Water Resources Research Center Annual Technical Report FY 2013

Introduction

This report covers the period March 1, 2013 to February 28, 2014, the 48th year of the Massachusetts Water Resources Research Center (WRRC). The Center is under the direction of Dr. Paula Rees, who holds joint appointments as Director of the WRRC, Director of Education and Outreach of the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere, and Director of Diversity Programs for the College of Engineering at the University of Massachusetts Amherst (UMass).

Due to automatic cuts caused by the Budget Control Act, funding to Water Resources Research Institutes was cut to $55,525 in 2013. As a result, we had to reduce the number of research projects supported through the USGS 104B Program to three:

Jonathan Roling of Bridgewater State University studied “Triclosan in Wastewater Effluent,” David Boutt worked on a project entitled “Linking groundwater heatflow to fish habitat in stream catchments with till-mantled bedrock” at the University of Massachusetts Amherst, while Andrew Kurtz at Boston University researched “Acid rain response and recovery in New England forests: Application of the novel calcium isotope tracer to the Hubbard Brook streamwater sample archive.”

The 104B Program also supported a Technology Transfer project: “Water Meetings Series,” which consisted of four conferences and workshops including: “Feeding Ourselves Thirsty: The Future of Water and Food Production” symposium at Tufts University, “Nuts and Bolts of Green Infrastructure Design Workshop and Vendor Fair” at Holyoke Community College, “Current Stormwater Concerns and Solutions Workshop” at Worcester Technical Institute; and “USGS workshop: Techniques to Quantify Stream-Groundwater Exchange and Shallow Transport” at the Woods Hole Oceanic Institution.

The USGS Supplemental Program supported the beginning of the research project “Developing Tools for Climate eRisk Assessment and Adaptation in Water Resources Systems” led by Casey Brown of UMass Amherst. The IWR– funded project “RiverSmart Communities and Federal Collaborators: Attuning Federal Agencies and Programs with the State, Regional, and local Efforts to Support Ecologically Restorative Flood Prevention and Remediation in New England” started in January 2014 under PI Eve Vogel of UMass Amherst.

Progress results for each project are summarized for the reporting year in the following sections.

Research Program Introduction

None.

Triclosan in Wastewater Effluent

Basic Information

Title:	Triclosan in Wastewater Effluent
Project Number:	2013MA408B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	MA-009
Research Category:	Water Quality
Focus Category:	Toxic Substances, Wastewater, Water Supply
Descriptors:	None
Principal Investigators:	Jonathan Roling

Publications

1. Woodward CE, Dean CG, and Roling JA., 2014 Effect of Triclosan Challenges on Chlorine Tolerance in Bacteria Found in Waste Water Effluent. Society of Toxicology National Annual Meeting, Phoenix AZ, March 2014.
2. Woodward CE, Dean CG, and Roling JA. Determination of Chlorine Tolerance in Bacterial Pre-Exposed to Triclosan from Wastewater Effluent. Eastern New England Biological Conference (ENEBC),North Andover MA, April 2014

Problem and Research Objectives:

Triclosan (TCS) is a chlorinated aromatic compound added to a wide variety of consumer products including body and hand soaps, hand lotions and creams, toothpastes, mouthwashes, underarm deodorants, cosmetics, fabrics, and plastics. A nationwide study conducted in 2000 found that 45% of all consumer soaps on the market contained either triclosan or triclocarban (Perencevich EN, et al. 2001). The average consumer uses 3-5mg of TCS per person per day resulting in a large amount of TCS in residential wastewater influent (McAvoy DC, et al. 2002).

The high use of TCS in consumer products has led to an increase of TCS in environmental waters. TCS persists through wastewater treatment plant processing. Within the US, it is estimated that 600,000 kg – 10 million kg of triclosan and triclocarban enters the environment each year (Miller TR, et al. 2008). Although optimal wastewater treatment can degrade and remove a great percentage of triclosan, some TCS passes through the treatment plant where it is released into rivers making it detectable in environmental water samples. A 1999 US Geological Survey detected triclosan in 58% of 139 streams across 30 states (Kolpin DW, et al. 2002).

Low TCS concentrations may lead to bacterial resistance by creating an environment where bacteria survive a future TCS exposure. Triclosan resistant bacteria may develop chlorine resistance due to the reactivity of the three chlorine atoms that may become bioavailable. Chlorination is used for a majority (93%) of the municipal drinking water purification systems within the USA. If bacteria gain chlorine tolerance, they may potentially survive standard disinfection, thereby threatening the safety of our drinking water and increasing the risk for human illness. The goal of this study is to identify if triclosan can lead to chlorine tolerance in bacteria strains isolated from different aquatic environments.

Previous work has verified chlorine tolerance after a triclosan challenge when comparing a remote relatively clean reference site (REF) in Monroe, MA to a site downstream a wastewater treatment plant (WWTP) in Bridgewater, MA. A broth based assay was developed to measure chlorine resistance. This novel approach was then verified using a traditional Kirby-Bauer antibiotic resistance assay with a chlorine substitution. We found that more than one third of all isolated colonies increase chlorine resistance after a triclosan exposure. Further, prior history of the water samples greatly influenced chlorine resistance with over half of the bacterial samples in the WWTP increasing tolerance while less than 8% in the REF site.

However, this study was limited in the scope of site selection. There was only one reference site and one contaminated site on separate watersheds with different hydrology and water use. Therefore, we analyzed water samples in a systematic approach to distinguish if bacterial communities do become more chlorine tolerant due to a wastewater treatment plant.

Perencevich EN, et al. 2001. *Am J Infect Control* 29: 281-283.
McAvoy DC, et al. 2002. *Environ Toxicol Chem* 21:1323-1329
Miller TR, et al. 2008. *Environ Sci Technol* 42:4570-4576.
Kolpin DW, et al. 2002. *Environ Sci Technol* 36:1202-1211.

The overall goal:
Verify if microbial communities have become chlorine resistant in waterways after residential use when compared to microbial communities upstream of effluent inputs.
To achieve this goal, the following specific objectives were formulated using bacteria sourced from 4 waterways. Each waterway was sampled upstream and downstream the first municipal wastewater treatment plant in the waterway in Massachusetts.

The Objectives were:

1. Identify the dose response of environmental bacteria in triclosan and chlorine.
2. Determine triclosan's effect on the development of chlorine tolerance in bacteria.
3. Quantify the role of wastewater effluent on chlorine tolerance after a triclosan exposure.
4. To determine if the site would affect chlorine tolerance after triclosan exposure.
5. Train undergraduates in scientific research.

Methodology:

Water sampling and Bacterial Isolation
In order to determine the baseline toxicity of chlorine and triclosan, a traditional dose-response assay was performed on environmental isolated bacteria from four environmental sources. Water was sourced before and after a WWTP on the Hoosic River (Adams, MA), Nashua River (Clinton, MA), the Nemasket River (Middleboro, MA) and the French Stream (Rockland, MA). Each of these sites **(Figure 1)**, are the first NPDES permit on each watershed and are, therefore, the only major documented source of pollution in these waterways. Sampling was performed upstream and downstream of the WWTP effluent on two occasions 1-3 days apart from June 3-9, 2013. Water parameters were measured over a 24 hour period using deployed Sondes (Hach, Loveland, CO). Triclosan was measured in the water sample using an ELISA assay according to manufacturer's instructions (Polysciences Inc., Warrington, PA).

Bacteria were isolated from water samples at each site visit. Each of four sites were visited up and downstream the municipal effluent on two different days. Water samples were serial diluted and 100uL was plated on LB agar plates within 12 hours of sample collection and grown at room temperature for 2 days. Individual colonies were counted and isolated into 600uL of 2x LB media and grown for 24 hours at 30^{o}C and 175 RPM in 96-well plates covered with Airpore tape (Qiagen, Foster City, CA). Samples were quick frozen in 25% glycerol and stored at -80^{o}C until analysis.

Dose Response assays
Bacterial plates were removed from the freezer and samples were regrown in fresh 2x LB media overnight as previously described. Bacteria from each site were chosen to produce baseline toxicity to triclosan and chlorine. Triclosan was diluted in a 1:4 serial dilution with 0.005% final ethanol concentration. Chlorine was diluted in a 1:3 serial dilution. 2xLB was used as the control media for each exposure. All samples were grown in triplicate plates. 10 uL of 1:50 diluted bacteria was added to 200uL of exposure media. Samples were grown for 24 hours at 30^{o}C and 175RPM. Growth was measured using 80uL with a spectrophotometer at 600nm. Differences between the controls were determined using pairwise t-test.

Measuring changes in chlorine tolerance after triclosan exposure

288 colonies from each of four sites were isolated. Half of the colonies were from upstream the effluent and half were downstream the effluent. Colonies were also split so half of each subset were from one of the two visits at each site. Each 96well plate included upstream, downstream, first site visit, and second site visit bacteria to eliminate sample bias. Plates were grown overnight at 30^{o}C and 175RPM. The next day, bacteria was diluted 1:50 and 10uL placed into 4 treatments in triplicate containing either 2xLB (control), 0.001mg/mL triclosan in 0.005% ethanol and 2xLB, 0.05mg/mL in 0.005% ethanol and 2xLB, or 0.5mg/mL chlorine in 2xLB. Samples were grown overnight as previous described. At 24 hours, 80uL was measured at 600nm to determine growth. The triclosan exposures were then diluted 1:50 and 10uL exposed to 0.5mg/mL chlorine in 2xLB. After 24 hours, growth was measured again, as previously described. Differences in chlorine tolerance were determined by comparing growth in chlorine prior to triclosan exposure and growth in chlorine after triclosan exposure using pairwise t-test (Figure 2).

