ecosystem function. The AWRC has given priority to solid scientific research proposals submitted by faculty to the 104B program; the intent has been to provide seed data to researchers such that larger proposals can be developed and submitted to extramural funding sources. The AWRC has funded several projects using 104B funding that have resulted in the award of extramural grants to continue the base research.

To formulate a research program relevant to state water issues, the Center works closely with state and federal agencies, and academic institutions. An advisory committee, composed of representatives from state and federal agencies, industry and academia, provides guidance for the Center. The technical advisory committee plays an important role in insuring that the water institute program (section 104) funds address current and regional issues. The priority research areas of the AWRC base program directly related to the program objectives of the Water Resources Research Act, including research that fosters improvements in water supply, explores new water quality issues, and expands the understanding of water resource and water related phenomena.

DETERMINATION OF THE MAGNITUDE OF MERCURY METHYLATION IN THE WATER COLUMN OF A HIGH ORGANIC CARBON RIVER, LOWER OUACHITA RIVER, UNION AND ASHLEY COUNTIES, ARKANSAS

Basic Information

Title: Determination of the magnitude of mercury methylation in the water column of a high organic carbon river, lower Ouachita River, Union and Ashley Counties, Arkansas

Project Number:	2010AR248B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	3 rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Toxic Substances, Surface Water, Hydrogeochemistry
Descriptors:	
Principal Investigators:	Phil D Hays, Stephen K Boss, John Van Brahana, Ralph K Davis

Publications

1. Schenk, Liam. 2011. Geochemical Controls on Mercury Methylation in Backwaters of a Gulf Coastal Plain River System, Implications for Water Column Processes. Thesis, Master of Science in Geology, University of Arkansas, Fayetteville, Arkansas.
2. DETERMINATION OF THE MAGNITUDE OF MERCURY METHYLATION IN THE WATER COLUMN OF A RIVER WITH HIGH DISSOLVED ORGANIC CARBON, LOWER OUACHITA RIVER, UNION AND ASHLEY COUNTIES, ARKANSAS: SCHENK, Liam N., Department of Geosciences, University of Arkansas, 113 Ozark Hall, Fayetteville, AR 72701, lschenk@uark.edu and HAYS, Phillip, U.S. Geological Survey, Ozark Hall 113, Fayetteville, AR 72701

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TECHNICAL PUBLICATION NUMBER MSC 102.2010– YEAR 2011

Arkansas Water Resources Center 104B Program Project – March 2010 through February 2011

Project Title: Determination of the Magnitude of Mercury Methylation in the Water Column of a High Organic Carbon River, Lower Ouachita River, Union and Ashley Counties, Arkansas

Project Team: Dr. Phil D. Hays, Arkansas US Geological Survey
Dr. Stephen K. Boss, Geosciences, University of Arkansas
Dr. John Van Brahana, Geosciences, University of Arkansas
Dr. Ralph K. Davis, Geosciences, University of Arkansas

Interpretative Summary:

The abundance and distribution of mercury and methyl mercury were investigated at three sites in the lower Ouachita River in the summer of 2010 in an effort to provide the first characterization of the extent of mercury contamination in this river system, and to investigate the potential for mercury methylation in the water column of backwaters off of the main channel. Results showed that filtered methyl mercury was positively correlated to dissolved organic carbon ($r_2=0.76$) for water samples taken from the bottom 1 ft of the water column at three sites, suggesting the importance of dissolved organic carbon in mercury methylation. Concentrations of filtered methyl mercury and filtered total mercury in the bottom-water were significantly different ($P=0.039$ and $P=0.022$ respectively) at two of the sample sites located approximately 14 river miles apart. Sulfide concentrations of 74.0-142.7 micrograms/liter indicate sulfate reduction was occurring in the bottom water or at the sediment-water interface, yet filtered and particulate methyl mercury concentrations were not significantly correlated to sulfide concentrations. The occurrence of sulfides in the bottom-water is important as sulfate-reducing bacteria are most commonly associated with mercury methylation. Water chemistry results for one site including total iron (39.8 milligrams/liter), high dissolved organic carbon (13.52 milligrams/liter), the highest filtered methyl mercury concentration observed for the study (1.90 nanograms/liter), and no detectable sulfate suggests the predominance of iron reduction at this site. Microbial iron reduction is also a known mercury methylation pathway. Total mercury concentrations for two of seven samples exceeded the Arkansas numeric water quality standard for total recoverable mercury in water (12 nanograms/liter), at concentrations of 13.76 and 13.99 nanograms/liter. These data provide evidence that availability of dissolved organic carbon affects mercury methylation at all three of the sites, and that iron reduction may contribute to mercury methylation at one of the sites. No correlation between sulfide and dissolved methyl mercury was observed, suggesting sulfate reduction may not be the driving process for mercury methylation at all our study sites, and indicating the presence of multiple controls on mercury methylation in this river system.

