Illinois Water Resources Center
Annual Technical Report
FY 2013

Introduction

The Illinois Water Resources Center (IWRC) serves the people of Illinois by providing science-based information and resources about the water research, policy, and education developments in the state. Located at the University of Illinois at Urbana-Champaign, IWRC is near the center of a diverse state that includes both the third largest metropolitan area in the United States, Chicago, and some of the most active coalfields in the nation; its water resources are as disparate as Lake Michigan, the Mississippi River, and a vast network of ditches draining Illinois' rich agricultural fields. Consequently, the associated research and technology needs for these water resources are varied and rapidly changing. This was particularly true of 2013, which saw floods, record cold, intense focus on the invasive species pathways created by the creation of the Chicago Area Waterways System 100 years ago, the passage of hydraulic fracturing legislation in Illinois, and the issuing of consent degrees governing stormwater and sewage overflows that have long plagued Chicago.

In 2013, IWRC researchers funded by 104B and 104G, the U.S. Geological Survey, and the U.S. Army Corps of Engineers completed 3 projects and continued work on 6. Outreach and technology transfer activities have included the biennial Governor's Conference on the Management of the Illinois River System, a drought workshop, updating and continued redesigning of the website, maintaining the blog and social media presence, supporting local agencies through Smallwatersupply.org and the Private Well Class, and facilitating the development of a nutrient reduction strategy for Illinois.

Research Program Introduction

None.

Determining the Fate and Toxicity of Polycyclic Aromatic Hydrocarbons Associated with Coal-Tar and Other Carbonaceous Material Particles in Urban Lakes

Basic Information

Title:	Determining the Fate and Toxicity of Polycyclic Aromatic Hydrocarbons Associated with Coal-Tar and Other Carbonaceous Material Particles in Urban Lakes
Project Number:	2011IL239G
Start Date:	8/1/2011
End Date:	7/31/2014
Funding Source:	104G
Congressional District:	15 IL
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Sediments, Surface Water
Descriptors:	None
Principal Investigators:	Charles J. Werth, Michael Jacob Plewa

Publications

There are no publications.

IWRC ANNUAL REPORT

USGS-NIWR Project Title:
Determining the Fate and Toxicity of Polycyclic Aromatic Hydrocarbons Associated with Coal-Tar and Other Carbonaceous Material Particles in Urban Lakes

Project PIs and Contact Information:
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Problem and Research Objectives:
Particle associated contaminants (PACs) have resulted in the impairment of thousands of streams, lakes, and reservoirs; PACs were responsible for fish-consumption advisories for 39 percent of total river mileage and 43 percent of total lake acreage in the United States in 2008. Results from recent water quality surveys indicate that metal, polychlorinated biphenyl, and DDT concentrations in freshwater sediments have generally decreased since their peak in the mid 1970's, consistent with their use and regulatory histories. However, total concentrations of polycyclic aromatic hydrocarbons (SPAHs) have increased, and generally with increasing urbanization. PAHs are toxic to aquatic life, and many are probable or suspected carcinogens. This is of special concern because many urban surface waters are used for human recreation (e.g., fishing, swimming) and/or drinking water.

Sources of particle-associated PAHs in urban lake sediments are located both within and outside the watershed. They include point (e.g., industrial emissions) and nonpoint (e.g., automobiles) combustion sources, asphalt from roads and parking lots, vulcanized rubber products such as automobile tires, and coal-tar and asphalt based sealcoats on parking lots and driveway pavement and roofs. Results from a number of our recent studies indicate that coal-tar pavement sealcoat is fluvially transported into urban streams and lakes with runoff, and can be the dominant source of PAHs in urban streams and lakes.

The overall goal of this study is to determine the fate and toxicity of PAHs associated with coal-tar particles in urban lake sediments. The specific objectives of this study are listed below.

1) Determine the sorption equilibrium and desorption kinetics of PAHs in coal-tar and other carbonaceous material particles that comprise urban lake sediments. We hypothesize that sorption capacities are low and release rates are high for PAHs in coal-tar and other less condensed carbonaceous materials (CMs) compared to highly condensed CMs like black carbon char and soot.

2) Determine PAH losses and redistribution associated with coal-tar particles in urban lake sediments. We hypothesize that lower molecular weight PAHs are released from coal-tar particles soon after burial (weeks to months) and taken up by more strongly sorbing black carbon, and that higher molecular weight PAHs are only lost to black carbon over much longer time scales (i.e., years) as phenolic and heterocyclic compounds that comprise coal-tar degrade. As a result, we hypothesize that PAHs are largely conserved in lake sediments and are not significantly released to the water column, and that sediment pore-water concentrations of PAHs decrease with aging.

3) Determine the toxicity of PAHs associated with coal-tar and other carbonaceous material particles in urban lake sediments. We hypothesize that toxicity of pore water in sediments decreases with time as PAHs and other organic pollutants redistribute from less strongly sorbing CMs like coal-tar to more strongly sorbing black carbon, and as less recalcitrant pollutants are biologically degraded over time. Such information is important because these lakes are sources of recreation and/or drinking water for large populations, and understanding coal-tar contributions to toxicity is an important step in protecting the environment and public health.

Methodology:

The proposed work combines bench scale laboratory experiments, field experiments, and laboratory analysis of field samples. It is divided into four tasks that cover 1) lake core retrieval, analysis, treatment, and in situ placement, 2) sorption isotherm and desorption kinetic profile measurement, 3) PAH and CM analysis of in situ cores, and 4) toxicity analysis of in situ cores.

Cores were taken from Whitnall Lake near Milwaukee, Wisconsin in June of 2013. A set of cores was amended with coal tar and other carbonaceous materials spiked with deuterated PAHs, and then placed back into Whitnall Lake. Another set will be used for sorption isotherm and desorption kinetic profile measurements in task 2.

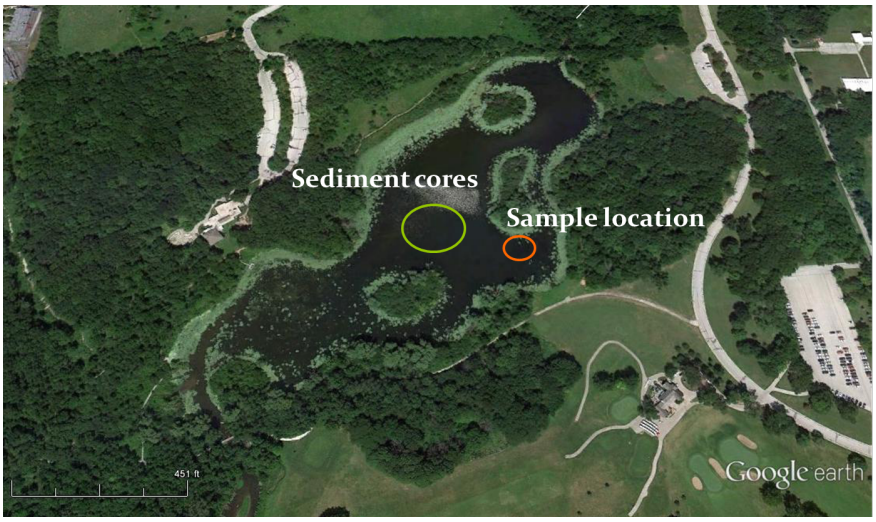

Figure 1: Location of sediment cores and sample deployment at Whitnall Park Pond

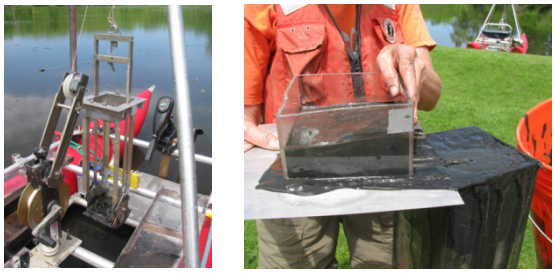

Figure 2: Taking sediment cores (credit: Peter Van Metre, USGS)

Figure 3: Sample core preparation: (a) carbonaceous materials loaded with deuterated PAHs (b) sediment and particles (c) sample cores (d) sample core holder to be pushed into lake sediment (credit: Victoria Boyd, UIUC)

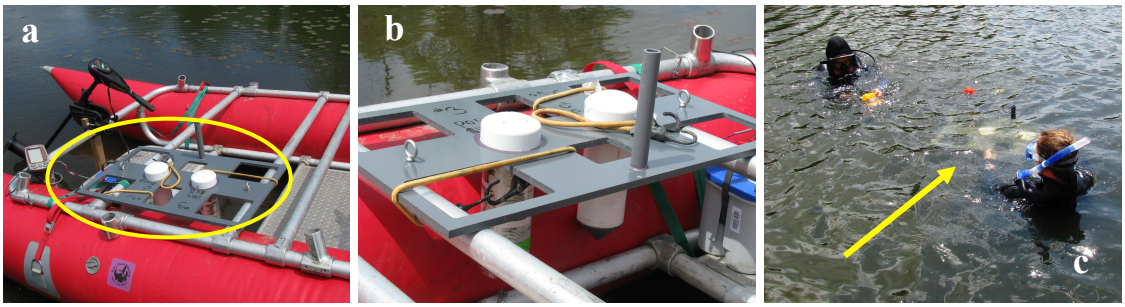

Figure 4: Placing sample cores into the lake sediment: (a) and (b) sample cores were transported to the sample location in a small boat (c) scuba divers placed the sample cores into the bottom of the lake, the arrow points to a submersed sample core (credit: Peter Van Metre, USGS)

The carbonaceous materials used in the field study included particles of coal tar, asphalt, charcoal, and soot. Each material was loaded with three different PAHs: a low molecular weight (160-188 g/mol), medium molecular weight (212-240 g/mol), and high molecular weight (264-288 g/mol) PAH. The purpose of using a range of molecular weights is to determine if there is a significant difference in PAH transport with changing molecular weight. PAHs which have been deuterated can be distinguished from natural PAHs using mass spectrometry, allowing for the differentiation between PAHs which were loaded onto the materials and those that are naturally present. PAHs added to carbonaceous particles comprised less than 10% of background concentrations.

Spiked cores placed back in Whitnall Lake will be retrieved after 1 year, 1.5 years, and 2 years, and then analyzed to determine deuterated and non-deuterated PAH concentrations, and concentrations of PAHs on individual CM particles. Measurement of

deuterated PAH concentrations will allow us to determine if PAHs associated with each type of CM were lost to the watershed, transferred to another CM, or degraded over time. The first round of sample core collection is scheduled for May 20, 2014.

Sorption isotherm measurements will be performed to determine the affinity of PAHs for different carbonaceous materials, including asphalt, coal tar, soot, and charcoal. Sorption kinetic profiles measurements will be performed to determine the time scales that PAHs transfer between carbonaceous materials in lake sediments.

The toxicity of extracts from the original cores, and spiked cores retrieved at different time intervals, will be determined.

Principal Finding and Significance:

Preliminary analysis of the lake sediment shows a decreasing concentration of PAHs with increasing depth. Figure 4 shows the contribution of individual PAHs to the total concentration in the sediment. The PAHs are divided into low (orange), medium (green), and high (grey) molecular weight. A composite sample, which is a mixture of all depths, is shown for comparison.