Principal Findings and Significance:

Water Sampling and Bacterial Isolation

No significant differences were observed between the sites (**Table 1**) or within the same site over a 24 hour period (data not shown). Using a colorimetric ELISA assay, no triclosan was quantified within any water sample collected. However, the lack of measured triclosan is not surprising since triclosan may be metabolized to other compounds and the low sensitivity of the assay.

The number of colony forming units (CFUs) was not variable between days collected and most sites. The addition of effluent at any of the four sites didn't change the total number of CFUs (**Figure 3a**). This is somewhat surprising since effluent usually contains high concentrations of macro and micronutrients. However there was a difference between the 4 sites. Rockland consistently had lower CFUs than the other sites (**Figure 3b**). However the lack of variability in other sites is expected.

Dose Response to Chlorine and Triclosan

A dose response assay to chlorine and triclosan were used to determine thresholds in the tolerance assay. The chlorine no observable effect concentration (NOEC) and the lowest observable effect concentration (LOEC) were 0.06 and 0.24mg/mL, respectively (**Figure 4b**). Using these thresholds, the chlorine concentration of 0.5mg/mL was used because most bacteria should have a significant effect unless a tolerance to chlorine is acquired. The NOEC and LOEC for triclosan were 0.06 and 0.25mg/mL, respectively (**Figure 4a**). Using these results, the triclosan concentrations chosen for the tolerance assay were 0.001mg/mL (a concentration well below the any hindrance in bacterial growth) and 0.05mg/mL (a concentration that may begin hinder growth).

Triclosan altering Chlorine Tolerance

The low concentrations of triclosan caused more chlorine tolerance than the high concentration of triclosan (**Figure 5a**). The dose of triclosan inversely affects the amount of chlorine resistance gained. Of the 1152 bacterial strains isolated, 13% increased chlorine tolerance after the low exposure while only a 5.2% increased after the high exposure. Some of the samples (3.6%) increased chlorine tolerance due to both exposures.

Effect of Wastewater Effluent on Chlorine Tolerance

Even though the low concentrations of triclosan caused more changes chlorine tolerance, the effluent effects did not cause a change (**Figure 5b**). The original hypothesis was that effluents have pre-exposed bacteria to triclosan and other chlorinated hydrocarbons would cause the bacteria to become resistant faster. However, this was not found as 82.8% of the bacteria upstream the effluent and 87.7% of the bacteria downstream had no effect.

Effect of Environmental Site on Capacity to Gain Tolerance

The four sites selected had no significant difference in tolerance (**Figure 5c**). The same pattern was observed in all four sites indicating none of these results are site-specific artifacts and probably transfer to any municipal effluent. Even though Rockland had fewer CFU (**Figure 2b**), the pattern of low triclosan exposure having the most influence was still present.

Training Undergraduate in Scientific Research

This grant provided the opportunity for two undergraduate students for 2013 summer research. Through this project, these students engaged method development, field site collection, sample processing, data processing, and presentations. The undergrads were intricately involved at every step of the process. By the end of the project the students had taken control of the project and each understood the data and project as well as any graduate student.

The undergraduate students also presented their work at national and regional conferences. The students were the presenters of their research “Effect of Triclosan Challenges on Chlorine Tolerance in Bacteria Found Downstream from Waste Water Effluent” was presented in March 2014 at the national Society of Toxicology (SOT) convention in Phoenix, AZ. Other presentations include “Determination of Chlorine Tolerance in Bacterial Pre-Exposed to Triclosan from Wastewater Effluent” in April 2014 at the Eastern New England Biological Conference (ENEBC) in North Andover, MA. There have been several campus presentations as well. One of the students is continuing this project next year. She is addressing if continued low dose triclosan exposure does cause bacteria to gain tolerance to triclosan. The other student is graduating in May 2014 and is pursuing a career in the medical field.

Conclusions

The low dose of 0.001mg/mL triclosan has an increased effect on chlorine tolerance. This is concerning since antimicrobial hand soaps can be as high as 0.5% triclosan. This high dose of triclosan may cause more problems as it dilutes in natural environments. However this potential problem may not be occurring since there are no changes caused by wastewater effluents (**Figure 5b**).

The mechanism of a chlorine tolerance is still not understood. Research is on-going to identify the mechanism. Currently bacteria are exposed to low doses of triclosan or chlorine to monitor if constant low doses activate a pathway to gain tolerance. In the future, we will be monitoring changes in gene expression in tolerant strains to understand the molecular mechanism of action. Undergraduate researchers will continue to be an integral part of the research project.

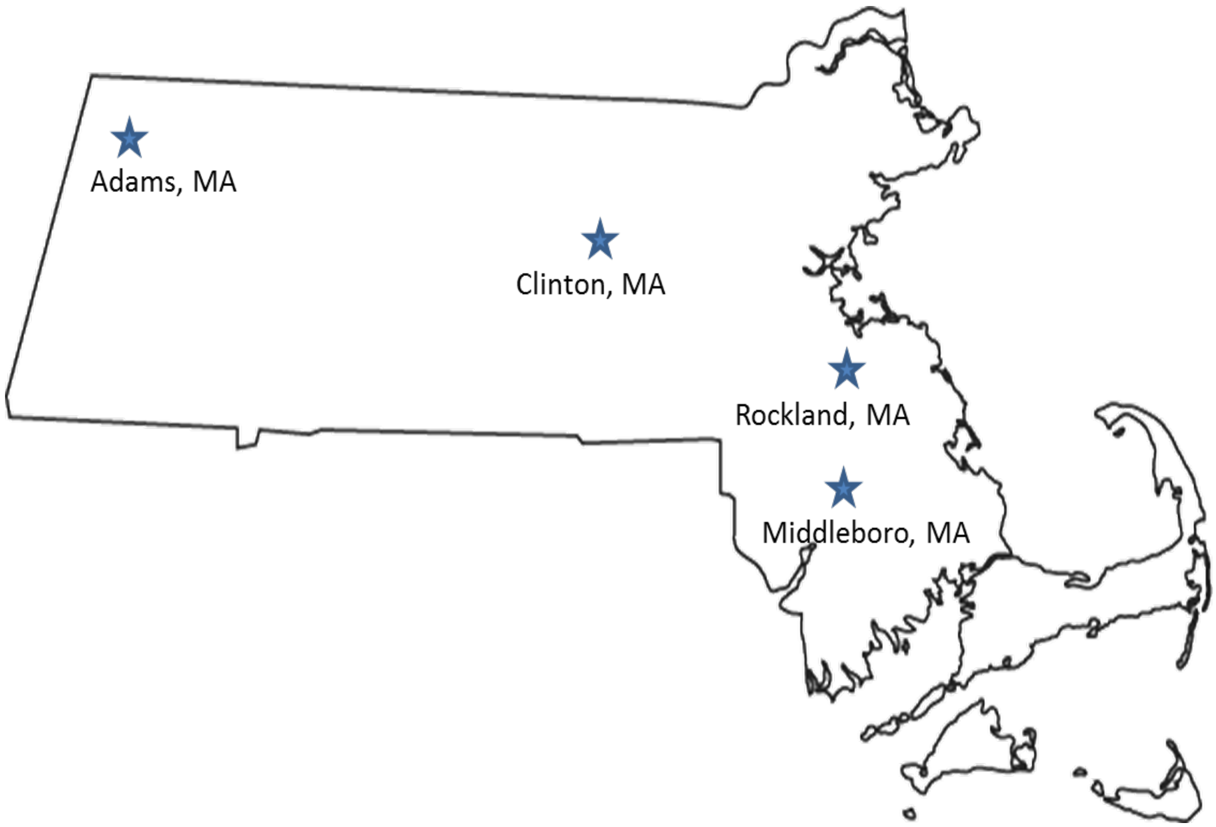

Figure 1: River sites chosen for bacteria isolation. Water samples were collected from the Hoosic River (Adams, MA), the Nashua River (Clinton, MA), the Nemasket River (Middleboro, MA) and the French Stream (Rockland, MA). These sites were selected because the waste water treatment plants held the first NPDES permit on each of the four watersheds.