Introduction:

Increased scientific knowledge on mercury (Hg) sources, transport, deposition and cycling, and the toxic effects of Hg species on human populations has led to growing concern over Hg contamination of aquatic systems in recent years. Hg is naturally present in the environment, but human activities such as the combustion of fossil fuels for power generation have increased the amount of Hg cycling through land, atmosphere, and ocean systems (N. E. Selin 2009). As such, atmospheric deposition of Hg is increasing in marine systems (Sunderland, et al. 2009), as well as in riverine systems (Delongchamp, et

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al. 2009). Riverine systems in some regions such as those draining cinnabar mining districts are at even greater risk of contamination due to exposure and mobilization of Hg during cinnabar mining (Holloway, et al. 2009).

Of primary concern is the formation of the most toxic form of Hg, methylmercury (MeHg). In aquatic systems, Hg can be deposited by either wet or dry deposition in its elemental (Hgo) and ionic (Hg(II)) forms. Hgo and Hg(II) can then be transformed into toxic and highly bioavailable MeHg, the result of processes largely carried out by anaerobic bacteria (Marvin-Dipasquale, et al. 2009). Epidemiological studies have linked exposure to MeHg in pregnant women to neurological and developmental effects in their offspring (Mergler, et al. 2007), (Clarkson 1990). High degrees of human exposure to MeHg most commonly results from the consumption of high trophic-level predaceous fish such as tuna and swordfish in marine systems, and black bass and piranha in freshwater systems.

The objective of this project is two-fold. The first objective is to provide the first detailed characterization of the occurrence and extent of Hg contamination in backwaters of the lower Ouachita River system, and second, to examine the geochemical controls on MeHg in the water column. A detailed multimedia, multi chemical-species sampling scheme was implemented to characterize the relation between organic carbon and Hg methylation. Field parameters along with sulfide, sulfate, and iron concentrations were assessed in the bottom 1-ft of the water column (hereafter referred to as bottom water) to provide insight into oxidation-reduction (redox) conditions that dominate the system and provide evidence for the presence of anaerobic bacteria known to be responsible for Hg methylation. Determination of the controls on MeHg occurrence in the bottom water is achieved by comparing total Hg (THg) and MeHg concentrations to field parameters, DOC, sulfide, iron, sulfate and MeHg sediment concentrations. The characterization of Hg contamination at three backwater sites on the lower Ouachita River provides detailed, state-of-the-science Hg data that give insight into the extent of Hg contamination.

Methods:

Three sites (RL-2, OR-2 and OR-11) were chosen as the most likely candidates for MeHG production in the Ouachita River System. Sampling of all three sites was conducted from late July to early August 2010. This time was selected to target the season that would have the highest ambient temperatures and water temperatures of the year, and lowest water flow, and thus the most likely time for stratification to occur in the water column. Surface water samples were collected three times at RL-2 and OR-2 and twice at OR-11 and analyzed for THg, MeHG, DOC, and physico-chemical parameters; sediment samples were collected and analyzed for MeHg. A diurnal sampling event was implemented at Or-2 to determine any potential fluctuations of Hg and sulfides over a 24-hour period.

Non-parametric statistics were used to compare median values of bottom-water concentrations of HG species and other parameters between sites. Sign-rank and rank-sum tests were used to test the equality of median values, and one-way ANOVA's were used to test for equality of means. Statistical significance was set at $\alpha=0.05$.

Results:

All three sites exhibited stratification with respect to temperature and DO, with high temperature and high DO in the shallow depths, and lower temperatures and anoxic conditions in the bottom-water. pH values did not vary much between sites or between water surface and bottom water, while specific conductance for all three sites increased with increasing depth in the water column.

Concentrations of Hg compiled from all three sites show increases from the dissolved MeHg (FMeHg) fraction to total Hg (THg), with the lowest FMeHg concentrations occurring at 0.05 ng/L, just above the MDL (0.04 ng/L), and the highest Hg concentrations occurring in the THg fraction at 13.99 ng/L, calculated as the sum of filtered and particulate THg.

Mercury concentrations in all size fractions and speciation varied between sites (Figure 1). RL-2 had the highest dissolved MeHg and THg as compared to the other sites. OR-11 had the lowest FMeHg, PMeHg, and FTHg, but had the highest PTHg and THg. Hg concentrations at OR-2 were between the other two sites for all size fractions and species. FMeHg and PMeHg at OR-2 showed variability in concentrations between sample days shown by the error bars in Figure 2 representing standard deviation of samples collected on three separate sample days.