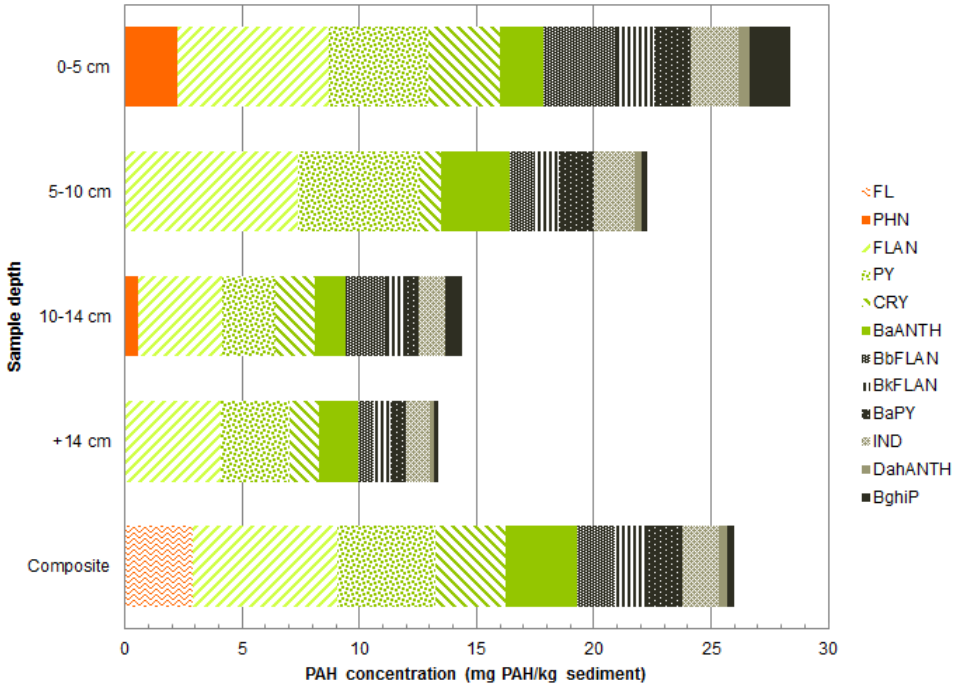

Figure 4: Individual PAH contribution to total PAH concentration (credit: Victoria Boyd, UIUC)

Medium molecular weight PAHs are the major contributors to overall PAH concentration. The concentrations measured are similar to those measured by Van Metre and Mahler (2010) in urban lakes in Minnesota and Wisconsin. However, the concentrations of PAHs were about an order of magnitude higher than those measured by Van Metre and Mahler (2010) at the same pond several years earlier. This could be due to increased urbanization in the area after 2010, which would lead to increased runoff of PAHs.

Notable Achievements:
We have developed the methods necessary to amend the carbonaceous material particles with deuterated PAHs, and to separate out the different carbonaceous material particles from the sediments after core retrieval. The deployment of the field study in 2013 was a significant milestone for the project.

Students supported with funding:
In the summer of 2012 two graduate students were hired. Ms. Tory Boyd was hired to perform the all work except toxicity testing. Ms. Boyd obtained her MS degree at Illinois, and the work in this proposal represents the bulk of her PhD thesis. The other graduate student is Ms. Azra, who is performing the toxicity testing.

Publications and presentations:
This work was presented at the Environmental Engineering and Science Symposium at the University of Illinois on April 3, 2014.

References:
Van Metre, P.C., Mahler, B.J., 2010. Contribution of PAHs from Coal-tar Pavement Sealcoat and Other Sources to 40 U.S. Lakes. Science of the Total Environment 409, 334-344.

Photos and figures credited to Boyd and Van Metre can be used in IWRC publications.

Award--Discharge Rating of Chicago River Controlling Works

Basic Information

Title:	Award--Discharge Rating of Chicago River Controlling Works
Project Number:	2013IL266S
Start Date:	12/1/2012
End Date:	11/30/2013
Funding Source:	Supplemental
Congressional District:	
Research Category:	Engineering
Focus Category:	Hydrology, Surface Water, Management and Planning
Descriptors:	
Principal Investigators:	Brian Miller, Marcelo Horacio Garcia

Publications

There are no publications.

Problem and Research Objective

As a part of the Chicago Area Waterway System (CAWS), the Chicago River has an important role in flood-control efforts for the Chicago metropolitan area. Water levels in the Chicago River can be lowered during intense rainfall events in order to minimize backwater effects on tributary streams, thereby minimizing upstream flooding. Water-levels in the Chicago River can be controlled by opening and closing a series of locks and sluice gates at the Chicago River Controlling Works (CRCW), located on Lake Michigan at Chicago Harbor; opening the lock at on the Chicago Ship and Sanitary Canal in Lockport, Illinois; and opening the lock on the North Shore Channel in Wilmette, Illinois. Of particular interest is a characterization of the total volume of water that back flows from the Chicago River into Lake Michigan via the CRCW. This location is relatively close to the drinking water intakes for the City of Chicago and poses a potential contamination risk from combined sewer overflow (CSO) events that occur along the CAWS during large storm events.

Previously, the CAWS has been investigated via a three-dimensional numerical model (Sinha et al., 2012) in order to characterize flow conditions and contaminant transport during wet-weather events. At this time, however, the conveyance capacity of the CRCW lock and sluice gates are not well known. There has only been a single equation available for estimation of the flow discharge through a single sluice gate and it is not representative of the total discharge when multiple sluice gates are open as well as the lock gates. Therefore, development of a method to more accurately estimate flow discharge through the lock and sluice gate structures at the mouth of Chicago River has become important for flood risk management and the Lake Michigan diversion.

The main objective of the current study is to develop discharge rating curves and hydraulic performance graphs (Yen and González-Castro, 2000) for the lock and southern/northern sluice gate batteries at the Chicago River Controlling Works (CRCW).

To obtain discharge ratings of the lock and sluice gate structures at CRCW (Chicago River Controlling Works), several flood cases are investigated by using 3-Dimensional Computational Fluid Dynamics (3D-CFD) simulations. For this purpose, a physical domain that includes the hydraulic structures and a portion of the Chicago River and Lake Michigan is generated and used as the computational domain with various boundary conditions applied for different test runs. The result of the individual modeling runs are used to construct a discharge rating curve for the structures. Additionally, another numerical simulation was implemented to determine the

influence of trash screens on energy losses through the sluice gates (Baines and Peterson, 1951).

The overall procedures for this study are detailed as follows:

- Examine the effect of different initial/boundary conditions on flow through the CRCW.
- Examine the effect of different operating scenarios on flow through the CRCW (i.e., different combinations of sluice gate/lock-gate openings)
- Development a discharge rating curves of each hydraulic structure for the different operating scenarios.
- Perform analytical and numerical studies on the effects of trash screens on the discharge rating curves for the sluice gates.
- Application of the discharge rating curves to a real flood case and calculation of total flow discharge throughout the flood.

Moreover, to better understand the hydraulics and fluid dynamics at the CRCW, flow patterns occurring in the vicinity of the locks and sluice gates are investigated and visualized.

Methodology

In this study three finite-volume CFD codes are employed to investigate the flow through the hydraulic structures and to develop the discharge rating curves: 1) ANSYS FLUENT, 2) Flow-3D, and 3) SSIIM (Sediment Simulation In Intakes with Multiblock option).

Firstly, the non-hydrostatic finite-volume commercial CFD codes, ANSYS FLUENT and Flow-3D are employed to solve the three dimensional Reynold's-averaged Navier-Stokes (RANS) equations and to investigate the discharge ratings for the hydraulic structures at CRCW as well as the hydrodynamics in that area during the flood. Both codes apply the volume-of-fluid method to track the free-surface (Hirt and Nichols, 1981), with a turbulence closure. Because field measurement during the flood is not possible, there are not real data available for the comparison. Therefore, the two commercial CFD codes, which are well-known to be verified by many cases, are implemented to support the results of each other. In the simulations, the combinations of the following boundary conditions and scenarios are considered.

- Four operation steps of the hydraulic structures, 1) opening all southern gates, 2) opening all northern and southern gates, 3) opening the lock gates halfway while maintaining step 2, and 4) opening the lock gates fully with all sluice gates

opened. These steps are exactly matched to the real operating procedures for flood control at CRCW.

- Lake level ranges between -3 ft CCD and +4 ft CCD.
- Gates open when river stage reaches +3.0 ft CCD through +4.0 ft CCD provided that river stage > lake stage.
- The initial water surface level in the Lake Michigan is controlled not to change during the simulation. A no-slip boundary condition is applied at all water-solid surface interfaces.

In addition, the RANS model, SSIIM (Olsen, 2009) is employed to perform the calculation of the time-averaged flow through a sluice gate with a screen. The screen effect in the study is investigated by substituting the netted geometry of the screen with solidity ratio of the screen. The solidity ratio is used in a porosity approach which is regarded as a force from the roughness on the water in each cell suggested by Engelund (1953). The porosity modeling is able to give smooth interactions between areas with small and large roughness so that it represents the effect of open or closed part of screen on the flow field.

Principal Findings and Significance

In this study we investigate the discharge rating curve at the CRCW in order to optimize efficient operation of the lock during high-water flow event on the CAWS. A single flow discharge equation through a sluice gate has been developed from the rating curve and has been compared to an existing formula used for flow though the sluice gates. An individual rating curve of each hydraulic structure as well as hydraulic performance graph at CRCW is developed based on CFD modeling results.

Based on the analysis, it appears that flow discharge through the hydraulic structures is very dependent on the initial water surface level at Lake Michigan. This is an important finding because the water-surface level at Lake Michigan has being observed to be decreasing for the last several decades. This means that the discharge characteristics are likely to vary over time and a single equation is unlikely to be sufficient to estimate discharge though the CRCW over time. Moreover, determination of the velocity distribution and turbulence characteristics of the flow through the hydraulic structures will aid in updating the operation guidelines (if necessary) and will help in developing guidelines for maintaining the structures against a flood situation.

Notable Achievements

This research resulted in the following achievements:

- Development of discharge rating curve as well as hydraulic performance graph for efficient operation of the lock and sluice gates at Chicago River Controlling Works.
- Estimation of Screen effect on the flow field through sluice gates by using a porosity approach in numerical simulations.
- Visualization of flow field including turbulent flow structures around hydraulic structures.

Students Supported with Funding

The following staffs in the Department of Civil & Environmental Engineering, University of Illinois were supported with the research grant:

- Su Jin Kim, postdoctoral research associate

Publications and Presentations

Due to the on-going nature of the project, no official reports or presentations have been based on this work at this time.

References

Baines, W. D., E. G. Peterson, 1951, An investigation of flow through screens, Transactions of the American Society of Mechanical Engineers, 73, 467-480.

Engelund, F. A., 1953, On the laminar and turbulent flow of groundwater through homogeneous sand, Transactions Danish Academy of Technical Sciences, 3(4), 1.

Hirt, C.W.; Nichols, B.D. (1981), "Volume of fluid (VOF) method for the dynamics of free boundaries", Journal of Computational Physics 39 (1): 201–225

Olsen, N. R. B., 2009, A three-dimensional numerical model for simulation of sediment movements in water intakes with multiblock option, Users manual: Ver. 1 and 2, Division of Hydraulic and Environmental Engineering, The Norwegian University of Science and Technology, URL: http://folk.ntnu.no/nilsol/ssiim/

Shinha, S., X. Liu, M. H. Garcia, 2012, Three-dimensional hydrodynamic modeling of the Chicago River, Illinois, Environmental Fluid Mechanics, 12(5), 471-494.

Yen, B., J. González-Castro, 2000, Open-channel sapacity determination using hydraulic performance graph, Journal of Hydraulic Engineering, 126(2), 112-122.