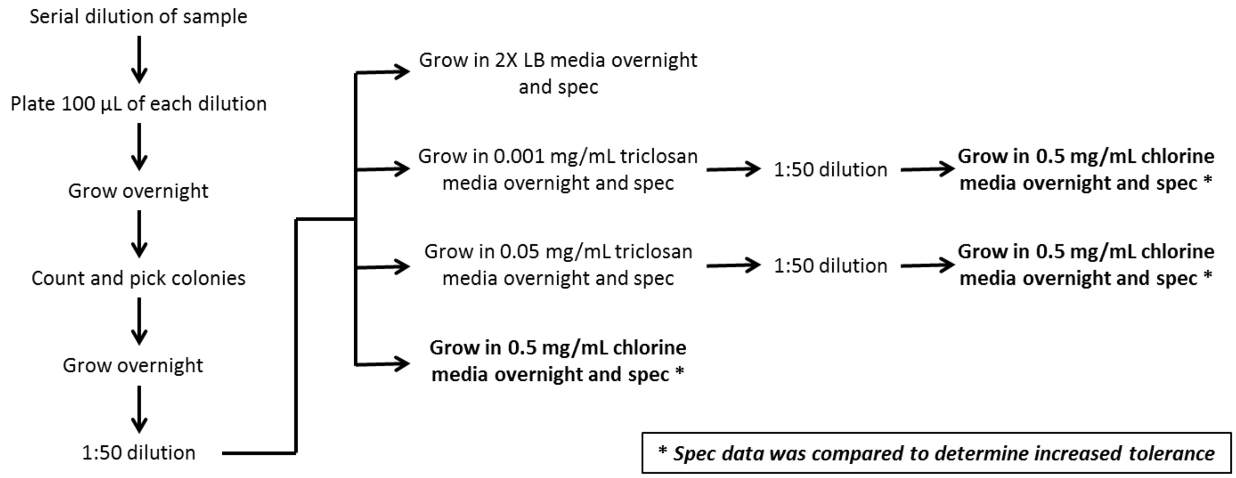

Figure 2: The methodology used for determining increased chlorine tolerance in bacteria after triclosan passages. Water samples were collected upstream and downstream to the WWTP effluent. 288 colonies from each of the four sites were selected and exposed to 0.05 and 0.001 mg/mL triclosan, 0.5 mg/mL chlorine, or 2X LB media for 24 hours. All samples were grown in triplicate at 30°C and 175 rpm. Growth was measured using spectrophotometry to read absorbance at 600nm. The bacteria exposed to the 0.05 and 0.001 mg/mL triclosan media were then re-plated in 0.5 mg/mL chlorine media. Growth was measured after 24 hours and compared to growth in chlorine media without exposure to triclosan.

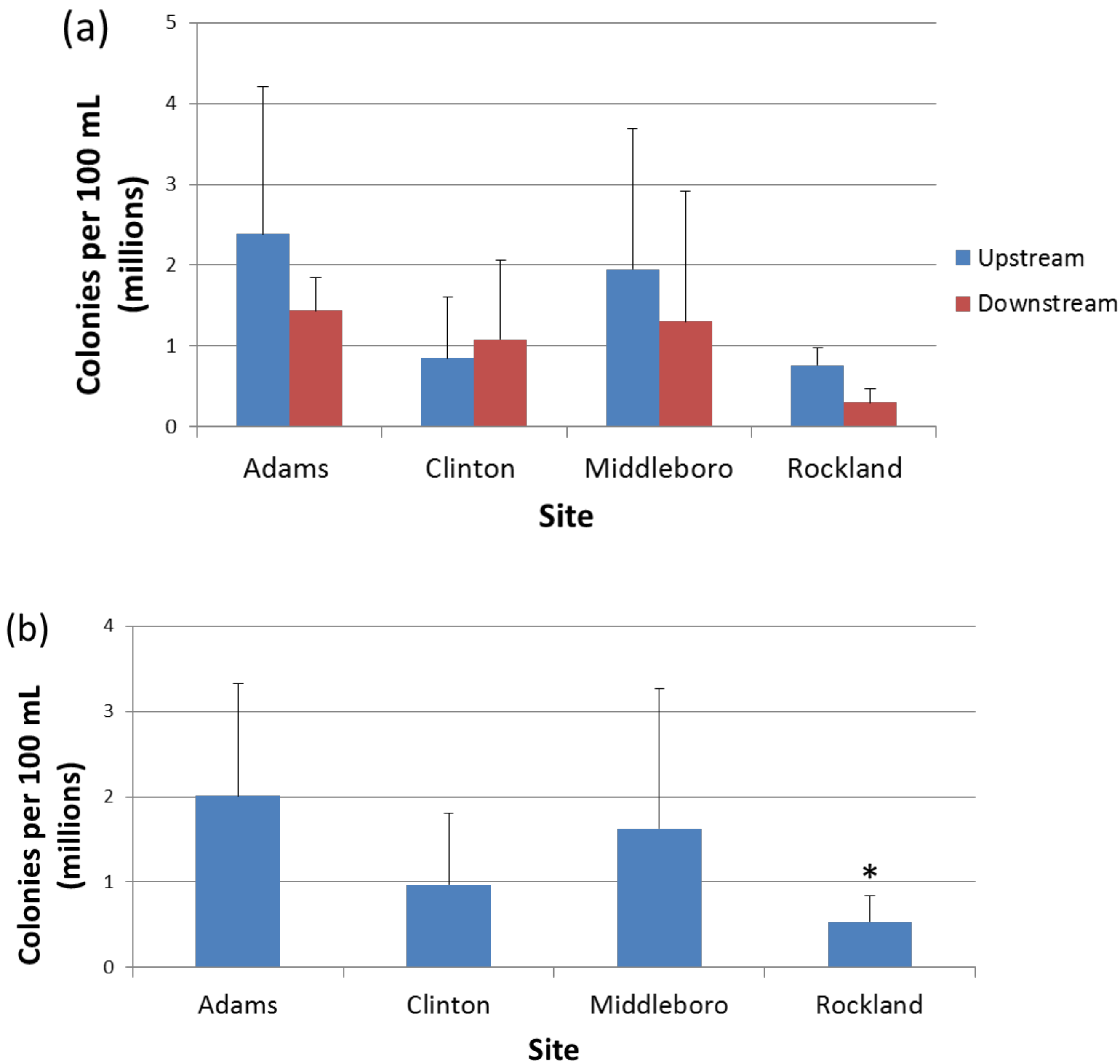

Figure 3: Colony forming units (CFUs) per 100 mL water sample. Samples were collected upstream and downstream to the WWTPs at 24-48 hour intervals. 100 µL water samples were plated on LB agar media from each of the four sites. The plates were incubated at 30°C overnight and colonies were counted. There was no difference in CFUs between day one and day two ($p<0.05$).

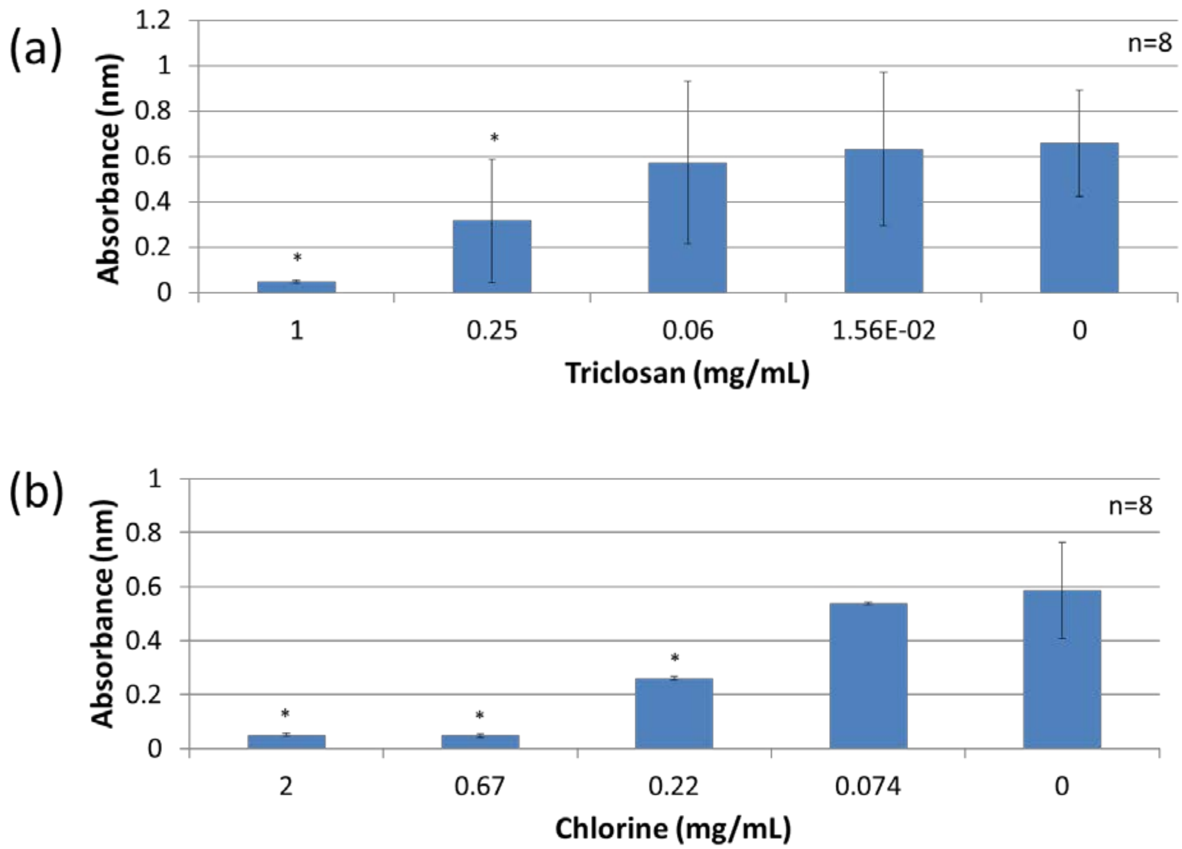

Figure 4: Standard curves for bacterial growth in triclosan and chlorine media. From each of the four sites, half of the bacteria were sourced upstream to the effluent and half were sourced downstream to the effluent. These bacteria were used in generating the standard curve. Sample bacteria were grown for two days at 30°C in 2X LB media, diluted 1:50, and then plated in triclosan or chlorine media. After 24 hours, growth was measured by reading absorbance at 600nm. (a) The NOAEC and LOAEC of triclosan were determined to be 0.06 and 0.25 mg/mL, respectively. (b) The NOAEC and LOAEC of chlorine were determined to be 0.074 and 0.22 mg/mL, respectively ($p<0.05$).