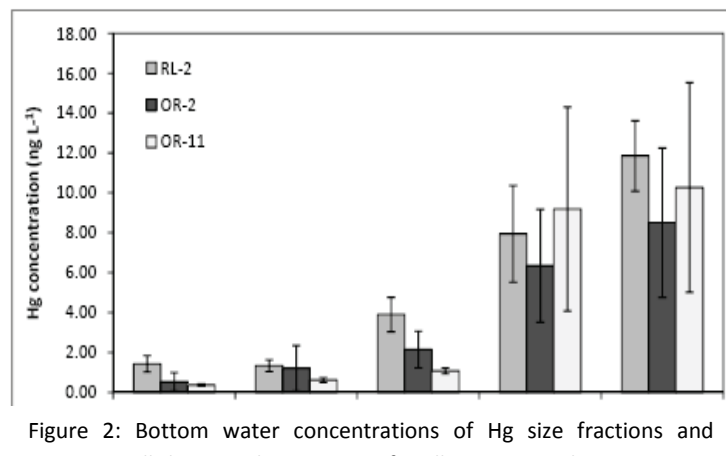
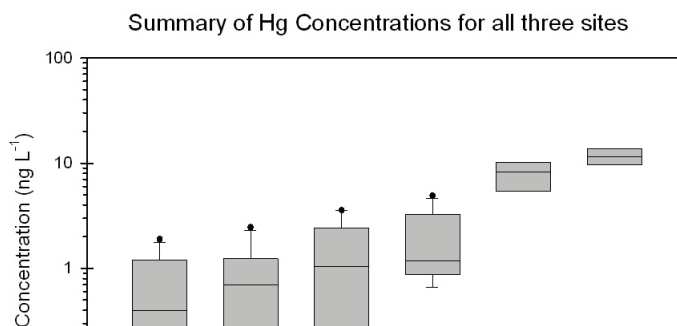


Figure 2: Bottom water concentrations of Hg size fractions and species at all three study sites. N=3 for all sites. Error bars represent standard deviations of samples collected on separate days.

Non-parametric statistics were used to compare bottom-water samples of Hg species and size fractions between sites. There was no statistical difference of median values at the bottom-water for any of the Hg species and size fractions when using rank-sum or sign-rank statistical tests. One-way ANOVA's used to test the difference of means resulted in statistical differences of FMeHg in the bottom-water between RL-2 and OR-11 ($P=0.039$) and FTHg between RL-2 and OR-11 ($P=0.022$) only. All other species and size fractions were not statistically different at the bottom-water between sites. MeHg and THg were positively correlated at the bottom-water for filtered samples, but not significantly correlated for total MeHg (TMeHg) and THg.

Of the three study sites, RL-2 exhibited the highest dissolved MeHg and THg, and particulate MeHg concentrations in the bottom water (Figure 2). Additionally, the highest DOC concentrations were encountered at this site (mean 13.37 mg/L, $n=3$), and the highest total iron concentration (39.8 mg/L). These data provide evidence for geochemical controls on Hg methylation at this site, as high DOC is often related to high rates of Hg methylation, and high iron concentration gives evidence for redox processes that may have been controlling methylation.

The highest dissolved MeHg concentrations of all three study sites occurred at RL-2 (mean 1.43 ng/L, $n=3$), which also had the highest DOC concentrations (mean 13.37 mg/L, $n=3$), highlighting the importance of DOC in Hg methylation processes at this site. The positive linear correlation with DOC and dissolved MeHg (Figure 34) indicates that DOC may not be inhibiting Hg methylation at this site, and is providing an energy source to methylating bacteria, potentially iron reducers, owing to the high iron concentration encountered at this site.

THg and MeHg concentrations at all three study sites on the lower Ouachita River are typically within the range of Hg values reported in the literature for the southeastern United States, and median and mean values exceeded reported concentrations in many areas. The highest dissolved MeHg concentration on the lower Ouachita River system was 1.90 ng/L at RL-2, highlighting the high rates of MeHg production. Although the three study sites on the lower Ouachita are not technically classified as wetlands, they can experience similar fluctuations in water levels as they are hydraulically connected to the main channel of the river, which fluctuates with seasons. These fluctuations do not expose large areas of sediment as compared to most freshwater wetlands. The concentrations of dissolved MeHg at the lower Ouachita sites are much higher than many/most of the regional concentrations, suggesting high rates of methylation, potentially due to similar conditions as explained by Hall, et al. (2008).

Conclusions:

Data generated from this study show the spatial variability in geochemistry at the study sites, which has a direct effect on MeHg production. Sites with high DOC had higher concentrations of dissolved MeHg as evidenced by positive correlation between these two constituents. Measureable sulfides in the bottom water at all three sites give evidence for sulfate reduction, yet high absolute values of redox potential indicate that redox potential is not low enough in the bottom-water at the study sites to allow sulfate and iron reduction.

The observed positive linear relation between dissolved MeHg and DOC at the bottom water at all three sites indicates an important influence of DOC on Hg methylation. This relation can be explained by DOC acting as an energy source that stimulates microbial activity, and by low pH in the bottom water providing protons to compete for negatively charged binding sites in DOC that would otherwise be utilized by Hg, thus leaving Hg bioavailable for methylation (Barkay, Gillman and Turner 1997). Channel morphology also plays an important role in the distribution of DOC, and in site specific stratification characteristics.