Hydrologic Impacts of an Alternative Agricultural Land Use: A Woody Perennial Polyculture

Basic Information

Title:	Hydrologic Impacts of an Alternative Agricultural Land Use: A Woody Perennial Polyculture
Project Number:	2013IL268B
Start Date:	3/1/2013
End Date:	2/1/2014
Funding Source:	104B
Congressional District:	15
Research Category:	Biological Sciences
Focus Category:	Management and Planning, Conservation, Ecology
Descriptors:	None
Principal Investigators:	Evan DeLucia, Kevin Wolz

Publications

There are no publications.

Hydrologic impacts of an alternative agricultural land use: a woody perennial polyculture

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Problem and Research Objective

Conversion of the Midwestern U.S. from native vegetation to intensive row crop agriculture dominated by the corn-soybean rotation has severely altered the region's hydrologic cycle. The physiological and physical properties of the vegetation, along with soil moisture properties, affect the weather and climate by altering the transfer of energy and water from the land surface to the atmosphere. The once-dominant matrix of oak savanna contained a diverse mix of perennial plants, which had very different physiological and physical properties than the now-dominant monocultures of annual crops. This conversion has reduced leaf and stem area, increased stomatal conductance, shortened growing season, decreased rooting depth, and reduced surface roughness.

Restoring the hydrologic cycle of the region, along with other valuable ecosystem services, has important implications for climate change adaptation and mitigation, water quality, and agricultural production. While complete reversion to native ecosystems would likely eventually restore the Midwest's natural hydrologic cycle and other ecosystem services, this option is clearly not viable given the growing population's ever-increasing need for calories (of both food and fuel). Here, we propose an alternative land-use option for the U.S. Midwest that maintains current economic and agricultural capacity while substantially altering hydrologic and ecological processes. This system is a woody, perennial polyculture (WPP) that has the macrostructure and function of a Midwestern oak savanna, the once-dominant ecosystem of the region, but has the composition and management of a modern agricultural system.

The woody and perennial growth habit, extended growing season, low-chemical requirements, heterogeneous structure, and diverse composition give the WPP the potential to ameliorate the hydrologic and environmental impacts described above. While profitable, large-scale examples of this type are already in place on once-degraded farmland across the Midwestern U.S., there has been no direct comparison of the hydrologic impacts of a WPP to the corn-soybean rotation. Our project studies the potential of a WPP to alter the hydrologic cycle in a side-by-side comparison to a corn-soybean rotation.

Methodology

This project utilizes a research site established in the spring of 2012 at the University of Illinois at Urbana-Champaign. The site consists of four replicates each of WPP and corn-soybean rotation arranged in a complete randomized block design. Site land use history has been conventional Illinois agriculture for over 100 years, allowing an ideal comparison for modeling conversions statewide. The site's 3,200 woody plants include 6 species: chestnut, hazelnut, and several varieties each of apple, grape, raspberry, and currant.

A robust combination of technologically advanced field measurements and state-of-the-art modeling techniques are being used to test this project's hypotheses by comparing the hydrologic cycle of a WPP to the corn-soybean monoculture. High-frequency soil moisture measurements (every three days), continuous precipitation monitoring, and measurements of plant stomatal responses combine to provide a complete picture of the major water fluxes and pools. The surface water runoff and infiltration measurements described in the original proposal were abandoned due to the relatively flat slope of the research site and negligible preexisting overland flow. Focus, instead, has been on capturing heterogeneity with the soil moisture measurements and discerning species-specific influences on evapotranspiration.

In the coming year, this field data will be combined with temporal and spatial modeling of hydrologic processes using the DayCENT biogeochemical model. Integration of modeling has been pushed back as the restriction of funds prevented enough field data collection to make proper model

parameterization possible. A second, more complete, year of field data will make the modeling procedure much more robust.

Principal Findings and Significance

1) The second year of growth in the WPP system has approximately the same daily evapotranspiration as the soybean control blocks, indicating that it will take a while before the WPP system has surpassed the corn-soybean rotation.
2) Even in just the second year of growth, the two different row-types that make up the WPP system studies had dramatically different rates of evapotranspiration, with rows containing the fast-growing bramble species transpiring much more than rows containing currants and long-lived nut trees. Analyses of different row compositions like this can provide insight into designing optimal systems with specific hydrological goals. The brambles may grow quickly and have a large impact on evapotranspiration now, but the long-lived tree species may dominate in the long run.
3) They alleys of hay between rows of woody plants in the WPP system contribute much more to the system's water use in the early spring and fall, with the woody plants dominating at mid-summer. Understanding the temporal contribution of the different WPP system components to evapotranspiration can provide insight into designing optimal systems with broader seasons of activity and higher productivity.

Notable Achievements

In the first year of hydrologic data collection, the soil moisture measurements were successfully collected regularly throughout the growing season (Figure 1) and used to calculate daily evapotranspiration. The method for calculating evapotranspiration was improved upon by adding in a visual observation of the drain tile outlet that drains the research site. This visual observation provides a visual confirmation of any changes in the drainage state of the field.

Cumulative growing season evapotranspiration

Hydrologic measurements of the different component rows have also been combined with carbon and nitrogen data to give a more complete picture of the potential biogeochemical impacts of WPP systems, including the agriculturally important metric: water use efficiency.

The DayCENT model was chosen as the most appropriate model for both corn-soybean rotation and WPP system. Its hydrologic output along with its other biogeochemical outputs will become an important tool over the next few months as the model is learned and over the next few years

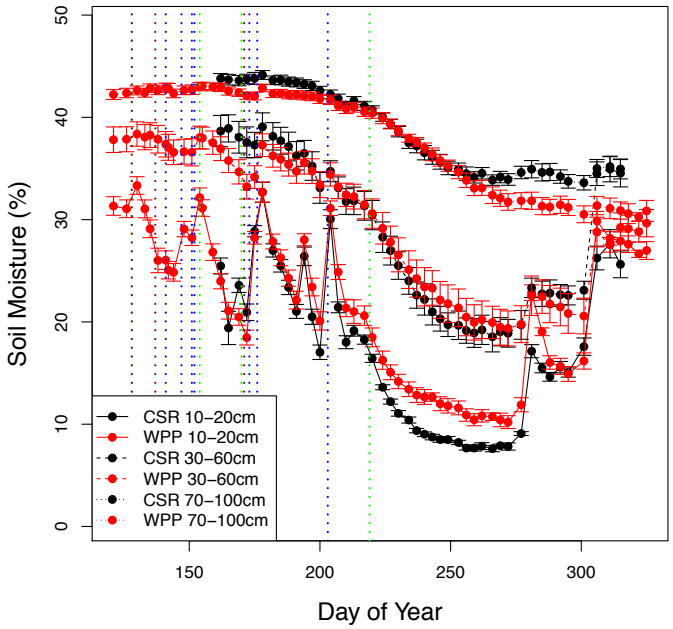

Figure 1. Averages by depth of high-frequency soil moisture measurements taken in the woody perennial polyculture (WPP) and corn-soybean rotation (CSR) treatment. Vertical blue lines indicate large rain events, and other color lines represent different management practices.

Statewide Surveillance of Emerging Flame Retardant Contamination in Illinois Waters via Fish Monitoring

Basic Information

Title:	Statewide Surveillance of Emerging Flame Retardant Contamination in Illinois Waters via Fish Monitoring
Project Number:	2013IL269B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	12
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	None
Principal Investigators:	Da Chen

Publications

There are no publications.

Project Title

Statewide Surveillance of Emerging Flame Retardant Contamination in Illinois Waters via Fish Monitoring

Principle Investigator

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Problem and Research Objective

Human activities generate large amounts of a wide range of pollutants. Some may impair water quality, aquatic ecosystem and human health. Current efforts of monitoring anthropogenic pollution in Illinois have largely focused on legacy pollutants. There is a lack of information on the spatial and temporal distribution of emerging contaminants, such as brominated flame retardants (BFRs), in Illinois aquatic environment. BFRs are of high concern as some of them have demonstrated environmental persistence, bioaccumulative and toxic potentials. This project aims to investigate the spatial and temporal distribution of BFRs in rivers and lakes across the state of Illinois via fish monitoring. The findings will provide preliminary understanding of the status of BFR contamination and associated risks in Illinois waters.

Specific goals of this project include: (1) Characterization of priority BFR contaminants in Illinois waters (Phase I); (2) Identification of impaired systems (Phase I); and (3) Retrospective investigation of temporal trends of contamination in selected hotspots (Phase II).

Methodology

Fish samples utilized by this project were retrieved from the Illinois Fish Contaminant Monitoring Program (FCMP). Two species, common carp (*Cyprinus carpio*) and channel catfish (*Ictalurus punctatus*), were selected as bio-monitoring species for this project. They were collected from a total of 30 selective aquatic systems across the state in 2011.

Fillet tissues removed from individual fish collected at each site were combined into a composite sample by species. Composite sample was ground with diatomaceous earth, spiked with internal standards, and then subject to accelerated solvent extraction. The extract was purified by gel permeation chromatography, followed by solid phase extraction cleanup. Final extract was analyzed on gas chromatography – mass spectrometry (GC-MS) and liquid

chromatography – triple quadrupole mass spectrometry (LC-MS/MS). A total of 16 polybrominated diphenyl ether (PBDE) congeners and 19 non-PBDE BFRs were determined in this project.

Principle Findings and Significance

We have completed the Phase I study that determined priority BFRs and investigated spatial distribution of BFRs in Illinois waters. Principle findings include:

(1) The data revealed that PBDE compounds were the most abundant BFR pollutants in Illinois water. PBDE levels were approximately 98% of total BFR concentrations in fish from all sites. Hexabromocyclododecane (HBCD) and dechlorane plus (DP) were also frequently detected, but at much lower concentrations. Other non-PBDE BFR pollutants were generally below detection limits.

(2) Our study sites were characterized as potential hotspots, unimpaired/impaired urban streams and lakes, or unimpaired/impaired rural/agricultural steams and lakes. Data showed that statistically highest concentrations were found in potential hotspots (e.g. Mississippi River and Cal-Sag Channel at Rt. 83), followed by impaired urban streams and lakes. For example, median PBDE concentrations were found to be 2300 μg/kg lipid weight in carp from hotspots and 1060 from impaired urban streams. Unimpaired urban streams and lakes, as well as impaired or unimpaired rural/agricultural steams and lakes, exhibited similar median contamination levels, generally lower than 100 μg/kg.

Notable Achievements

(1) The project revealed PBDEs are the most abundant BFR pollutants in Illinois waters. Although commercial PBDE products have been discontinued in 2004, their high environmental concentrations merit continuing monitoring. The project also raised the importance of monitoring HBCD and DP pollutants, as they are subject to continued usage without regulation.

(2) The project mapped the spatial contamination pattern of BFRs in Illinois waters. It developed a baseline for understanding BFR contamination in Illinois aquatic systems and identified contamination hotspots. Potential human exposure and heath risks via edible fishes from hotspots merit further investigations. The findings essentially contributed to the database of water pollution developed by the Illinois EPA Fish Contaminant Monitoring Program and other agencies.

Students Supported With Funding

Malgorzata Widelka, Department of Zoology, Southern Illinois University, Bachelor of Science (awarded in May 2014).

Hillary Marler, Department of Zoology, Southern Illinois University, doctoral student (expected to be awarded in December 2017).

Publications and Presentations

Widelka, M., H. Marler, M. Lydy, T. Hornshaw, D. Chen, 2013, Statewide Surveillance of emerging flame retardant contamination in Illinois waters via fish monitoring, The 34th Society of Environmental Toxicology and Chemistry (SETAC) North American Annual Meeting, Nashville, TN, November 17-21.