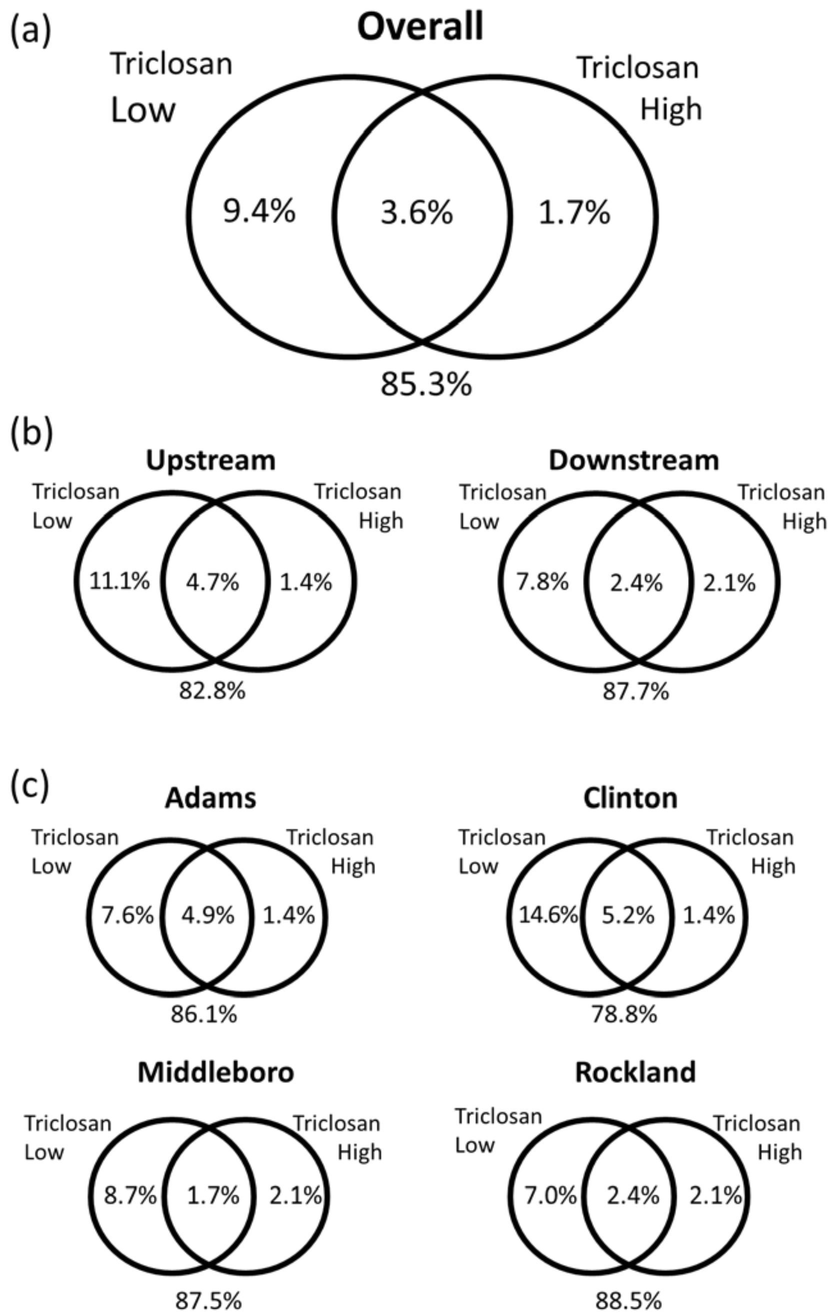

Figure 5: Increased chlorine tolerance after triclosan exposure in environmental bacteria. (a) 14.7% of the bacteria tested had increased chlorine tolerance after exposure to triclosan (n=1152). (b) 17.2% of the bacteria collected upstream and 12.3% collected downstream from the effluent had increased chlorine tolerance after triclosan exposure (n=576). (c) There was no difference in bacterial capacity for increased chlorine tolerance between the four sites (n=288).

Table 1: Physical parameters and of water collection sites.

Site	Coordinates	Temp (^oC)	DO (%)	DO (mg/L)	pH
Adams	42.6439, -73.1074	15.58	94.61	9.47	7.79
Clinton	42.4300, -71.6792	17.91	93.47	8.97	7.40
Middleboro	41.9096, -70.9167	19.47	89.54	8.25	7.50
Rockland	42.1049, -70.8962	17.79	87.89	8.38	7.08

Linking groundwater heatflow to fish habitat in stream catchments with till-mantled bedrock

Basic Information

Title:	Linking groundwater heatflow to fish habitat in stream catchments with till-mantled bedrock
Project Number:	2013MA409B
Start Date:	4/1/2013
End Date:	3/31/2014
Funding Source:	104B
Congressional District:	MA-02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Groundwater, Water Quality
Descriptors:	
Principal Investigators:	David Boutt

Publication

1. Mitchell R. Isaacson; David F. Boutt (2013), How do hydrodynamics in the critical zone relate to stream temperature distribution?, Abstract H23F-1350 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.

Problem and Research Objectives:

Stream temperature models based on air temperature alone cannot be uniformly applied to regions of differing geologic stratigraphy without accompanying physical models to incorporate subsurface heat flow. By coupling stream temperature distributions with subsurface heat flow dynamics we can better understand the resilience of thermal microhabitats in streams in the Northeast to climate changes. Our study focuses on a critical gap in our understanding of how temperature dynamics within subsurface flow paths relate to stream temperature distributions and the prevalence of thermal refugia for fish habitat.

Methodology:

We used fiber-optic distributed temperature sensing (DTS) to characterize stream temperature distributions with high spatial and temporal resolution. In conjunction with physical groundwater heat flow models, we use detailed stream temperature distribution profiles to provide new insight into the temperature variability and thermal buffering capacity of streams in till-mantled fracture bedrock catchments.

Principal Findings and Significance:

Our findings show that mean annual groundwater temperatures range consistently between 9-10° C in fractured bedrock at depths greater than 40 ft below ground surface. Till aquifer temperatures show greater seasonal variation, ranging from 6 – 13° C which fall along a damped phase lag of 3.5 months from air temperature. Shallow soil aquifer temperatures at depths of 1 m below ground surface surprisingly show a similar phase lag of 1-3 months ranging from 0 -15° C. Main channel stream temperature ranged between 1 – 20° C with a phase lag of <1 month. Most interestingly, localized groundwater input in the stream channel provided temperature offsets of up to 3° C, where 2° C temperature differences were common, despite a relatively well mixed channel area.

The timing and magnitude of these localized groundwater inputs support the hypothesis that groundwater is responsible for providing relatively cooler microhabitats during the cold or frozen winter months and warm summer months where stream temperatures can reach the extreme tolerance for salmonid survival. We observed that in-stream temperature variability was less present in stream reaches with extensive sand and gravel, rather the highest concentration of localized groundwater inputs coincided with bedrock outcrops and high near-stream hydraulic heads. Ongoing work will investigate the temperature variability of the streambed sediments and their relationship to site selection for egg-laying female brook char during the autumn redd.