Measurable sulfide detected at the bottom water at all three sites suggest that sulfate reduction and associated MeHg production may be occurring either in the anoxic water at the base of the water column, at the sediment-water interface, or in sediment pore water with sulfide and MeHg moving out of sediment into the overlying water column. However, ORP values do not show the potential for sulfate reduction in the anoxic bottom waters at the lower Ouachita River sites. Given the conflicting evidence of absolute ORP, further data are needed at corroborate the occurrence of sulfate reduction in the bottom water at these sites including a larger sulfide data set, dissolved iron analysis, and a larger sulfate data set.

Of the three study sites, RL-2 exhibited the highest filtered MeHg, THg, and particulate MeHg concentrations in the bottom water as well as the highest DOC concentrations (mean 13.37 mg/L, n=3). Measureable sulfide at this site indicates that sulfate reduction may be occurring concurrently with iron reduction. It is therefore possible that multiple microbial communities that methylate Hg are responsible for the high concentrations of MeHg at RL-2, potentially even FeRB. Assessment of seasonal fluctuations of Hg from existing USGS data at sites proximal to the lower Ouachita River sampling sites show peaks in the occurrence of filtered THg and MeHg during late spring, indicating seasonal controls on MeHg production. An increase in the supply of DOC during high precipitation or flood events may increase MeHg production by enhancing microbial activity.

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This study provides crucial data describing the extent of Hg contamination in Arkansas, with two of eight bottom-water samples exceeding the numeric water quality standard of 12 ng/L total recoverable Hg in water. As atmospheric Hg deposition increases across the country, the Hg issue in Arkansas only stands to become more prominent, giving impetus for additional research to be conducted on this important environmental issue.

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Hall, B.D., G.R. Aiken, D.P. Krabbenhoft, M. Marvin-DiPasquale, and C.M. Swarzenski. "Wetlands as principal zones of methylmercury production in southern Louisiana and the Gulf of Mexico region." *Environmental Pollution* 154 (2008): 124-134.

Research Publications Stemming from this Project:

Schenk, Liam. 2011. Geochemical Controls on Mercury Methylation in Backwaters of a Gulf Coastal Plain River System, Implications for Water Column Processes. Thesis, Master of Science in Geology, University of Arkansas, Fayetteville, Arkansas.

ASSESSMENT OF WATER QUALITY AND STREAM BANK STABILITY FOLLOWING BMP IMPLEMENTATION ON THE UPPER STRAWBERRY RIVER WATERSHED

Basic Information

Title: Assessment of water quality and stream bank stability following BMP implementation on the upper Strawberry River watershed

Project Number:	2010AR249B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	3 rd Congressional District of Arkansas
Research Category:	
Focus Category:	
Descriptors:	
Principal Investigators:	Jennifer L. Bouldin

Publications

1. Brueggen, T.R. In progress. Effects of Best Management Practices on the Upper Strawberry River Watershed, Fulton CO, AR. Environmental Sciences, Arkansas State University.

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TECHNICAL PUBLICATION NUMBER MSC 102.2009– YEAR 2010

Arkansas Water Resources Center 104B Program Project – March 2010 through February 2011

Project Title: Investigation of Land Use and Best Management Practices on the Strawberry River Watershed

Project Team: Dr. Jennifer Bouldin, Environmental Biology, Arkansas State University and Teresa Brueggen, Environmental Sciences, Arkansas State University

Interpretative Summary:

Best Management Practices (BMPs) including exclusion of cattle from waterways, providing alternative watering facilities, and use of no-till planting methods have been put into place on three creeks in the upper watershed of the Strawberry River, AR. This study incorporates physical, biological and chemical analyses to determine the effects of the implemented BMPs on water and sediment quality of the three creeks. Protection of upper headwater streams will improve ecosystem integrity downstream in this Ecologically Sensitive Waterbody. This study has the potential to expand the knowledge base of improved water quality from stream-side agricultural BMPs.

Introduction:

The Strawberry River Watershed is located in the Ozark Highland Ecoregion of Arkansas and defined as an Extraordinary Resource Water, Ecologically Sensitive Water Body, and Scenic Waterway (ADEQ, 2008). The waters of the Strawberry River support a diversity of species including the endogenous Strawberry River Darter, diverse communities of aquatic macroinvertebrates including several ranked or listed freshwater mussels (Harp and Robinson, 2006). The ADEQ (2008) defines the designated uses for the Strawberry River as Primary and Secondary Contact Recreation, Domestic, Industrial and Agricultural Water Supply. Seven reaches of the Strawberry River Watershed are included in the 303d list as not supporting aquatic life due to excess turbidity (ADEQ, 2008). Land use in the watershed is primarily forested (56.5%) and grassland (35.3%) (ADEQ, 2003), with livestock grazing and hay harvesting for livestock common among the grassland owners. Grazing practices often do not include fencing from the streambed leading to increased bank sloughing. Best management practice implementation is presently underway in the upper watershed and landowner participation is encouraged through an EPA 319 grant issued to the Fulton County Conservation District and Arkansas State University. Upstream and downstream monitoring sites are located on Little Strawberry, Greasy Creek and Sandy Creek.