Widelka, M., H. Marler, M. Lydy, T. Hornshaw, D. Chen, 2014, Statewide Surveillance of emerging flame retardant contamination in Illinois waters via fish monitoring, Southern Illinois University Carbondale Annual Undergraduate Research and Creative Activities Forum, Carbondale, IL, April 7.

Influence of Water Quality and Stormwater Management on the Ecology of Mosquito-Borne Disease

Basic Information

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Publications

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Illinois Water Resources Center Annual Progress Report

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Project Title: Influence of Water Quality and Stormwater Management on the Ecology of Mosquito-Borne Disease

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Problem and Research Objective:

Urban ecosystems are notoriously prone to outbreaks of mosquito-borne diseases due to the extensive adaptations by mosquito vectors to urban environments (Bradley & Altizer 2007). Mosquitoes undergo a 'complex' life cycle involving both aquatic juvenile stages (egg, larva and pupa) and an adult terrestrial stage. Mosquitoes that have adapted to reproduce in urban environments are those that are best able to utilize the many nutrient-rich aquatic habitats that urban development often provisions. Preventing juvenile mosquito development in these habitats is considered one of the most effective strategies for reducing adult mosquito abundance and public health risk due to mosquito-borne disease and is thus a primary focus of urban mosquito control programs (Floore 2006). This is largely accomplished through the application of insecticides targeting the juvenile life stages (e.g. larvicides), and by modifying conditions or human behaviors that create or maintain productive environments for mosquito development (e.g. source reduction, public education, etc.). For these prevention programs to be effective identifying risk factors for vector mosquito production in urban aquatic habitats is required.

Development of the juvenile life stages of the primary mosquito vectors of West Nile virus (WNV) in Illinois (*Culex pipiens* and *Cx. restuans*) is closely associated with urban stormwater management systems. These structures may be particularly prolific habitats for vector mosquitoes when receiving nutrient-enriched runoff or septic effluent. High-nutrient loading in aquatic habitats encourages oviposition by these species and can alleviate negative

effects of larval competition on the rate of juvenile development and survivorship (Reiskind *et al.* 2004, Alto *et al*. 2012, Kraus and Vonesh 2012). Additionally, adult mosquitoes emerging from nutrient-rich environments are typically larger and possess greater nutrient reserves, which can enhance longevity, fecundity and dispersal range (Akoh *et al.* 1992, Drummond *et al.* 2006, Alto *et al.* 2012), and may ultimately alter their potential to acquire and transmit a pathogen.

In addition to altering conditions for developing mosquitoes, the retention of nutrient-rich runoff in stormwater management structures facilitates invasion by cattails (*Typha* spp.) and other emergent, aquatic macrophyte species tolerant of saturated, eutrophic conditions (McCormick et al. 2004, Kettenring et al. 2011). These invasive plants can competitively displace desired vegetation (e.g. turfgrass, native flood-tolerant or aquatic flora, etc.), resulting in dense, monospecific stands reaching several meters in height (Kominkova et al. 2000, Vaccoro et al. 2009), with an above-ground biomass often exceeding 1 kg / m^2 (Mason and Bryant 1975). To control this undesirable vegetation, managers of stormwater infrastructure may employ annual or semi-annual mowing, herbicide applications, or prescribed burning.

Emergent, aquatic plant growth and its management can have variable effects on the abundance and species composition of juvenile mosquitoes, depending on the plant species, type of aquatic habitat, and temporal concordance between vegetation management activities and hydroperiod (Walton 2012). In semi-permanent or permanent habitats (e.g., constructed wetlands, retention ponds), dense aquatic vegetation can provide juvenile mosquitoes refuge from predation (De Szalay and Resh 2000), and is therefore often characterized as a significant risk factor for the production of vector mosquitoes. Reducing the density of emergent vegetation has been shown to be an effective environmental management tool for diminishing juvenile mosquito abundance in these settings (De Szalay *et al.* 1995, Thullen *et al.* 2002, Lawler *et al.* 2007). However, vegetation management practices can also promote eutrophic conditions that support high juvenile mosquito densities when the resulting plant litter is later inundated and decomposes, particularly in ephemeral or seasonally flooded aquatic environments (Jiannino and Walton 2004, Walton and Jiannino 2005). Thick accumulations of plant litter in these habitats can also alter drainage, creating fragmented, nutrient-rich habitats that obstruct the movement or functional response of predators that regulate juvenile mosquito populations (Berkelhamer and Bradley 1989).

The overall objectives of this study were to examine the potential consequences to vector mosquito production resulting from colonization of two common stormwater management tools (ditches and dry detention basins) by one of the most widespread and invasive, aquatic macrophytes groups in urban landscapes (cattails), and from actions taken to control these invasive macrophytes (mowing), and to evaluate whether these effects of invasive vegetation or vegetation management on the larval ecology of vector mosquitoes are mediated by water quality. The specific goals of this study were:

<u>*Goal 1.*</u> Conduct a field survey of stormwater ditches and dry detention basins to evaluate relationships among plant composition (grasses vs. cattails), plant management (mowing), water quality and the abundance of juvenile *Culex* spp. mosquitoes.

Goal 2. Determine whether the type of plant detritus in aquatic habitats (cattails vs. turfgrass), or exogenous orthophosphate enrichment, influence the oviposition response of *Culex* spp. mosquitoes, and whether differences in the responses of *Cx. pipiens* and *Cx. restuans* to these factors are reflective of differences in the distribution of their juveniles in storm water BMPs observed in Goal 1.

Goal 3. Determine whether the type of plant detritus in aquatic habitats (cattails vs. turfgrass) or exogenous orthophosphate enrichment change the juvenile development rate of the primary epidemic vector of WNV (*Cx. pipiens*), or impact fitness characteristics of adult mosquitoes emerging from these aquatic habitats that relate to their potential to transmit human pathogens (e.g. body size, longevity).

Methodology:

Goal 1.

A total of 36 stormwater management structures (16 dry detention basins and 20 drainage ditches) were selected in the communities of Urbana, Champaign and Savoy, IL, based on dominant plant species composition and the presence of standing water in the early spring (≈1 month prior to sampling juvenile mosquitoes). Grasses (primarily turfgrass) were the dominant vegetation at 11 sites, and the remaining 25 sites were colonized by cattails. Vegetation within 17 of the study sites was mowed at least once during the study period as part of existing municipal or private maintenance programs.

Juvenile mosquito abundance and water quality at each study site were assessed at ≈2 week intervals, from 3 June to 16 August, 2013 (total 5-6 inspection dates per site). When standing water was present, a sample of mosquito larval and pupae was collected (20 dips per sample), and specimens were counted and identified to species (larvae) or genus (pupae). Hand-held meters were used to collect field measurements of dissolved oxygen, pH, conductivity, salinity and total dissolved solids. A water sample was collected from each mosquito sampling location, transported to the lab on ice and analyzed immediately for total reactive phosphorus and nitrates by colorimetry (Hach 2009). The relative influences of various site characteristics (e.g. vegetation type, mowing history, type of structure) on larval abundance were evaluated as fixed effects in a General Linear Mixed Model (GLMM). Water quality measures and lagged intervals of cumulative rainfall and mean daily air temperature in the two weeks preceding sampling, were explored as covariates. A spearman correlation analysis was also used to compare relationships between juvenile mosquito abundance and each water quality parameter.

Goal 2.

A field assay was performed to compare the oviposition response of vector mosquitoes to infusions of decaying cattail and turfgrass substrates. We also evaluated whether orthophosphate enrichment changes this response. For both plant substrates, we compared three enrichment scenarios: a) no enrichment, b) weekly addition of 0.27 mg PO_4-P / L / week, and c) a single dose of 0.81 mg PO_4-P / L added at the start of the assay. A seventh treatment consisted of

weekly enrichment 0.27 mg PO_4-P / L / week in the absence of plant substrate. The weekly enrichment rate used in this assay (0.27 mg PO_4-P / L) is comparable to the median concentration of reactive phosphorus measured in storm water BMPs contemporaneously with a high abundance of *Cx.* spp. larvae in Goal 1 (>3 per dip; Fig. 1).

The field assay was performed at 5 sites in Urbana, IL. At each study site, ovitraps representing each of seven treatments were randomly assigned to sheltered locations at least 10 m apart along the margins of woody vegetation. Ovitraps were prepared by submerging 36 g of plant substrate in 8 liters of tap water in a 19 L pail. Five and fifteen milliliters of a 13.97 mM KH_2PO_4 stock solution were added to weekly (total = 2.16 mg of PO_4-P / ovitrap) and single pulse (6.49 mg of PO_4-P / ovitrap) enrichment treatments, respectively. From 4 September to 1 October, 2012, egg rafts were collected daily from the water surface of ovitraps and the position of each ovitrap was rotated among locations within each study site. At the end of each week, ovitrap positions were re-randomized and an additional 5 ml of the KH_2PO_4 stock solution was added to weekly enrichment treatments. First instar larvae eclosing from field-collected egg rafts were identified to species. For both *Cx. pipiens* and *Cx. restuans*, the daily numbers of egg rafts in each ovitrap, as a proportion of the daily total at each site, were fit to a GLMM with a binomial distribution and logit link function. Trap location nested within study site was included as a random effect. Post-hoc, pairwise comparisons between the average proportion of egg rafts collected in each treatment were performed using a sequential Bufferoni adjustment.

Goal 3.

Two laboratory experiments were performed to examine how nutrient enrichment of the aquatic environment from plant detritus and exogenous orthophosphate inputs affect the juvenile development and adult fitness of *Cx. pipiens*. As the effects of nutrient availability are mediated by intraspecific competition, larval density was also varied within each experiment. Experiments were performed by adding 10 (low density) or 20 (high density) newly-hatched *Cx. pipiens* larvae to 360 ml of a plant infusion (with or without the addition of orthophosphate) that was allowed to decompose for 3 days prior to the experiment. After transitioning to the final aquatic life stage (pupa), mosquitoes were transferred to individual cages. To obtain an indirect measure of energy reserves acquired during juvenile development, starvation resistance was assessed in newly emerged adult mosquitoes by depriving them of food and observing them every 12 hours until death. Juvenile development time was defined as the duration from egg hatching to adult emergence. Starvation resistance was defined as the average numbers of days adults survived in the absence of food after completing their aquatic development (i.e. emergence from the pupal stage). Measurements of adult winglength (i.e. body size) will also be collected as a second measure of adult fitness (work ongoing).

The first laboratory experiment examined the effect of high orthophosphate enrichment (0.81 mg PO_4-P / L) on the juvenile development rate and adult fitness of *Cx. pipiens* reared in an infusion of decomposing cattails (4.5 g / L). Four treatments (+/- orthophosphate enrichment x 2 larval densities) were replicated four times in this experiment.

In the second laboratory experiment, we evaluated how the type (cattails vs. turfgrass) and concentration of plant substrate present in the aquatic environment influences the juvenile development and adult fitness of *Cx. pipiens*. Infusions were prepared using three concentrations of cattails (1.5, 4.5, and 9.0 g / L), and two concentrations of turfgrass (0.75 and 1.5 g / L). Each treatment was replicated 5 times.

Principle Findings and Significance.

Goal 1.