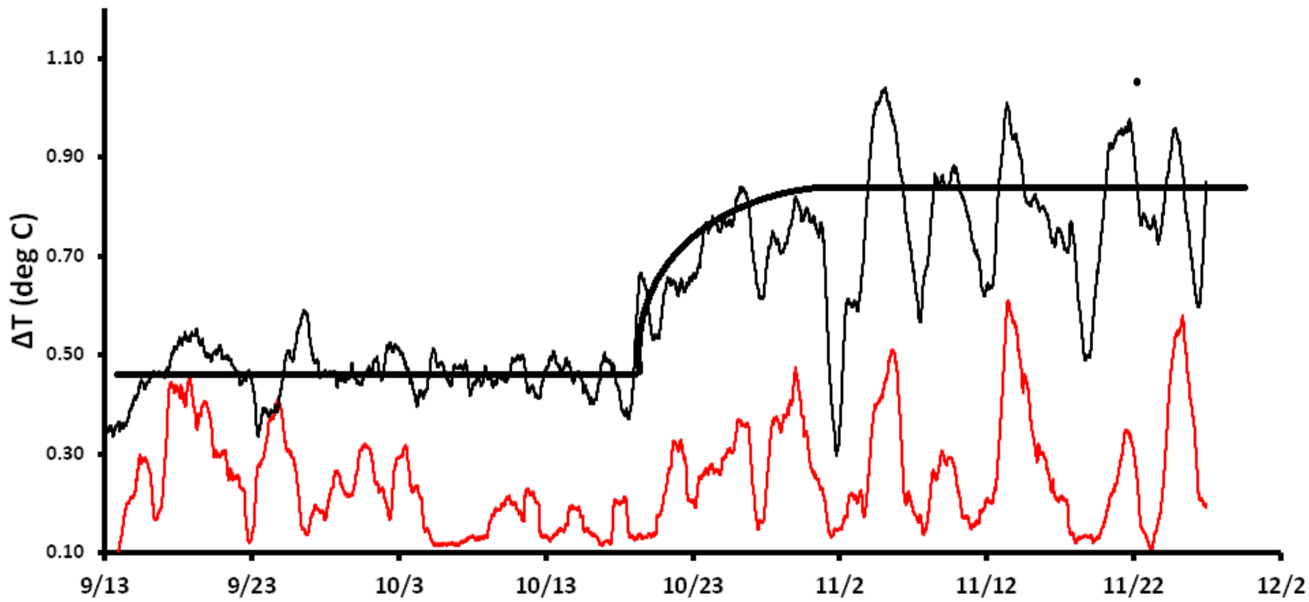

Figure 1: Red and black lines indicate the temperature differences between localized in-stream groundwater seeps and the main stream channel. Notice a step increase in dT around October 20th, 2013.

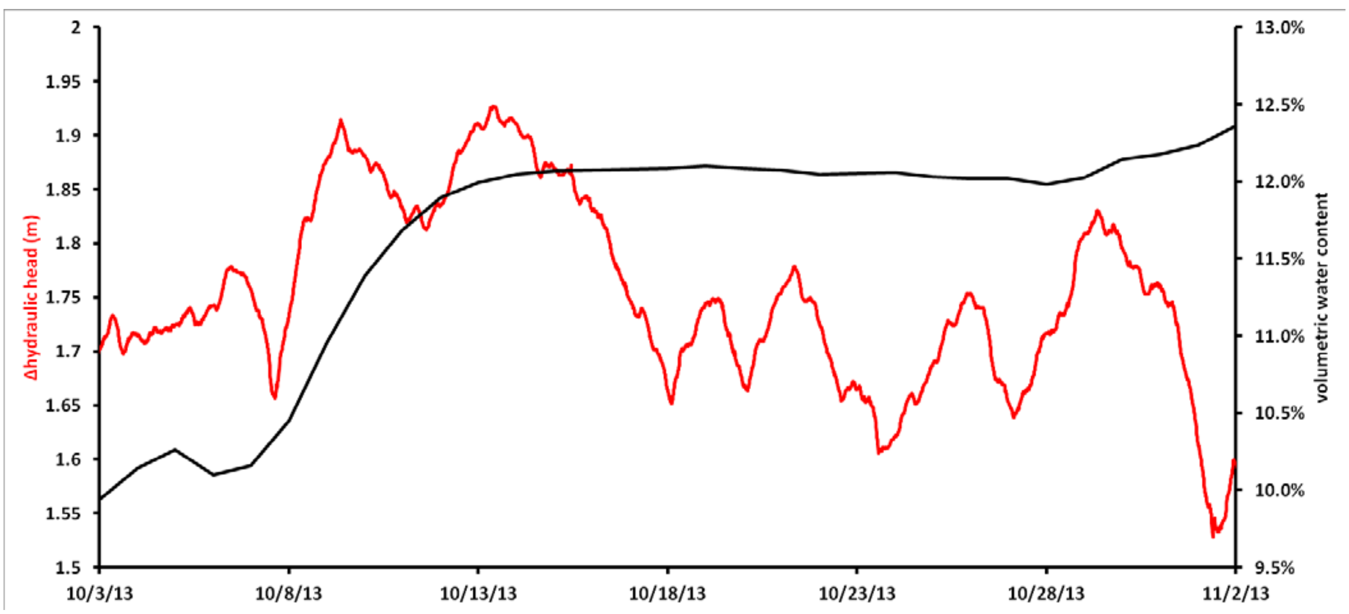

Figure 2: Hydraulic head changes in the surficial till (red) and saturation state of overlying soils (1m depth). A similar response to increased saturation can be seen as hillslope aquifers discharge to localized seeps in upstream reaches of Jimmy Nolan Brook

Acid rain response and recovery in New England forests: Application of the novel calcium isotope tracer to the Hubbard Brook streamwater sample archive

Basic Information

Title:	Acid rain response and recovery in New England forests: Application of the novel calcium isotope tracer to the Hubbard Brook streamwater sample archive
Project Number:	2013MA415B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	MA-8
Research Category:	Climate and Hydrologic Processes
Focus Category:	Acid Deposition, Hydrogeochemistry, Nutrients
Descriptors:	None
Principal Investigators:	Andrew Kurtz

Publications

1. Takagi, K., A. Kurtz, S. Bailey, Sourcing streamwater Ca following clear-cutting of a New England watershed, Goldschmidt Conference, Sacramento, CA, June, 2014.
2. Takagi, K., A. Kurtz, S. Bailey, T. Bullen, Constraining sources of streamwater Ca in a New England watershed using Ca isotopes, Annual Hubbard Brook Cooperators Meeting, July 2013.

Deposition of acid rain in the Northeast United States beginning in the middle of the 20th century resulted in increased hydrologic export of calcium from forested watersheds, an important nutrient that is stored in biomass and in soils. Forest harvesting similarly results in accelerated loss of nutrient Ca. Both effects have important implications for forest sustainability, as decreased Ca availability diminishes tree resistance to cold and disease. Despite extensive work on forest nutrient mass balances, much of which was done at Hubbard Brook Experimental Forest in New Hampshire, there remains some uncertainty in terms of the mechanisms that cause this accelerated Ca loss. The goal of this project was to conduct a pilot study of the application of calcium stable isotopes to historical changes in forest calcium cycling at Hubbard Brook based in archived samples, and to use these preliminary data to motivate a larger-scale proposal to the National Science Foundation. Ca stable isotopes are naturally fractionated in forests primarily by preferential uptake of light Ca (^{40}Ca) by plant roots. This process imparts variability in the ratio of ^{40}Ca to ^{44}Ca in different Ca pools (root-, woody-, and leaf-biomass, soil exchange sites, soil Ca-oxalate) within a forest ecosystem. The $^{44}Ca/^{40}Ca$ ratio of dissolved Ca exported by streams is influenced by this fractionation and losses from these pools.

Methodology:

Research samples for this study come from an extensive archive of materials at Hubbard Brook Experimental Forest, including streamwater, soils, and plant tissues. Our initial work has focused on a 1983 experimental clear-cut of one of the first order watersheds (Watershed 5) at Hubbard Brook. We subsampled archived streamwater samples from both the experimental watershed (Watershed 5) and a nearby control watershed (Watershed 6), bracketing the experimental manipulation (1977 to 1988). Samples were selected to capture a range in both seasonality and discharge. We also subsampled glacial till and archived soil profiles from Watershed 5 in order to characterize the Ca isotope ratios of the weathering parent material, and plant-available soil Ca pools. Recently we have expanded our collection subsamples (streamwaters and soils) to investigate decadal-scale changes in Ca cycling driven by changes in acid deposition at Hubbard Brook between the late 1960s and mid 1980s.

The vast majority of the research effort in this project took place in the Boston University Thermal Ionization Mass Spectrometry (TIMS) Facility, improving our analytical method and collecting both Ca concentration data and measurements of Ca isotope ratios of samples. Determining $^{44}Ca/^{40}Ca$ ratios on natural samples is tricky because there is a significant isotopic fractionation that takes place within the instrument during analysis that must be separated from natural isotopic effects. These complications are overcome by mixing the natural sample with a carefully calibrated mixture of ^{43}Ca and ^{48}Ca (a “double spike cocktail”) prior to separation of Ca by cation exchange columns. At the start of this project, we were successfully applying the double spike method to determination of $^{44}Ca/^{40}Ca$ ratios but with less reproducibility than expected. In December 2013 we traced the problem to Ca contamination sometimes occurring during sample preparation. Eliminating this source of Ca (a “loading blank”) has greatly improved reproducibility.

Principal Findings and Significance:

Our initial work shows that there is a measurable range in the $^{44}Ca/^{40}Ca$ ratio of both streamwaters and forest ecosystem Ca pools and that there is interpretable variability in streamwaters both as a function of discharge and as a response to the 1983 experimental harvesting. $^{44}Ca/^{40}Ca$ ratios are presented in the “delta notation” common in stable isotope geochemistry, reflecting permil variations relative to a standard (in this case seawater Ca). The $\delta^{44}Ca$ of the glacial till parent material is -1.1‰, within the range typical of silicate rocks. Ca on soil ion exchange sites (plant-available) is isotopically light (enriched in ^{40}Ca) relative to till (-1.4 to -1.8‰), and lightest in shallow soils, which also contain the largest amounts of exchangeable Ca. Streamwater values of $\delta^{44}Ca$ vary between -1.1 and -1.7‰, and are lightest (most negative) during high discharge events. We interpret this as evidence of hydrologic flowpath control over export of dissolved Ca to streams, with increased contributions from the shallow soil pool relative to deep weathering during storm events. $\delta^{44}Ca$ values in watershed 5 shift by an average of -0.3‰ as a response to the experimental harvesting. The shift towards lighter Ca post-harvest is consistent with increased export of plant-available shallow soil Ca in responses to changes in soil biogeochemistry and hydrology that result from clear-cutting.