Methods:

Erosion pins were used to assess bank stability and estimate sediment transport from bank erosion. Multiple pins were installed perpendicular into the stream bank. These pins will be installed at the active bank and above the active bank determined at each designated sampling location (Zaines et al., 2005). A survey of each stream reach quantified the extent of stream with bank instability.

Benthic surveys will be performed with D-frame nets using the traveling kick method. Organisms will be keyed to species according to Merritt et al. (2008) whenever possible and 10% of samples will be referred to a benthic taxonomist for Quality Assurance of identification.

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Enumeration of *E. coli* and measures of chlorophyll *a* will be determined monthly. *Escherichia coli* and chlorophyll *a* concentrations will be determined using the filtration technique in accordance with the American Public Health Association (APHA, 2005).

Aqueous and sediment toxicity studies will be performed in the fall and spring. Bioassays will be used to measure the presence of toxicity. *Ceriodaphnia dubia* and *Pimphales promelas* will be used in whole effluent toxicity (WET) 7-d chronic tests, in accordance with the EPA guidelines (2002) to determine aqueous toxicity. Presence of sediment toxicity will be measured using *Chironomus dilutus* with a 10-d acute toxicity test in accordance with EPA guidelines (2000).

Results:

Approximately 5480 m of stream bank was assessed within the Little Strawberry Creek. It was determined that there were 24 sites of severe or very severe erosion totaling approximately 746 m of stream bank. Approximately 6340 m of stream bank were assessed of Greasy Creek. In this stretch 16 sites were determined as severely or very severely eroded totaling approximately 500 m. Approximately 13260 m of stream bank was assessed of Sandy Creek. Twenty two sites were classified with severe or very severe erosion totaling approximately 505 m. An assessment of the erosion pins was performed in October 2010.

In spring and fall 2010 benthic macroinvertebrate collections, 2705 and 1328 total organisms were collected, respectively (Fig 1). Sandy Creek upper site was not sampled fall 2010 due to dry conditions. This included the following: Coleoptera, Diptera, Ephemeroptera, Hemiptera, Megaloptera, Odonata, Plecoptera, Trichoptera, Decapoda, and Mollusca. Total family diversity between sites for spring and fall ranged from 2-24 and 6-19, respectively (Fig 2).

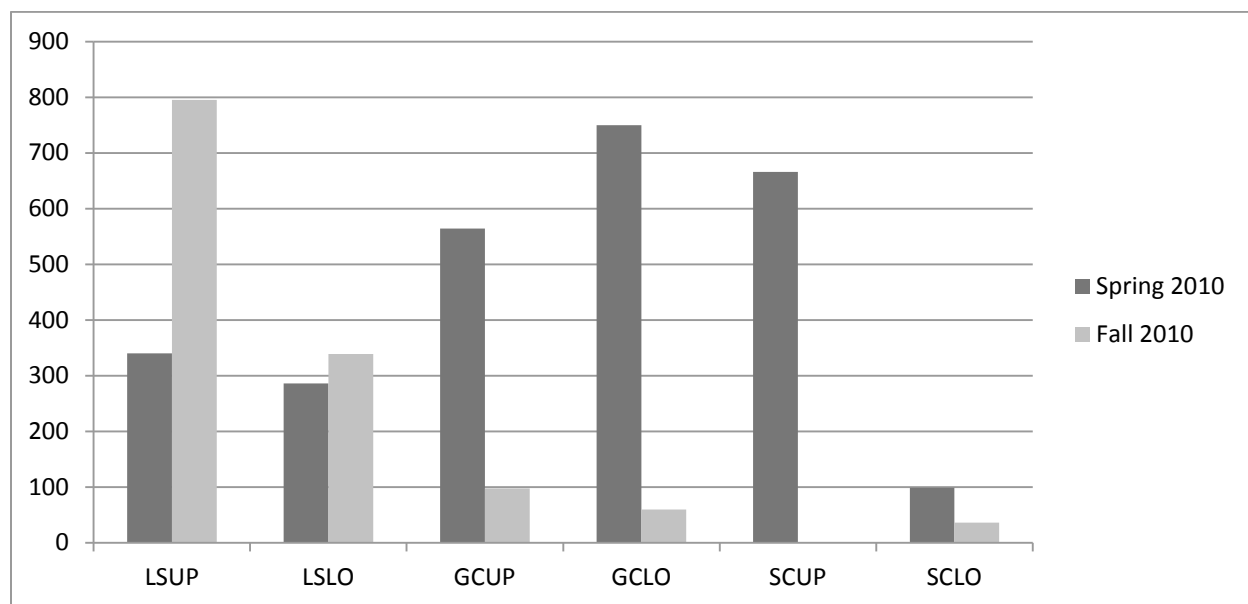


Figure 1. Total number of organisms collected at monitoring sites in the upper watershed of the Strawberry River. Little Strawberry (LS), Greasy Creek (GC), Sandy Creel (SC), upper location (UP) and lower location (LO). SCUP not sampled fall 2010 due to dry sampling location.