1) A substantial increase in the abundance of juvenile mosquitoes (*Cx.* sp. pupae and larvae of *Cx. pipiens* and *Cx. restuans*) occurred immediately following mowing of vegetation in stormwater structures (Fig. 2). Abundance of *Cx.* spp. juveniles was low in habitats with unmanaged vegetation or vegetation mowed >2 weeks previously. The class of structure (dry detention basin or ditch) was not a significant influence on the abundance of mosquito juveniles.
2) Dominant plant type mediated the response of *Cx. pipiens* to mowing. The abundance of *Cx. pipiens* larvae and *Cx.* sp. pupae were much greater in recently mowed turfgrass habitats than in recently mowed habitats colonized by cattails (Fig. 2a, 2c). The abundance of *Cx. restuans* larvae was not significantly influenced by plant type (Fig. 2b).
3) Total reactive phosphorus concentration varied greatly among samples (Fig. 1), and was positively correlated with the abundance of *Cx. restuans* larvae (P=0.004) and *Culex* sp. pupae (P=0.038). The abundance of *Cx. pipiens* larvae was positively correlated with reactive phosphorus concentration in dry detention basins (P=0.036), but not in ditches (P>0.05). Relationships between juvenile mosquito abundance and nitrate concentration were not significant.

Goal 2.

1) In the absence of orthophosphate enrichment, the type of plant substrate had significant and asymmetrical effects on the oviposition behavior of *Cx. pipiens* and *Cx. restuans* (open bars, Fig. 3). Consistent with our observations in Goal 1, *Cx. pipiens* deposited a greater proportion of egg rafts in turfgrass infusions, compared with cattail infusions. In contrast, *Cx. restuans* preferred to oviposit in cattail infusions.
2) Weekly enrichment of plant infusions with PO_4-P (0.27 mg / L / wk) did not affect the oviposition behavior of either species (light grey bars, Fig. 3). However, both species responded positively to cattail infusions enriched with a single, large orthophosphate dose (0.81 mg PO_4-P / L; dark grey bars, Fig. 3).

Goal 3.

1) A GLM analysis revealed that enrichment of cattail infusions with 0.81 mg PO_4-P / L did not significantly affect the juvenile development rate of *Cx. pipiens* males or females (Table 1).

2) Orthophosphate enrichment of cattail infusions had a significant negative effect on the starvation resistance of adult males (P=0.006; Table 2), and a marginally positive effect on the starvation resistance of adult females (P=0.051).
3) At high larval densities (20 per replicate), juvenile development rate of *Cx. pipiens* was significantly more rapid in turfgrass infusions, compared with infusions containing a 2 fold (males) or 6 fold (females) greater biomass of cattails (Fig. 4).
4) At low larval densities (10 per replicate), starvation resistance was greater in adult *Cx. pipiens* that completed their juvenile development in turfgrass infusions, compared with adults reared in cattail infusions with up to a 3 fold higher biomass of plant material (Fig. 5). The influence of plant substrate type on starvation resistance was not apparent for adults reared at the high larval density.

These finding demonstrate that mowing of vegetation in stormwater management structures during the growing season substantially increases the immediate risk of these habitats supporting vector mosquito production. Conversely, ditches and dry detention basins with unmanaged vegetation are associated with a relatively low abundance of *Culex* spp. juveniles. These results indicate that caution should be used when conducting maintenance activities that result in the deposition of plant debris in locations likely to collect standing water. Vegetation management practices applied during the growing season should be coordinated with public health agencies so that larval surveillance, and if necessary insecticide treatments, can be implemented to prevent production of vector mosquitoes. When possible, vegetation management should be performed in the early spring or late fall, when enrichment of aquatic habitats is unlikely to coincide with the peak seasonal activity of vector mosquitoes and WNV transmission risk.

Results from our study indicate that colonization by cattails does not increase public health risks associated with mowing of vegetation in dry detention basins and ditches. In recently mowed structures, the presence of cattails was associated with a lower relative abundance of larvae of *Cx. pipiens*, the primary epidemic vector of WNV. Compared with turfgrass, addition of cattail detritus resulted in aquatic habitats that were less attractive to ovipositing *Cx. pipiens*, provided a poorer quality environment for their juvenile development, and produced adult mosquitoes that may have a lower potential to survive long enough to acquire and transmit a pathogen (i.e. are less resistant to starvation). However, results of our field assay suggest that the negative influence of cattails on *Cx. pipiens* oviposition could be negated in mowed structures receiving high inputs of biologically active forms of phosphorus.

Similar to previous studies (Mercer *et al.* 2005, Gingrich 2006, Young *et al*. 2014), we observed a positive association between reactive phosphorus and juvenile mosquito abundance. Average mosquito abundance and reactive phosphorus concentration were both highest in recently mowed habitats. Although we did not attempt to identify the source of phosphorus loading, it is likely that these relatively high reactive phosphorus concentrations were a result of both direct inputs from runoff and endogenous release from decomposing plant detritus deposited by mowing, and represents an overall increase in nutrient availability in mowed structures. However, we regard the study design in Goal 2 and Goal 3 (experiment 1) to represent

a realistic scenario for possible interactions between cattail detritus and exogenous inputs of biologically-active phosphorus from stormwater runoff. The P concentrations used in the lab and field experiments (0.27 and 0.81 mg PO_4-P / L) are within the moderate to high range of soluble reactive P reported from urban stormwater runoff (Waschbusch *et al.* 1999), and comparable or greater P loading may occur in stormwater BMPs intercepting highly-enriched runoff from sources such as fertilized lawns or compost amendments used for erosion control (Waschbusch *et al.* 1999, Faucette et al. 2005).

Notable Achievements.

This study provides the first evidence of invasive aquatic plants and their management mediating the abundance and species composition of mosquitoes of public health significance in two common urban stormwater management tools; ditches and dry detention basins. Our study identifies a potential mechanism for the observed effects of plant species composition effects on juvenile vector communities in these habitats (i.e. oviposition preference) and demonstrates that that plant species composition can also influence important traits of adult mosquitoes produced in stormwater management structures. Our results also suggest an interaction between plant type and high exogenous phosphorus enrichment in stormwater infrastructure that could alter the species composition or abundance of juvenile vectors.

Students Supported With Funding.

Funds provided by the IWRC supported the honors thesis research of Eleanor Moen (laboratory experiments described in Goal 3), currently an undergraduate student in the School of Integrative Biology with an expected graduation date of May 2015.

Publications and Presentations.

Presentations:

Andrew Mackay, Department of Entomology Colloquium Series, December 2, 2013.

Publications:

A manuscript from this research is in preparation for submission to the journal *Ecological Applications*.

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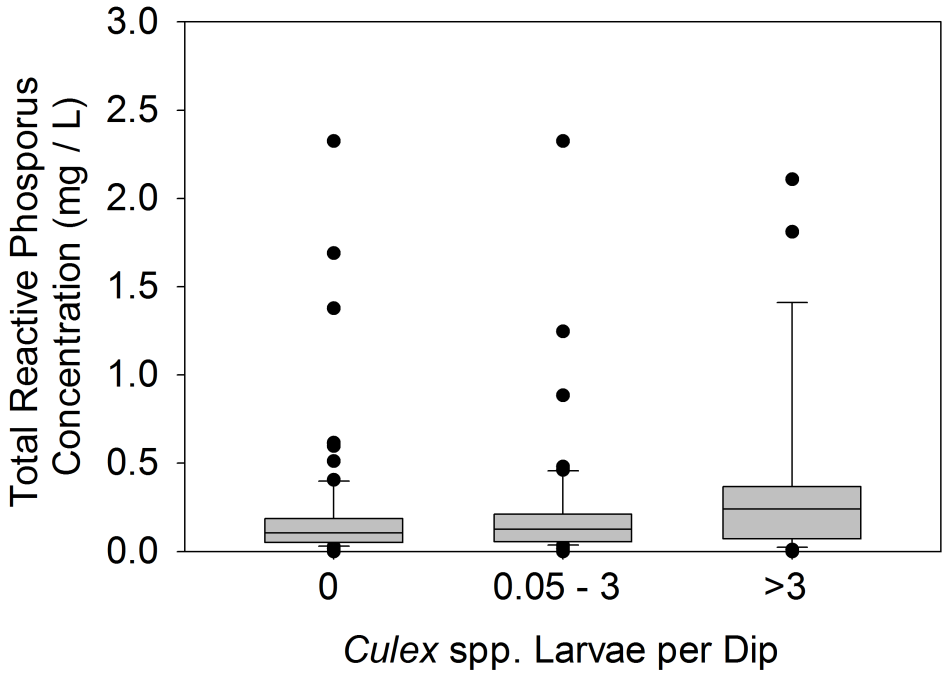

Figure 1. Box plot comparison of total reactive phosphorus concentration by larval mosquito abundance class.

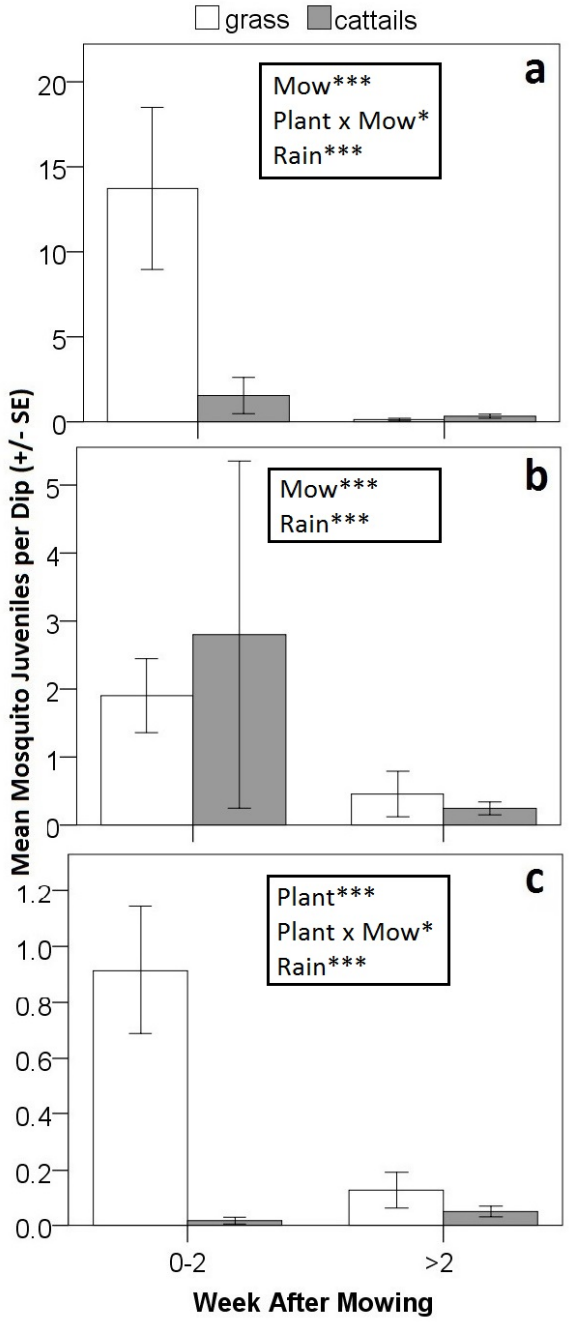

Figure 2. Effect of plant type and recent mowing on the average numbers of *Cx. pipiens* larvae (a), *Cx. restuans* larvae (b), and *Culex* sp. pupae (c) collected from stormwater ditches and detention basins, 03 June to 16 August, 2013 (observations from dry sites excluded from calculation of average values). Significant effects and interactions in GLMMs are shown for each group [**Plant** = dominant plant type (grass or cattails), **Mow** = vegetation mowed ~≤ 2 weeks prior to sampling, **Rain** = cumulative rainfall 0 to 8 days prior to sampling; * p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001].