Developing Tools for Climate eRisk Assessment and Adaptation in Water Resources Systems

Basic Information

Title:	Developing Tools for Climate eRisk Assessment and Adaptation in Water Resources Systems
Project Number:	2014MA432S
Start Date:	11/25/2013
End Date:	7/31/2014
Funding Source:	Supplemental
Congressional District:	MA-2
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Casey Brown

Publications

There are no publications.

Problem and Research Objectives:

The effects of climate change and potential non-stationarity in hydrologic variables undermine assumptions upon which water resources infrastructure has been historically managed and designed. The impact and severity of hydroclimatic change on water system performance is difficult to assess due to uncertainty in future climate projections, complicating decision-making and risk management. This study describes the development and introduction of a web-based decision support tool for small-scale water utilities in the Northeast US that may lack the resources to investigate climate change risk. The purpose of this tool is to provide stakeholders and water managers with a user-friendly decision system model that enables the exploration of problematic future climate conditions using a stress test, in which the performance of local reservoir systems are tested over a wide range of potential climate changes. With a map-based interface, a generic water resource system simulator models the behavior of reservoir operations over changes in temperature, precipitation, and water supply demand. Probabilities of those conditions developed from climate projections help inform utility operators of impending risk. The application and utility of the web-based tool to water supply systems in the Northeast United States is vetted with water managers and stakeholders.

The UMass Hydrosystems Research Group will develop a new tool broadly applicable for conducting climate risk assessments for USACE projects using the Decision Scaling methodology.

Objective 1 - A stochastic climate/weather generator will be developed to produce time-series of daily weather variables that are appropriate for conducting decision scaling and the climate stress test with USACE water resources planning and hydrologic models at any location within the CONUS or internationally.

Objective 2 - Application of the decision scaling methodology to a prototypical flood risk reduction and a water supply adaptation decision using the tools developed in steps 1 and/or 2.

Objective 3 - The insights developed through this effort will be documented in a best practices guide that formalizes the decision scaling methodology for USACE application and describes the appropriate uses and limitations.

A challenge that remains is the trade-off between a tool that can be easily understood by any users, and the general applicability of the tool. The current version of the tool is straightforward to apply but may be restrictive in terms of kinds of water supply systems it can be applied to. Evaluating the degree to which the tool can be generally applied is the next step in the analysis.

Principal Findings and Significance:

Funding for this project was set up in January 2014 and as of February 28, 2014, there were no findings yet.

RiverSmart Communities and Federal Collaborators: Attuning Federal Agencies and Programs with the State, Regional, and local Efforts to Support Ecologically Restorative Flood Prevention and Remediation in New England

Basic Information

Title:	RiverSmart Communities and Federal Collaborators: Attuning Federal Agencies and Programs with the State, Regional, and local Efforts to Support Ecologically Restorative Flood Prevention and Remediation in New England
Project Number:	2014MA433S
Start Date:	1/20/2014
End Date:	9/7/2015
Funding Source:	Other
Congressional District:	MA-2
Research Category:	Climate and Hydrologic Processes
Focus Category:	Floods, Law, Institutions, and Policy, None
Descriptors:	Floods, Remediation, Federal agencies
Principal Investigators:	Eve Vogel

Publications

There are no publications.

Problem and Research Objectives:

The Problem: Damaging River Floods, and Three Fundamental Challenges.
New England residents, landowners, infrastructure and businesses located along the region's often-narrow river valleys are frequently impacted by damaging floods that accompany heavy rains. Tropical Storm Irene was but one recent, drastic event; in 2011 in Vermont alone it affected 500 miles of state highways, 200 bridges, 960 culverts, and caused more than $175 million of damage. Damaging floods are likely to become more common and costly, as climate scientists predict more intense storms and increased annual precipitation in the Northeast.

Unfortunately, three fundamental challenges make managing floods and addressing flood damage particularly challenging in New England. First, common structural approaches to flood mitigation and post-flood restoration in the region can increase flood hazards downstream, and re-create infrastructure vulnerable to future flood events. These approaches also often are environmentally damaging and require increased expenditures for environmental mitigation and restoration.

Second, jurisdictional authority is particularly fragmented in New England, because of the history of early small town settlement and incorporation, and the "home rule" traditions of several of the states. There are over 1500 towns and cities in the six New England states, each of which has at least some independent authorities over land and water use and regulation. Many of these have only a few hundred residents, and operate with volunteer governing bodies and only skeletal staff. Jurisdictional fragmentation is also more challenging because the federal government, which often plays a unifying role in river management in other parts of the country, has historically played a relatively small and distant role here, partly because the region was developed before the rise of many major federal land and water agencies, and partly because of frequent political insistence on state and local independence.

The third fundamental challenge is that governmental agencies at all levels as well as nonprofit agencies are facing a funding squeeze from reduced federal and state government budgets.

Objective: Ecologically restorative flood prevention and remediation, based on fluvial geomorphological science, met through collaborations that stretch from local municipalities to federal agencies and programs

The following are three strategies, which address each of the challenges listed above:
a. Advance ecologically restorative flood prevention and remediation by orienting policy and practice to work with natural dynamic river processes;
Flood mitigation and protection can work *with*, rather than against, natural fluvial and geomorphological processes. The approach is to allow much-increased water and sediment sufficient room to flow, by building large-enough culverts and bridge spans; and to allow rivers to spread out and move laterally during major flood events wherever possible, by protecting river "corridors" or "meander belts." This approach is founded on the science of fluvial geomorphology. It can provide longer-term flood protection, and concurrently support environmental, fish and wildlife goals.

b. Collaborate with and across a wide array of jurisdictions and agencies in ways that are effective and accessible, from small remote New England municipalities to federal agencies.

In New England, in order to achieve ecologically restorative flood hazard management, collaborations must be accessible even to small remote and rural municipalities, which often bear the worst flood damage. Though these communities have both the need and the jurisdictional authority to manage land and water resources, they often lack needed institutional capacity, and technical and financial resources. Federal agencies, in contrast, often have capacity and some resources, but may not be able to provide individualized support and response for every community. Systems of nested and interconnected inter-agency relationships are needed to link these.

c. Build institutions and approaches that can achieve better ecologically restorative and flood prevention results with limited budgets.
Both of the above strategies must be accomplished with limited budgets, and fortunately, can also be resource-efficient. Inter-agency collaborations can use resources in complementary rather than repetitive ways, and target resources where they can provide the greatest benefit. Flood risk assessment, remediation and prevention that are shaped to predict and adapt to natural dynamic river processes can last long-term without the need for costly structural repairs or the risk of amplified downstream damage.

The importance of federal agencies and programs – including FEMA, the USACE, NRCS, USF&W and others – is clear. However, research has suggested that several of these agencies and programs are perceived or experienced by people working in small, often remote New England towns as cumbersome, ineffective and difficult to access.

A project objective is to advance improved coordination and mutual assistance between federal agencies and federal programs, on the one hand, and local, state and regional ones on the other. Federal programs have a great deal to offer; with multi-level coordination, education and attention to the needs of specific localities, these resources can be made accessible to and effective for small communities.

Methodology:

A. RiverSmart Communities and Federal Collaborators: Model Case Studies.
Researchers will produce a report of four case studies analyzing collaborations in which federal agencies and programs have worked successfully with state, regional, local and/or nonprofit efforts in New England to promote ecologically restorative flood prevention and remediation. In each of the planned case studies, federal agencies and programs meet one or more of the three fundamental challenges listed at the start of this section. Our research is oriented toward understanding specifically how they achieve these results – with what institutional structures, programs, funding mechanisms, etc. specifically, they:

a) Advance ecologically restorative flood prevention and remediation by orienting policy and practice to work with natural dynamic river processes
b) Collaborate with and across a wide array of jurisdictions and agencies in ways that are effective and accessible, from small remote New England municipalities to federal agencies;
c) Employ approaches that can achieve better results with limited budgets.

Case Study 1. US Army Corps of Engineers New England District / The Nature Conservancy (TNC-USACE) Connecticut River Partnership – barrier-crossing collaborations with demonstrated analytical and policy success
Project summary: Under two partnerships, the USACE New England District and TNC are working together to provide more natural river flows, functions, connectivity and habitat. There have been two key efforts thus far: developing a basin-wide hydrologic flow model, and rewriting road-stream

crossings standards for ACOE permits across New England. The flow model and its analyses may help develop new flow strategies for management of the ACOE's flood control dams, as well as other major dams in the basin. The model is also being applied in the current FERC relicensing process of five privately owned mainstem hydropower projects. The road-stream crossings standards are now in use by ACOE permitting in all six New England states.

Our investigations: We will investigate how and with what institutional, programmatic and on-the-ground effects the TNC and USACE have been able to work with each other as well as across an array of stakeholders and jurisdictions.

Case Study 2. USACE Silver Jackets Program: Federal collaborators helping to manage flood hazard risk.