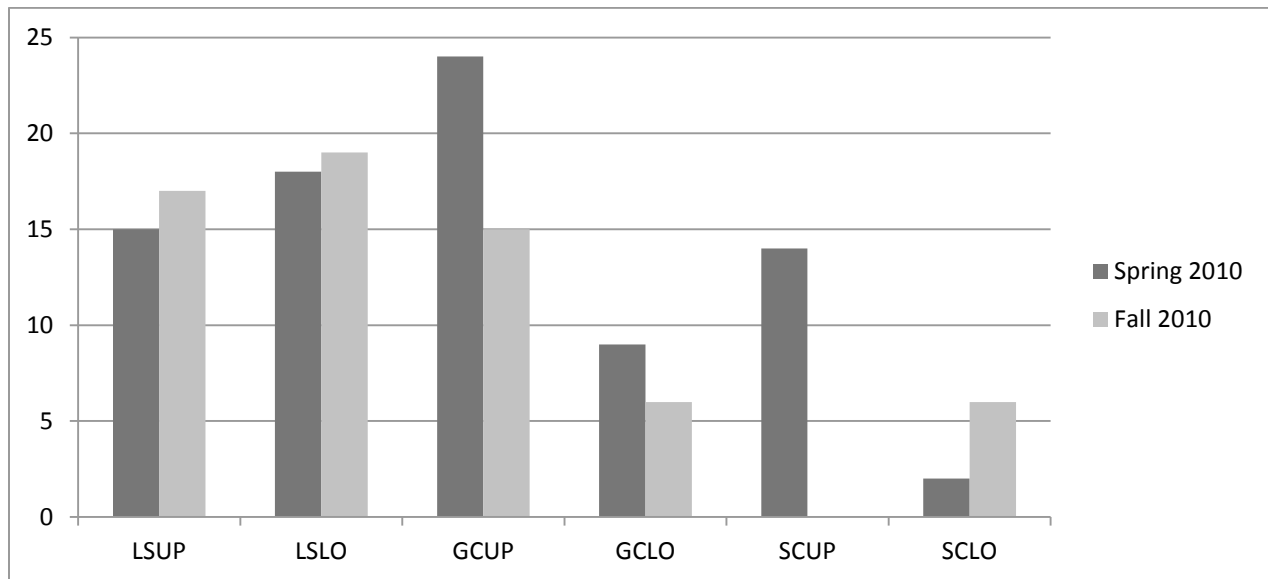


Figure 2. Total number of families identified at monitoring sites in the upper watershed of the Strawberry River. Little Strawberry (LS), Greasy Creek (GC), Sandy Creel (SC), upper location (UP) and lower location (LO). SCUP not sampled fall 2010 due to dry sampling location.

E. coli mean values ranged from 51-215 colony forming units (CFUs). No single sample concentrations exceeded allowable limits (APCEC, 2010). Little Strawberry upper site indicated significant lethal aqueous toxicity using *P. promelas* in Spring 2010 and lethal sediment toxicity in Fall 2010.

Conclusions:

This is an ongoing study; therefore, final conclusions are limited. It is evident that multiple years of analysis assessing physical, chemical and biological parameters are vital to evaluate the impact of implemented BMPs. Much variability can occur from year to year as environmental parameters outside of the researcher's control fluctuate (e.g. rainfall, temperature).

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Harp, G.L. and H.W. Robison. 2006. Aquatic Macroinvertebrates of the Strawberry river system in north-central Arkansas. *Journal of the Arkansas Academy of Science* 60:46-61.

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United States Environmental Protection Agency. 2002. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. 4th ed. EPA 600/4-91/002.

Zaimes, G. N., Schultz, R.C., Isenhardt, T.M., Mickleson, S.K., Kovar, J.L., Russell, J.R. and Powers, W.P. 2005. Stream bank erosion under different riparian land-use practices in northeast Iowa: AFTA 2005 Conference Proceedings, 1-10.

Research Publications Stemming from this Project:

Brueggen, T.R. In progress. Effects of Best Management Practices on the Upper Strawberry River Watershed, Fulton CO, AR. Environmental Sciences, Arkansas State University.

DENITRIFICATION, INTERNAL N CYCLING, AND N RETENTION IN RIVER IMPOUND RESERVOIRS

Basic Information

Title:	Denitrificaton, internal N cycling and N rentention in river reservoirs
Project Number:	2010AR252B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	3 rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Nutrients, Sediments
Descriptors:	
Principal Investigators:	Jefferson Thad Scott

Publications

1. Grantz, E. 2011. Denitrification efficiency in water impoundment reservoirs, Department of Crop, Soil, and Environmental Sciences, University of Arkansas.