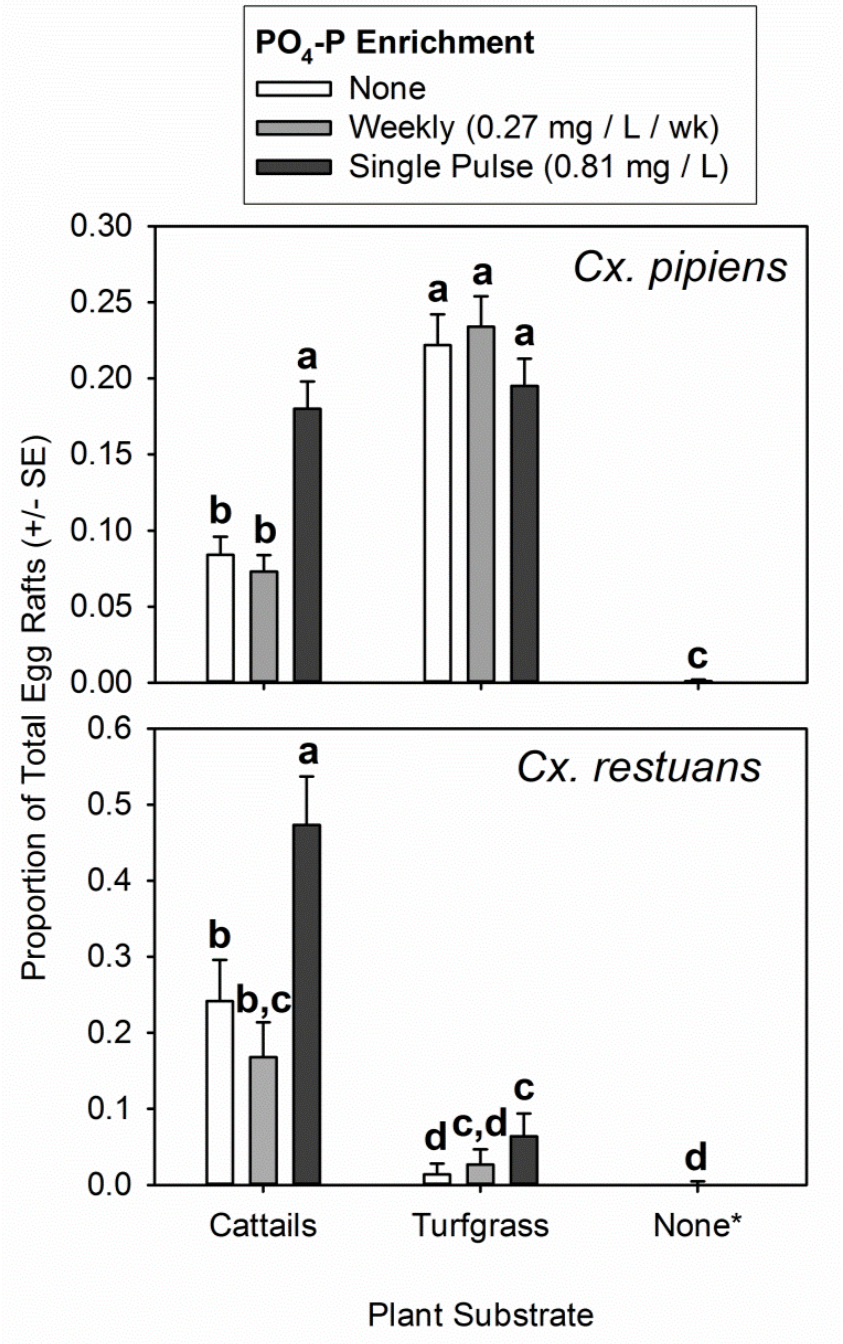

Figure 3. Influence of orthophosphate enrichment on the average daily oviposition rate of Cx. *pipiens* and *Cx. restuans* in ovitraps baited with cattails or turfgrass clippings (4.5 g / l). Mean values sharing the same symbol were not significantly different (post-hoc test with sequential bufferoni adjustment in negative binomial GLMM; P>0.05).

* Traps without plant substrate were enriched with 0.27 mg PO_4-P / L / week.

Table 1. General linear models of the influence of rearing density and orthophosphate enrichment (0.81 mg PO_4-P / L) of cattail infusions (4.5 g / l) on juvenile development time [Log_{10}(Days from hatching to adult eclosion)] for male and female *Cx. pipiens*.

Sex	Parameter	Coeff. (± 95% CI)	t	p-value
M	Intercept	0.988 (0.019)	114.5	<.001
	Orthophosphate	-0.001 (0.021)	-0.1	.939
	Larval Density	-0.018 (0.022)	-1.8	.093
F	Intercept	1.061 (0.030)	76.7	<.001
	Orthophosphate	-0.015 (0.034)	0.9	.368
	Larval Density	**-0.056 (0.034)**	**-3.5**	**.004**

Table 2. General linear models of the influence of rearing density and orthophosphate enrichment (0.81 mg PO_4-P / L) of cattail infusions (4.5 g / l) on adult starvation resistance [1 / (days surviving after emergence)] for male and female *Cx. pipiens*.

Sex	Parameter	Coeff. (± 95% CI)	t	p-value
M	Intercept	0.581 (0.036)	34.6	<.001
	Orthophosphate	**-0.064 (0.041)**	**-3.3**	**.006**
	Larval Density	**-0.186 (0.042)**	**-9.6**	**<.001**
F	Intercept	0.397 (0.056)	15.2	<.001
	Orthophosphate	0.065 (0.065)	2.2	.051
	Larval Density	-0.007 (0.065)	-0.2	.817

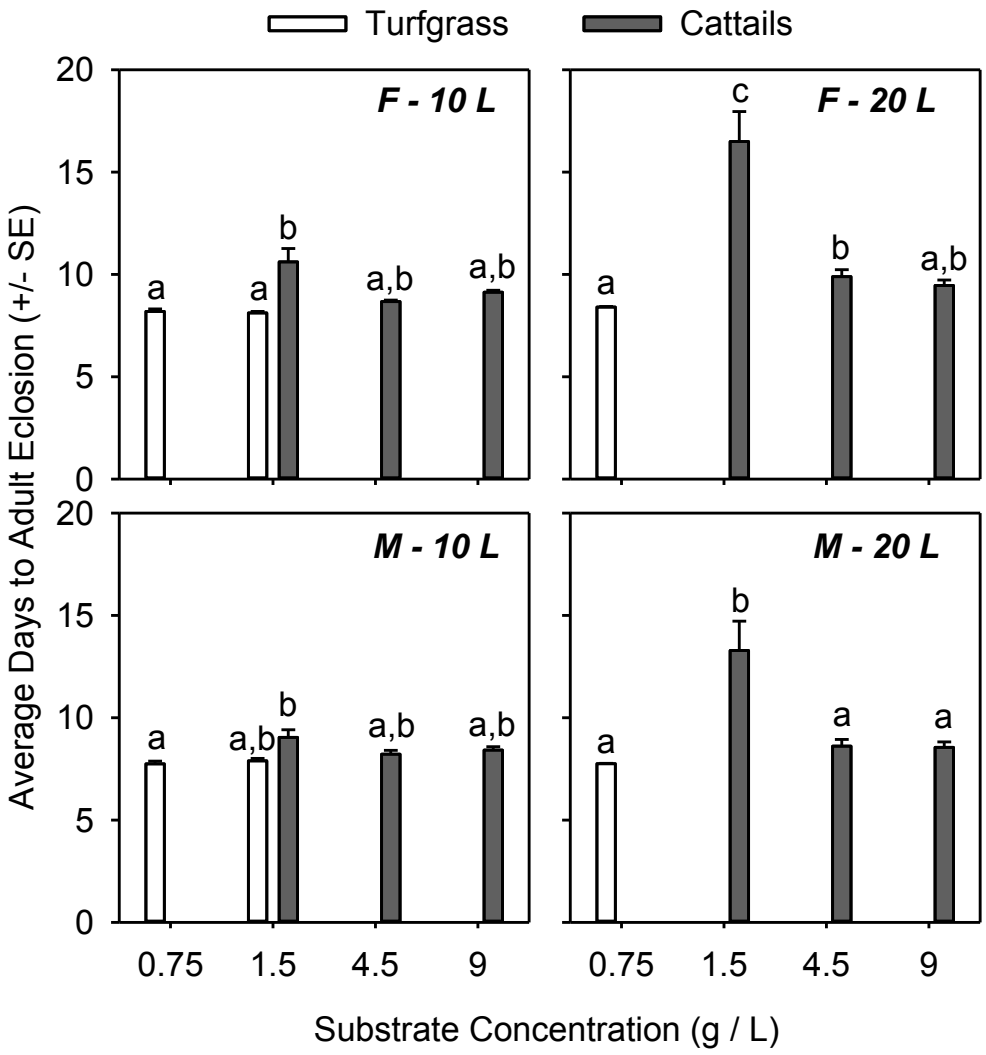

Figure 4. Preimaginal development time of male (M) and female (F) *Cx*. *pipiens* reared at low (10 L) and high (20 L) larval densities in infusions containing varying concentrations of turfgrass or cattail substrates. Data from the high turfgrass concentration (1.5 g / L) / high larval density (20 larvae / rep) treatment is excluded due to excessive larval mortality. Columns with the same letter are not significantly different (P>0.05; post-hoc test with sequential buferroni correction in GLM using 1/(Days to Eclosion) as response variable).

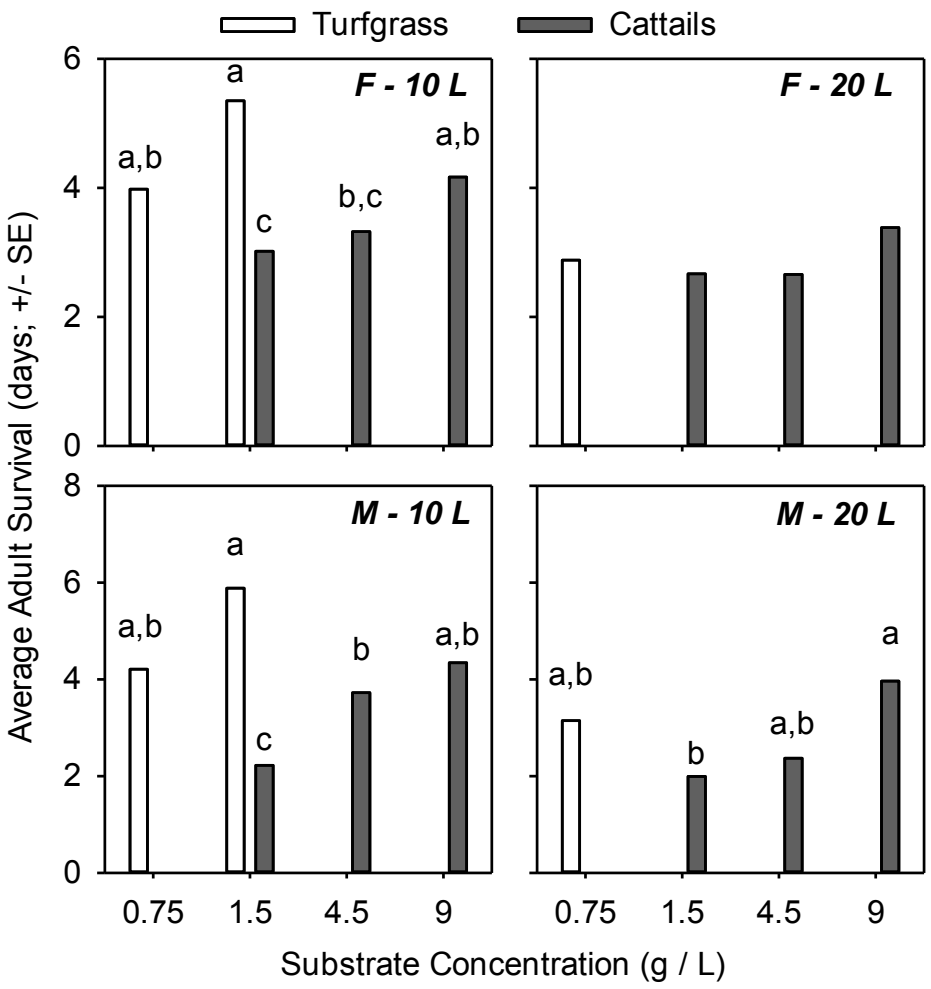

Figure 5. Starvation resistance of adult male (M) and female (F) *Cx. pipiens* reared at 2 larval densities in infusions containing varying concentrations of turfgrass and cattail substrate. Data from the high turfgrass concentration (1.5 g / L) / high larval density (20 larvae / rep) treatment is excluded due to excessive larval mortality. Columns with the same letter are not significantly different ($P>0.05$; post-hoc test with sequential Buferroni correction in GLM using Log_{10}(days surviving) as response variable).