Project summary: The USACE's Silver Jackets (SJ) program brings together federal agencies, including USACE and FEMA, with state and sometimes regional and local agencies, into a unified forum to address a state's flood hazard risk management priorities. Teams are state based and led. SJ provides a formal and consistent structure and support for interagency collaboration. Significantly for our purposes, the Silver Jackets approach emphasizes addressing "life-cycle flood risk".

Our investigations: We will investigate possible benefits and approaches for SJ in New England. Among New England's six states, only New Hampshire, Massachusetts and Rhode Island have actively working teams. Maine and Vermont have teams that meet less regularly. We will investigate how further development of SJ teams in New England might improve inter-jurisdictional coordination and river flood prevention and remediation. We will investigate the active Pennsylvania (PA) and one or two other state teams, comparing their activities with those occurring in New England. We will also examine the process by which the New Hampshire and Massachusetts SJ teams have been established, their early activities, and their results thus far.

Case Study 3. NRCS Emergency Watershed Protection Program (EWP): Providing communities with Easy-to-Access Technical and Financial Support

Project summary: The NRCS EWP provides "work, installations or repairs to protect lives, land or property" from an imminent threat following a flood (or other natural occurrence). It works directly with towns, conservation districts or other political subdivisions, when neither the state nor the local community is able to repair a damaged watershed by itself (NRCS). Our interviews in the Deerfield River suggest that among federal agencies the NRCS is perceived as particularly accessible, responsive, efficient and cost-effective by community leaders.

Our investigations: We will investigate the factors contributing to NRCS success in serving local communities and how replicable these factors might be. What institutional structures and relationships, policies and programs make the NRCS so readily accessible and responsive to community leaders in the Deerfield watershed, and so efficient and low-cost? Do NRCS projects also meet the goal of making post-flood recovery attuned to natural river processes?

Case Study 4: Data sharing in watershed and flood management: Making data community-specific, accessible, and reliable by emergency response efforts

Project summary: Several federal data-sharing efforts, including Homeland Security's Automated Critical Asset Management System (ACAMS), FEMA's Risk Mapping and Assessment Program (Risk MAP), and USACE's Floodplain Management Services (FPMS) program, produce hazard risk and response data for requesting parties and other audiences. These products may vary in the degree to which they are standardized or communicated, in order to make them more broadly accessible and responsive to community-specific needs. Our research suggests that many communities lack clear, easily understandable data on rivers and flood hazard risk. They also often lack the capacity to contribute to more widely shared, standardized data that might inform, for example, watershed-wide assessments or state funding priorities.

Our investigations: We will investigate whether ACAMS, Risk MAP and FPMS are successfully reaching, or could be made more useful to, community-based participants.

B. RiverSmart Communities and Federal Collaborators: Paired Applied Flood Prevention, Mitigation and Remediation Workshops.

Researchers will participate in a series of community meetings and produce a one-day workshop. This workshop will first distill community needs and ideas related to flood prevention, mitigation and remediation in an applied setting, the Deerfield River watershed (VT and MA). Next, federal agency and legislative opportunities, constraints, and possible solutions will be identified to better meet these needs or follow these ideas.

Community Conversations about Irene: voices from the watershed. (November 2014-January 2015)
Researchers will attend a series of community meetings at the regularly scheduled venues of town select boards, regional agencies, and state and federal agencies and NGOs already working closely within the Deerfield river watershed, particularly those who have been involved with Tropical Storm Irene issues. Discussions will focus on local experiences, perspectives and lessons learned on the three fundamental challenges and solutions to advancing ecologically restorative flood prevention and remediation. Community representatives will discuss their assessments and experience, emphasizing data and assessments of on-the-ground needs, their technical and funding needs, experience with federal agency assistance, and their thoughts about how federal agencies could more readily meet the three fundamental challenges identified by this project. Using examples from the Deerfield River, community members will distill recommendations for federal agencies to meet the three challenges to ecologically restorative flood prevention and remediation. This task is underway.

Workshop. *Problem-solving federal collaborations.* (January 2015).
Main participants will be federal agencies and legislators, and state agency and legislative collaborators. Also invited: selected community representatives.

Morning: Project investigators present draft recommendations built from case studies and outcomes of the community meetings. Federal representatives respond and present on their own programs and experience, focusing on potentially feasible ways to meet some of communities' recommendations. Which things are they already doing, but communities are not accessing or understanding? Which approaches are impractical for statutory or regulatory reasons but might be changed with viable alterations in law or policy? Which are achievable with existing authorities, by reworking institutions or reorienting practice?

Afternoon: Facilitated discussion to develop strategies for reorienting federal programs or outreach, including with collaboration of other agencies.

C. RiverSmart Communities & Federal Collaborators: Recommendations.
Researchers will produce a white paper, based on the model case studies, community meetings, and workshop discussions. This paper will describe specific ways federal agencies, personnel and programs should and can be structured and targeted to work more effectively, economically and sustainably with state, regional and local agencies and programs in New England to effect ecologically restorative flood prevention and remediation. Recommendations will include specific measures for policy or regulatory change, as well as improved implementation of existing policies and programs.

D. RiverSmart Communities & Federal Collaborators: Information Tools.
Researchers will produce six to ten conferences and one-on-one presentations, a website, a social media site, and several easy-to-understand factsheets to disseminate analyses and recommendations to target audiences, federal and state agencies and legislators, and municipal leaders and employees in New England communities.

Principal Findings and Significance
As of February 28, 2014, no findings to report as funding was just put in place.

Information Transfer Program Introduction

None.

Water Workshops Series

Basic Information

Title:	Water Workshops Series
Project Number:	2013MA417B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	MA-02
Research Category:	Not Applicable
Focus Category:	Groundwater, Water Quantity, Agriculture
Descriptors:	
Principal Investigators:	Paula Sturdevant Rees, Marie-Francoise Hatte

Publications

There are no publications.

WRRC Water Meeting Series

One of the Massachusetts Water Resources Center's goals is the transfer of information on water resources. We proposed to hold the following four meetings: Approaches for Quantifying Groundwater-Surface Water Interactions in the Northeast US, with Dr. Christine Hatch and Dr. David Boutt of the Geosciences Department at the University of Massachusetts; Prioritization of Stream Restoration Sites for Maximum Stream Ecological Benefit, with the Massachusetts Division of Ecological Restoration, UMass (WRRC, Environmental Conservation, Geosciences, and Environmental Engineering), and the Massachusetts Office of Energy and Environmental Affairs; Tufts Water Science, Systems, and Society Symposium, with Tufts University; and Water Sustainability from Land to Stream, with Robert J. Johnston of Clark University, and Paul P. Mathisen at WPI.

Due to lack of interest and resources from our original collaborators, we eliminated the second workshop on Stream Restoration and replaced it with a Green Infrastructure Workshop. Except for the Tufts Conference, all workshops occurred after February 28, 2014 and we obtained a no-cost extension for them. We are reporting here on three of the symposia and workshops that are completed as well as one that will occur in early June.

Feeding Ourselves Thirsty: The Future of Water and Food Production
This was the 4th Annual Interdisciplinary Water Symposium at Tufts University, a conference organized by Tufts University students with help from their faculty advisors and the Water: Systems, Science and Society Faculty Steering Committee.

This conference took place on the Tufts University campus on April 5, 2013 and attracted about 200 participants. WRRC facilitated some logistics and organized the poster session and student poster contest. There were 28 student posters, and 17 judges.

The topic of discussion was described as: "Agriculture accounts for between 70-80% of water use worldwide. A growing world population is estimated to require a doubling of global food production by 2050. Meanwhile, debilitating droughts and devastating floods threaten an already vulnerable global food supply. This year, students, academics, and professionals from the public, private, and non-governmental sectors will explore the nexus of water and agriculture. Symposium topics will include climate change and vulnerability, water availability, water rights and the economics of water allocation, water pollution, public health, natural resource management and collaboration."