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TECHNICAL PUBLICATION NUMBER MSC 102.2010– YEAR 2011

Arkansas Water Resources Center 104B Program Project – March 2010 through February 2011

Project Title: NITROGEN RETENTION AND DENITRIFICATION EFFECIENCY IN WATER IMPOUNDMENTS

Project Team: J. Thad Scott, Department of Crop, Soil, and Environmental Sciences, Univ. of Arkansas

Interpretative Summary:

Reactive nitrogen loss from human-impacted landscapes may be degrading water quality in downstream coastal environments. This project was conducted to determine what role water impoundment reservoirs play in attenuating reactive N from surface waters by transformation to N₂ gas via denitrification. Over the last two years we sampled three reservoirs in Northwest Arkansas to determine their capacity to store and transform reactive N. We collected intact sediment cores to quantify denitrification rates, created N mass balances, and developed a new method for estimating whole-ecosystem N₂ flux data from thermally stratified reservoirs. Our data suggest that reservoirs are indeed important N sinks and that a substantial portion of stored N is eventually denitrified.

Introduction:

Denitrification in water impoundment reservoirs may remove substantial quantities of reactive N from surface waters, but few comprehensive denitrification studies have been conducted on reservoirs (David et al. (2006)). More work is needed to quantify denitrification rates in reservoirs and the factors that cause rates to vary across space and time. In particular, these studies should address what percentage of N retention is caused by denitrification. Developing a thorough understanding of the factors that control denitrification in reservoirs will allow us to maximize reservoir N retention through proper reservoir management.

In this study we measured sediment denitrification rates, seasonal ecosystem-scale denitrification, and N storage (mass balance) in three water impoundment reservoirs in Northwest Arkansas. The objective of the study was to quantify denitrification rates in these reservoirs and estimate what portion of stored N in the reservoirs is ultimately denitrified.

Methods:

We used intact sediment cores collected from epilimnetic sediments during spring and summer stratification periods, and all sediments during winter mixing, to estimate the rate of denitrification in sediments. Denitrification on intact cores was estimated using a mass balance on N₂ concentrations occurring in the inflow and outflow of flow-through core chambers. N₂ concentrations were derived from the N₂/Ar ratio, measured using membrane inlet mass spectrometry.

Hypolimnetic denitrification was estimated by monitoring the N₂/Ar ratio in the hypolimnion of the three study reservoirs through the period of summer stratification in 2010. Briefly, water samples from 4m, 6m, and 8m were collected weekly and preserved immediately with zinc chloride. N₂/Ar ratio of these samples was measured using MIMS as described previously. The rate of N₂ accumulation was estimated by assuming that Ar concentrations were controlled only by temperature and that the slope of a statistically significant linear regression of N₂ concentration versus time represented the N₂ accumulation rate.

Nitrogen retention in reservoirs was calculated as the difference between riverine N inputs and outputs. Nitrogen inputs to reservoirs were estimated using the rating curve method (Shivers and Moglen 2008). Briefly, a relationship between stream stage, streamflow, and total N concentrations were derived for inflowing and outflowing streams to estimate N inputs from continuously monitored stream stage. Yields from gauged streams were applied to ungauged streams to estimate whole-system inputs.

Results:

Epilimnetic Sediment Denitrification – Average net sediment N₂ flux rates for all three lakes are provided in Figure 1. All three lakes exhibit net denitrification (i.e. positive net N₂ flux) during winter. This condition coincides with measurable nitrate-nitrogen (NO₃-N) in the lakes during this time. Spring and summer net N₂ flux was either negative (i.e. net N₂ fixation in May 2010) or zero (i.e. equal amounts of denitrification and N₂ fixation). Nitrate concentrations in the epilimnion of these lakes during summer is below detection levels and is probably the limiting factor that inhibits denitrification and cause net zero sediment N₂ flux from epilimnetic sediments during spring and summer stratification.

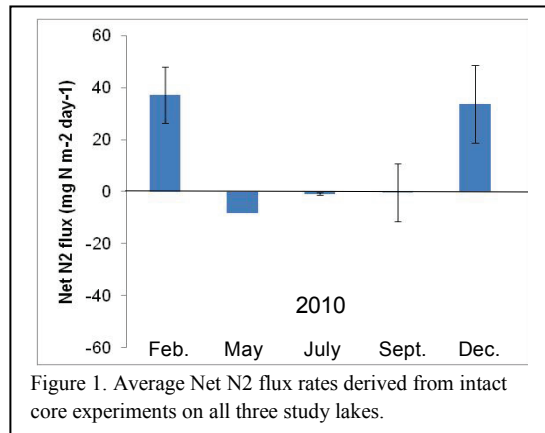


Figure 1. Average Net N₂ flux rates derived from intact core experiments on all three study lakes.