Restoration Trajectories and Restored Floodplain Wetlands and their Ecosystem Services

Basic Information

Title:	Restoration Trajectories and Restored Floodplain Wetlands and their Ecosystem Services
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Focus Category:	Wetlands, Water Quality, None
Descriptors:	None
Principal Investigators:	Angela Kent

Publications

There are no publications.

Project Title: Restoration trajectories of restored floodplain wetlands and their ecosystem services

PI:
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Problem and research objective:
Ecosystem restoration activities operate under the presumption that establishing or restoring floodplain environmental conditions will lead to the establishment of microbial populations that are capable of nutrient removal and other ecosystem services, however, our previous results indicate that this may not be the case. Since wetland microbial communities carry out a number of desirable ecosystem services (nutrient processing, decomposition, etc.) that contribute to water quality, there is a *critical need* to better understand how soil microbial communities and their activities respond to land use change and to floodplain restoration. Failure to address this need will limit development of restoration strategies that enhance recovery of microbial processes that contribute to environmental quality.

The *objective* of this project is to evaluate restoration trajectories of microbial communities and their functions in restored wetlands throughout Illinois. We are further interested in identifying landscape, design, or management factors linked with successful delivery of microbial functions, and to improve our understanding of how wetland restoration priorities influence delivery of microbial ecosystem services. The *central hypothesis* underlying this work is that wetland microbial communities are controlled by a hierarchy of ecological factors, and that restoration of a favorable suite of environmental conditions can be expected to enhance restoration of microbial processes related to water quality. The *rationale* for the proposed studies is that improving our understanding of the ecological drivers governing microbial community structure and function will lead to ecosystem management strategies that will promote the restoration of wetland water quality functions.

Methodology
In order to determine whether microbial community composition and denitrification capacity of constructed wetlands are linked, soil was collected from 30 constructed wetlands across Illinois during the summer in 2012 and again in 2013 (this also enabled a comparison of drought vs. flood years). Fifteen of the 30 sites were paired with nearby high quality reference sites.

Soil samples consisted of 8 cores (1.9 cm diameter) with a depth of 12 cm were collected from each of 8 randomly selected quadrats along plant survey transects in each wetland.

Ferrihydride-coated PVC pipes (Indicators of Reduction in Soil – IRIS) were left in place for >1 month to evaluate soil redox conditions.

Potential rates of denitrification were ascertained in the lab immediately following collection using the acetylene block technique, followed by N_2O detection via gas chromatography.

Aliquots of soil samples were air dried for soil chemistry analyses, or freeze-dried for microbial community analyses. DNA was extracted from frozen and freeze-dried soils, and used to compare microbial community composition among soil samples using DNA fingerprinting approaches based on the rRNA operon (for total bacteria) or the *nosZ* (nitrous oxide reductase) gene (for denitrifiers),

Plant community data and wildlife data were recorded by collaborators as well.

Statistical analyses, including multivariate approaches such as nonmetric multidimensional scaling analysis and correspondence analysis, were carried out to determine if microbial community structure or denitrification function in restored floodplains is similar to those in natural wetlands. We evaluated restoration trajectories of microbial communities by comparing similarity of microbial denitrifier structure and function to reference ecosystems as a function of site age in a chronosequence of restored floodplains.

Principal findings and significance

We found that differences in denitrification capacity between constructed and reference sites were highly variable, though on average the reference sites did not perform significantly better than the constructed sites (Figure 1), contrary to our previous findings at some of these sites in 2007, suggesting that delivery of ecosystem services at restored sites may be improving over time. Average denitrification capacity was significantly higher in 2013 than in 2012, presumably due to the drought that Illinois experienced in 2012.

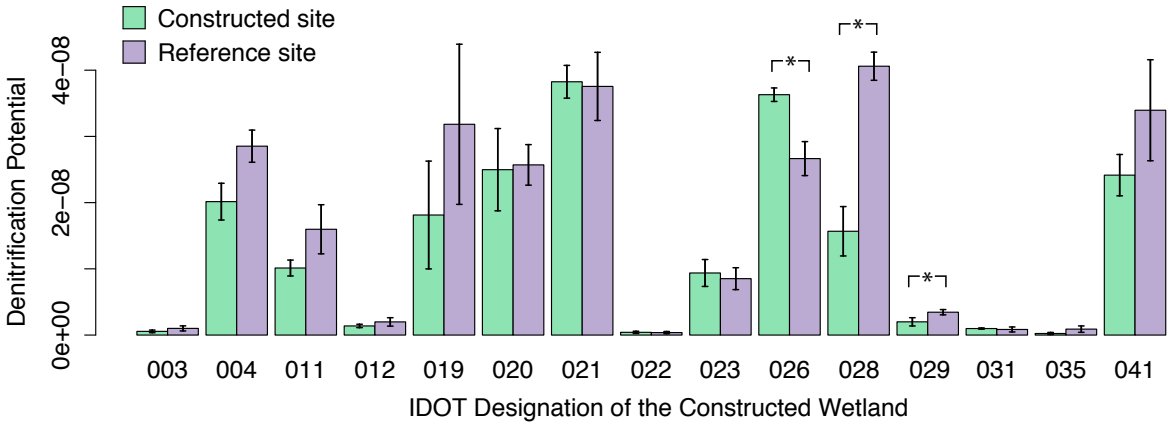

Figure 1. Comparison of denitrification potential (mol N g^{-1}soil hr^{-1}) in reference and constructed wetlands in Illinois in June/July 2013. Error bars represent ±SE. * indicates pairs of reference and restored wetlands that differ significantly in denitrification potential.

We used ferrihydride coated PVC Indicators of Reduction in Soil (IRIS) to assess soil reduction over time, and determined that in both years, soils at constructed sites had much greater reduction than at the restored sites ($p << 0.001$) (Figure 2).

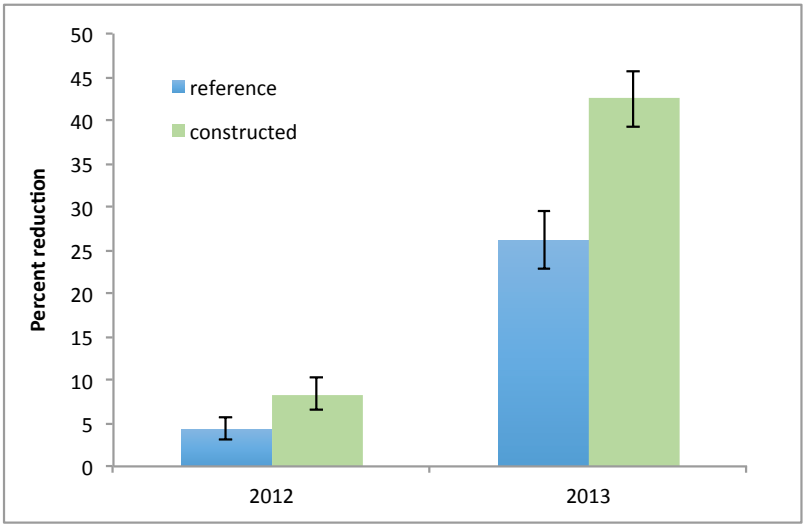

Figure 2. Soil reducing potential based on reduction of the ferrihydride coating on PVC indicatiors of reduction in soil.

We investigated whether the microbial community composition can explain the observed differences in denitrification capacity in individual wetland pairs. We found a moderately positive trend between community similarity of denitrifiers in restored and reference sites and functional similarity (Figure 3), which suggests that wetland microbial community composition is linked to denitrification.

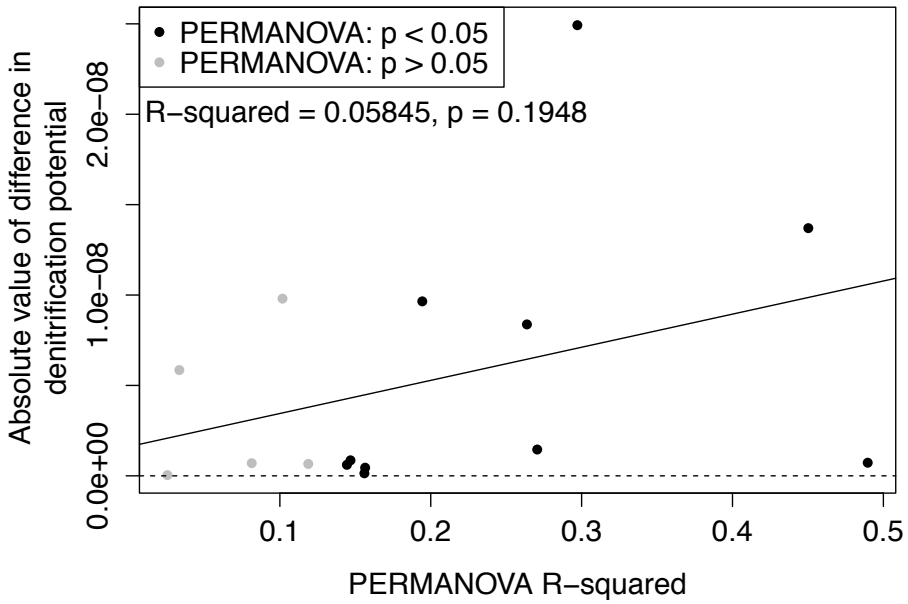

Figure 3. Regression of difference in denitrification potential in paired wetlands based on difference in denitrifier community composition in each pair of wetlands (based on Permutational Multivariate Analysis of Variance – PERMANOVA). Denitrifier communities that are more similar in composition also tend to be more similar in function.

Soil chemistry results indicate that C:N was significantly higher ($p<0.05$) in constructed wetlands in both years, and that pH tends to be lower in natural wetlands, though the difference is not statistically significant (Figures 4 and 5).

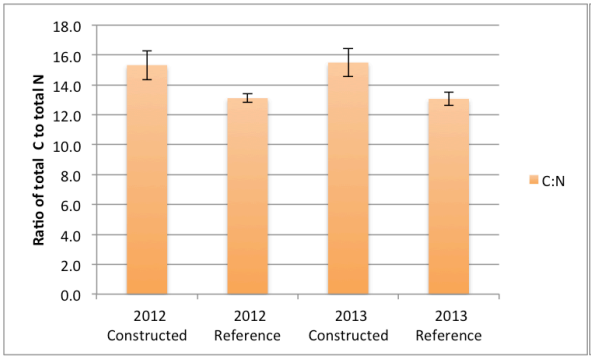

Figure 4. C:N ratios for reference and constructed wetlands in this study.

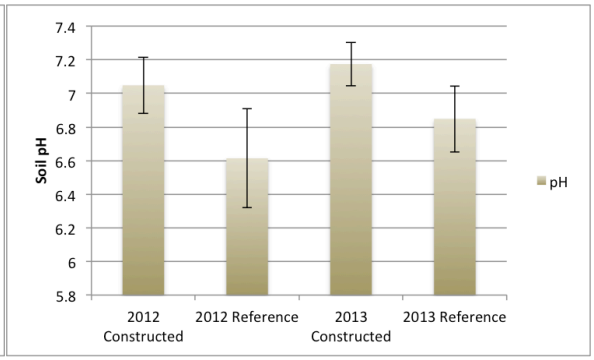

Figure 5. Soil pH for reference and constructed wetlands in this study.

We are currently using modeling techniques to determine whether the variability in denitrification is a reflection of the age of the constructed wetland. Further, microbial communities are known to be affected by edaphic factors such as pH, SOC, and redox conditions, so we expect to find a relationship between soil characteristics, community composition, and denitrification capacity.

Notable achievements:
One of the problems faced by wetland mitigation is that the restored sites do not always achieve the same level of ecosystem services as the wetlands they were intended to replace. In particular, microbial ecosystem services are typically not monitored, and are presumed to occur at established sites. Our data demonstrate that denitrification rates are quite variable, but many restored sites are performing denitrification at similar rates to their natural reference wetlands. Our efforts will identify factors that may be limiting success of denitrification in restored sites. In collaboration with other wetland researchers, we are using these data to determine if there are tradeoffs in delivery of ecosystem services. That is – does restoration of denitrification potential come at the cost of other ecosystem services, such as habitat for plants or wildlife?

Students supported with funding:
The funding has support training in wetland microbial ecology, fieldwork, experimental design, and laboratory analyses for graduate students Dora Cohen (PEEC) and Natalie Stevenson (NRES), supervised by PI Angela Kent. They will continue to receive training in data analysis as we further explore this dataset.

Publications and presentations:
Graduate students working on this project are scheduled to present results as a poster at the Joint Aquatic Sciences Meeting in Portland, Oregon in May, 2014.

Information Transfer Program Introduction

None.

Transfering Water Resources Information to the People of Illinois

Basic Information

Title:	Transfering Water Resources Information to the People of Illinois
Project Number:	2013IL267B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	15th
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	None
Principal Investigators:	Lisa Merrifield

Publication

1. Blue, Carla, ed.2013. Governor's Conference on the Illinois River program abstract book.http://www.conferences.uiuc.edu/conferences/conference.asp?ID=413

Transferring Water Resources Information to the People of Illinois

IWRC Webpage

The IWRC website was completely redesigned and rewritten during 2012. Consequently, 2013 was spent continuing to edit the webpage, update content, and rearrange troublesome sections. To reflect our growing role in research and policy facilitation in Illinois, we created an Outreach section on the webpage which includes all conference proceedings as well as a outreach support section that provides tools and ideas to researchers seeking to achieve broader impacts through their grant-funded research. 2013 also saw our site on the University of Illinois Extension's top 30 most visited website list for the first time.

Blog

The Illinois Water blog (illinoiswater.blogspot.com) was launched in January of 2013, and we have spent the year developing two major series: Water Jobs and Research Highlights. Water Jobs focuses on water-related careers in Illinois and has featured interviews of professors, researchers, wastewater treatment plant managers, and an artist who has found a way to bridge the gap between art and science through her multimedia work. We've also offered background on the outlook of water-related jobs and some useful tips from hiring managers. The Water Job related posts have garnered over 1,500 visits to the blog, including over 400 visits to our professor interview. The Research Highlights series follows the efforts and findings of IWRC-supported researchers. We have featured work about flame-retardants, urban flooding, and water use in biofuels.

In addition to original content, the blog has provided us with an easy-to-update platform for our announcements and those of our partners. For example, a posting about a drought workshop we hosted in October generated nearly 300 visits. We have also been able to use the blog to post lecture series hosted by colleagues and partner conferences.

Social Media

IWRC has maintained a social media presence on both Facebook (https://www.facebook.com/IllinoisWaterResourcesCenter) and Twitter (@IllinoisWater) during 2013. While our followings have grown substantially this year, they remain small, but comparable to those of other NIWR members.

Our social media connections have proved to be excellent information resources. A number of our subjects for the Water Jobs interviews published on our blog were found through Twitter interactions. Additionally, Twitter has allowed us to share funding information with Illinois researchers and to interact with other Illinois research and environmental organizations, thus increasing our outreach opportunities and building a network of collaborators.

Illinois Water Conference

IWRC has hosted a biennial water conference since the 1990s to provide an opportunity for government employees, educators, corporate representatives, citizen groups, and non-government organization members to present and discuss the latest water resources research and policy directions for Illinois.

The Water Conference 2014 will be held in Urbana, Illinois on October 14 and 15 at the Illini Union. During 2013, IWRC staff selected the conference dates, reserved the meeting space, met with the IWRC advisory committee, and began to research plenary session ideas and speakers.

Governor's Conference on the Management of the Illinois River System

IWRC staff helped plan this biennale event, which was held in Peoria, IL from October 1-3, 2013. IWRC staff designed the abstract book, provided a place to upload conference presentations, and produced the electronic conference proceedings. IWRC staff also attended the conference, staffed an exhibit, and hosted a drought workshop (see below).

Drought Workshop

Illinois experienced a historic drought during 2012, which caused University of Illinois professor and former IWRC grant recipient Dr. Ximing Cai to question how his work in long ranger precipitation forecasting could be better accessed and applied by state and industry planners. Dr. Cai approached IWRC to help him develop an outreach opportunity that would bring multiple stakeholders together to address the research needs and gaps of drought planning in the state. The workshop was held October 1, 2013 during the Governor's Conference on the Management of the Illinois River System and drew nearly 50 attendees in multiple state regulatory, planning, and research agencies. The workshop highlighted the need for great coordination among researches and planners, and IWRC staff members were invited to present workshop findings to an evening reception of the conference's planning committee.

Nutrient Reduction Strategy

As a populous and highly agricultural state, Illinois produces high loads of nutrient pollution through its wastewater and industrial treatment plant discharges and field runoff. Those nutrients eventually arrive at the Gulf of Mexico where they contribute to the Hypoxic Zone. Nationwide efforts to reduce this dead zone resulted in an action plan in 2008 that called on Mississippi River watershed states to produce a nutrient reduction strategy to decrease their nutrient loading contributions by 45%. Illinois chose to create this plan with a multi-stakeholder working group comprised of representatives from state and federal agencies, industry organizations, environmental non-profits, and research organizations and co-led by the Illinois Environmental Protection Agency (IEPA) and Department of Agriculture (IDA). Early in the process, IEPA and IDA decided that an

impartial third-party facilitator would be a useful management approach for the reduction strategy and brought IWRC on board.

As facilitators, IWRC arranges working group meetings, gathers input from an ever-growing group of working group meeting attendees, and manages the production of the nutrient reduction strategy. During 2013, IWRC helped developed systems for gathering feedback, improved working relationships with stakeholders, and conducted research on other Midwestern state strategies to determine what nutrient reduction methods could be adapted to Illinois's situation. The strategy is expected to be completed and go through a public comment period during the summer of 2014.

Drinking Water Education and Protection

Small communities and rural areas face real challenges obtaining and maintaining safe water supplies. The Illinois Water Resources Center is a partner with the Illinois State Water Survey on two websites funded by the US EPA, in partnership with the Rural Community Assistance Partnership (RCAP), which address education and outreach barriers to safe water. Both websites share a key mission, to distill best-available information into user-friendly content and lessons that serve small communities and rural areas across the United States.

The Private Well Class

PrivateWellClass.org centers on a 10-week email course (The Private Well Class) that teaches homeowners how to properly care for and maintain their water well. This includes introductory information on geology, well contamination, and water testing. The site is designed to serve the 45 million Americans who rely on a private well for their drinking water and includes a pre- and post-test quiz to test knowledge improvement. Understanding how to prevent groundwater contamination, both on the property and via cross-connection control, is addressed in the lessons as well as during a series of three live webinars. To date, more than 2,800 individuals have signed up for The Private Well Class. During 2014-2015, PrivateWellClass.org will be expanded to include audio and video lessons.

Small Water Supply

SmallWaterSupply.org is a one-of-a-kind resource website on many drinking water, wastewater, and utility management topics. It aggregates information from across the web so that users can save significant time finding the documents, training events, and news they need. The site is designed to serve water operators in small communities and tribes across the United States. It reaches more than 1,100 water industry professionals with the most timely and relevant information available. During 2014-2015, SmallWaterSupply.org will be re-branded as WaterOperator.org in order to serve a wider audience.

Notable Awards and Achievements

During 2013, the Private Well Class saw more than 2700 homeowners in all 50 states have sign up to receive free online training to improve understanding of proper well care and ensure their water remains safe to drink.

Through Small Water Supply more than 300 communities in Illinois and 3700 nationwide have accessed online resources that assist small communities with sustainably operating and maintaining their public water and wastewater systems in the past four years.

USGS Summer Intern Program

Basic Information

Start Date:	1/1/2013
End Date:	1/1/2013
Sponsor:	
Mentors:	Marcelo Horacio Garcia
Students:	Som Dutta

Internship Evaluation

Question	Score
Utilization of your knowledge and experience	Very Good
Technical interaction with USGS scientists	Very Good
Treatment by USGS as member of a team	Very Good
Exposure and access to scientific equipment	Good
Learning Experience	Very Good
Travel	About Right
Field Experience Provided	About Right
Overall Rating	A

Additional Remarks

Basic Information

Start Date:	1/1/2013
End Date:	1/1/2013
Sponsor:	
Mentors:	Marcelo Horacio Garcia
Students:	Tatiana Garcia

Internship Evaluation

Question	Score
Utilization of your knowledge and experience	Very Good
Technical interaction with USGS scientists	Very Good
Treatment by USGS as member of a team	Very Good
Exposure and access to scientific equipment	Very Good
Learning Experience	Very Good
Travel	About Right
Field Experience Provided	About Right
Overall Rating	A

Additional Remarks

The USGS Student Internship Program has been a great experience for me, not only because I had the opportunity to work on solving a critical problem like the invasion of Asian carp, but also because I had the opportunity of working and receiving valuable mentoring from Elizabeth Murphy, Hydrologist - USGS Illinois Water Science Center, and Ryan Jackson, Hydrologist - USGS Illinois Water Science Center. The interaction with USGS scientists has been a great learning experience that has taught me to keep research under an applicable perspective. Regular meetings with USGS scientists help me to be motivated and provided me continuous feedback on my own research.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	0	0	0	0	0
Ph.D.	4	2	2	0	8
Post-Doc.	1	0	0	0	1
Total	7	2	2	0	11

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Publications from Prior Years