Hypolimnetic Denitrification – Hypolimnetic N₂ accumulation from one of the study lakes is shown in Figure 2. N₂ gas accumulated at a linear rate throughout the period of spring and summer stratification in Lake Fayetteville. The N₂ accumulation in the hypolimnion was equivalent to a denitrification rate of 62 mg N m⁻² day⁻¹. When combined with sediment denitrification rates, the whole-ecosystem denitrification flux in Lake Fayetteville was 17 ± 9 (S.D.) g N m⁻² year⁻¹.

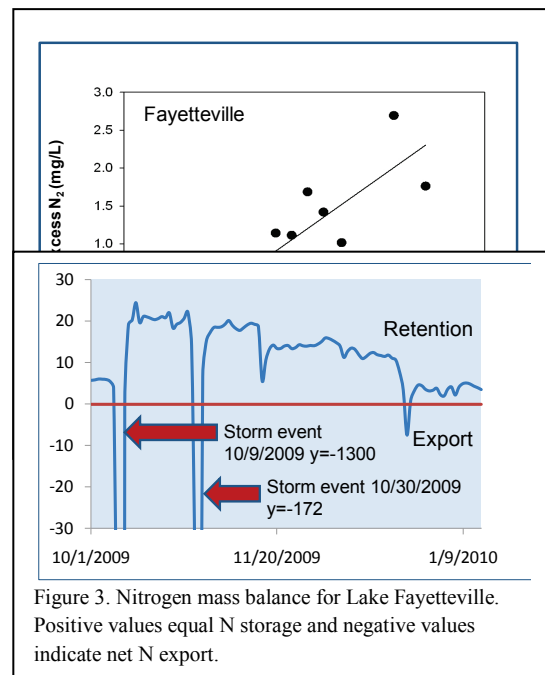


Figure 3. Nitrogen mass balance for Lake Fayetteville. Positive values equal N storage and negative values indicate net N export.

Whole-lake N mass balance – An example of whole-lake N mass balance for Lake Fayetteville is shown in Figure 3. We are currently developing mass balance estimates for the entire study period. Nitrogen storage and export was highly dependent upon hydrology. During baseflow conditions the reservoirs were tremendous N sinks. However, the reservoirs acted as net N sources from brief periods during storm events. When considered together, preliminary estimates indicate that the reservoirs store between 10 – 50 g N m⁻² year⁻¹.

Conclusions:

Reservoirs can be substantial N sinks and are hotspots for denitrification. As much as 50 g N m⁻² year⁻¹ may be trapped by reservoirs, and between 34 – 100% of this stored N is eventually denitrified. These estimates are preliminary and require substantial refinement. However, these preliminary data suggest

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that reservoirs are very important N sinks and transformers in the landscape that protect downstream water quality by permanently removing reactive N from surface waters.

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Research Publications Stemming from this Project:

Grantz, E. 2011. Denitrification efficiency in water impoundment reservoirs, Department of Crop, Soil, and Environmental Sciences, University of Arkansas.

Information Transfer Program Introduction

Dissemination of information is one of the main objectives of the Arkansas Water Resources Center. To achieve this objective, AWRC sponsors an annual water conference held in Fayetteville, Arkansas, which draws approximately 100 researchers, students, agency personnel, and interested citizens to learn about current research and hot topics in water resources throughout the State. AWRC also co-sponsors workshops and other water-related conferences in the state and region.

The AWRC maintains a technical library containing over 900 titles, many of which are available online. This valuable resource is utilized by a variety of user groups including researchers, students, regulators, planners, lawyers and citizens. Many of AWRC library holdings have been converted to electronic PDF format which can be accessed via the AWRC website at www.uark.edu/depts/awrc/publications.htm. AWRC is continuing to add archived documents from the library to this electronic data set, and all new titles are added when received.

AWRC INFORMATION TRANSFER PROGRAM

Basic Information

Title:	Arkansas Water Resources Center Information Transfer Program
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End Date:	2/28/2011
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Congressional District:	3 rd Congressional District of Arkansas
Research Category:	Not Applicable
Focus Category:	Surface Water, Groundwater, Water Use
Descriptors:	
Principal Investigators:	Brian E. Haggard

Publications

1. Massey, L.B., B.E. Haggard, J.M. Galloway, K.A. Loftin, M.T. Meyer, and W.R. Green. 2010. Antibiotic fate and transport in three effluent-dominated Ozark streams. *Ecological Engineering* 36(7): 930-938.
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Student Support

Category	Section 104B Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	4	0	0	3	7
Masters	2	0	0	2	4
Ph.D.	3	0	0	0	3
Post-Doctoral	0	0	0	0	0
Total	9	0	0	5	14

Notable Awards and Achievements

Brian Haggard, Director of the Arkansas Water Resources Center received the College of Engineering Outstanding Researcher award for the department of Biological and Agricultural Engineering at the University of Arkansas, 2010-2011.