Agenda:

9:00 – 9:10 am	Welcoming Remarks
9:10 – 9:55 am	Keynote Address: Craig Cox
10:00 – 10:55 am	Panel 1: Approaches for Mitigating Agricultural Water Contamination in the United States
10:55 – 11:15 am	Coffee Break
11:15 – 12:10 pm	Panel 2: Water, Food, and Conflicting Resource Demands
12:10 – 1:20 pm	Lunch and Poster Session

1:20 – 1:35 pm	Alternative Perspectives: Food and Water Practices of the Mashpee Wampanoag
1:40 – 2:35 pm	Panel 3: Solutions for Sustainable Water Resource Management
2:35 – 2:55 pm	Coffee Break
2:55 – 3:40 pm	Keynote Address: Dr. Roberto Lenton
3:45 – 4:15 pm	Closing Remarks and Student Awards

Nuts & Bolts of Green Infrastructure Design & Construction Workshop and Vendor Fair
This event was held at Holyoke Community College on March 17, 2014 and focused on green infrastructure practices for the development community. It was a collaborative effort between EPA (A&P2 and the Office of Research and Development (ORD), Pioneer Valley Planning Commission (PVPC), University of Massachusetts, and the Horsley & Witten Group. The goal of the workshop was to provide Green Infrastructure training and assistance in response to a request by the PVPC as part of the Sustainable Knowledge Corridor Initiative. The steering committee was made up of:
Richard Claytor, Horsley Witten Group, Inc.
Patty Gambarini, Pioneer Valley Planning Commission
Marie-Françoise Hatte, Mass. WRRC
Ingrid Heilke, USEPA ORD
Margie Miranda, USEPA Region 1
Myra Schwartz, USEPA Region 1
Gina Snyder, USEPA Region 1
Marilyn Ten Brink, USEPA ORD
Michael Viola, USEPA ORD

There were 85 sign-ups + 4 walk-ins. In the end, 78 people participated. Of those, 11 were organizers and 17 were vendors. Of the other 50 participants, one was from academia, 18 were from the construction/consulting field, 3 were from government agencies, 23 from municipalities, 3 from non-profit organizations, and 3 from regional agencies.
This whole day workshop consisted of presentations, exercises and activities, a vendor fair, and networking. See agenda below:

8:30 to 9:00	**Registration**
9:00 to 9:20	**Welcome, introductions, and interactive exercise**
9:20 to 10:00	**Design and construction considerations and process on green infrastructure BMPs** Major steps in the process and important considerations; which practice makes sense where; and special considerations for using a suite of BMPs.
10:00 to 10:15	**Break**
10:15 to 11:45	**The nitty gritty of design and construction on three green infrastructure projects** Presentations will include a virtual tour, and focus on technical

information about how projects were designed, permitted, constructed, as well as information on cost and maintenance.

- Streetside bioretention in a downtown - *Douglas Clark, P.E., City of Pittsfield, and Jon W. Dietrich, P.E., Associate, Sr. Transportation Engineer and Daniel F. Delany, P.E., Project Manager both of Fuss & O'Neill*
- Porous paving and bioretention on a University campus - *Edward Marshall, ASLA, Stephen Stimson Associates*)
- Gravel wetlands in a municipal park - *Michael F. Clark, Polaris Consultants LLC*

11:45 to 12:15 **Ask the experts (facilitated discussion)**
Ask questions, exchange ideas, and share your experience on green infrastructure construction and design with a panel of practitioners.

12:15 to 1:00 **Lunch and Networking Activities**

1:00 to 3:00 **Vendors' fair**
Vendors and contractors representing the range of materials and services used for stormwater green infrastructure projects fill a room to showcase their products. Participants "speed date" the vendors to learn about the New England network of materials, resources, and contractors involved in green infrastructure.

3:00 – 4:00 **Key tools and resources to help practitioners design, construct, and maintain Green Infrastructure systems**
Walk participants through specific resources and tools used by practitioners in design, construction, and maintenance of green infrastructure BMPs. *What resources and tools does HW use when they go to design GI BMPs? What are emerging tools, information that designers and developers will find useful?*

4:00 – 4:15 **Next steps**

- Soak up the Rain website as a tool for communicating with the public about green infrastructure
- Survey results
- Upcoming related events

Current Stormwater Concerns and Solutions Workshop Report

This workshop took place on Wednesday March 12, 2014 on the campus of the Worcester Polytechnic Institute. It was developed with the help of a Steering Committee consisting of: Paul Mathisen (WPI), Rob Johnston (Clark University), Robert Ryan (UMass Amherst), Ed Himlan (Massachusetts Watershed Coalition), Paula Rees and MF Hatte (WRRC).

The goal of this workshop was to link researchers, practitioners, and policymakers with and among each other to identify challenges, opportunities, and next steps within the context of stormwater in our region. This event aimed to gather up to 80 individuals from the above mentioned arenas.

The event was advertised on the WRRC listserv, and filled up to capacity within two days of the announcement. Altogether, 112 individuals signed up for the event. Some cancelled out, and some were left on a waiting list. Seventy-Nine actually participated in the workshop. A breakdown of participants' affiliations can be found in Table 1.

Table 1: Affiliation of workshop participants

Affiliation type	Number of participants
Academics	18
Commercial companies	15
Governmental agencies	22
Legislator offices	2
Municipalities	6
Non-profit organizations	14
Regional agencies	2

There were twelve presentations organized into three sessions to discuss stormwater issues, regulations, and solutions, followed by a moderated discussion to identify knowledge gaps and research needs.

Agenda

8:30-9:00 **Registration**

9:00-9:15 **Welcome, goals and objectives** - Paula Rees and Paul Mathisen

9:15-11:00 **Stormwater and Land Use: Issues and Concerns** (Paula Rees, moderator)

- Non Point Sources Impacts - Ed Himlan, Mass. Watershed Coalition
- Land Use Issues - Robert Ryan, UMass LARP
- Water Quality Issues - Paul Mathisen, WPI
- Climate Change Issues - Thomas Maguire, MassDEP

11:00-11:15 **Break**

11:15-12:30 **Regulations and Policy** (Robert Johnston, moderator)

- TMDLs - Kimberly Groff - MassDEP Watershed Planning Program

- Stormwater: MS4, Phase II - Thelma Murphy, EPA Region 1
- Water Quality: New Fertilizer Regulations - Mary Owen, UMass Extension
- Sustainable Water Management Initiative - Vandana Rao, Mass. EEA

12:30-1:30 **Lunch**

1:30-3:15 **Solutions** (Robert Ryan, moderator)

- Quantifying Economic Advantages of Riparian Restoration - Rob Johnston, Clark University
- Water Conservation Solutions - Heidi Ricci, Mass Audubon
- Stormwater Management Solutions - Andrea Braga, Geosyntec Consultants
- Water Infrastructure Legislation - Julia Blatt, Mass. Rivers Alliance

3:15-3:30 **Break**

3:30-4:30 **Pulling it all together** (Paul Mathisen, moderator)
Discussion and sign-up for a Working Group to look at opportunities

On March 14, an email was sent to all participants, asking them to fill out an electronic evaluation (Table 2).

Table 2: Workshop evaluation

Question	Response
The conference was well organized	Strongly agree, agree, disagree, strongly disagree
Comments on the organization	Text
The topics covered by the conference sessions were appropriate and informative	Strongly agree, agree, disagree, strongly disagree
Comments on the sessions	Text
What other topics would you like to have been covered?	Text
Did you feel the length of workshop sessions was too long, just about right, or too short?	Too long, too short, just about right
Overall, how satisfied were you with the speakers/presenters? Were the speakers informative, prepared, and understandable?	Very satisfied, satisfied, dissatisfied, very dissatisfied
Do you have any comments on the speakers?	Text
How satisfied were you with the registration process?	Very satisfied, satisfied, dissatisfied, very dissatisfied
What did you like most about the workshop?	Text
What did you like least about the workshop?	
In what ways could this workshop be	Text

improved?	
What suggestions do you have for future workshops?	Test
Are you interested in being part of a working group focused on next steps?	Yes, no
If you answered yes, please provide your name	Text
Can we share information about you with others at the workshop to help facilitate future collaborations?	Yes, no
If you answered yes, please provide the following information: Short "bio" about you professionally	Text
What would you like from a collaboration?	Text
What can you give to a collaboration	Text

There were 28 responses, all being very satisfied or satisfied with the gathering, from its organization, to topics, to speakers. Most were satisfied with the presentations, with one attendee suggesting that too much known information was presented. Several good suggestions were offered for future workshops, such as "A discussion of the environmental and human cost/benefit tradeoffs between surface water and subsurface discharges of stormwater." Seventeen participants indicated that they were interested in being part of a focus group on next steps. We are still working on getting this focus group off the ground.

USGS workshop: Techniques to Quantify Stream-Groundwater Exchange and Shallow Transport

On June 9, 10, and 11, 2014, the USGS will be running a workshop at Woods Hole on *Techniques to Quantify Stream-Groundwater Exchange and Shallow Transport*. In this workshop, the theory behind the measurement of stream-groundwater exchange using four techniques will be presented, including conservative tracers, electrical resistivity, smart tracers, and heat tracing. Solute transport and exchange modeling using data from these approaches will also be discussed. A full field day will provide attendees the opportunity to implement and practice these stream-groundwater exchange quantification techniques.

The Massachusetts Water Resources Research Center, in collaboration with UMass Geosciences and the U.S. Geological Survey, has selected four students to participate in this workshop. The students applied for the opportunity and were selected based on their interest and subject of study. Through a generous offer from Glorianna Davenport, the students will be staying free of charge at the Tidmarsh Farm research station in Plymouth, MA to make commuting to the workshop easier and affordable. UMass Professor and WRRC collaborator Christine Hatch will be leading a portion of the workshop.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	5	0	0	0	5
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

Publications from Prior Years

1. 2010MA241B ("Impact of the hemlock woolly adelgid on the water cycle in New England: Differences in hydrologic fluxes between hemlock and deciduous forest stands") - Articles in Refereed Scientific Journals - Guswa, Andrew J., 2012. Canopy versus roots: Production and destruction of variability in soil moisture and hydrologic fluxes, Vadose Zone Journal, doi:10.2136/vzj2011.0159.
2. 2009MA177B ("Bacterial Toxicity of Oxide Nanoparticles and Their Adhesion") - Articles in Refereed Scientific Journals - Wang, Z., Xie, X., Zhao, J., Liu, X., Feng, W., White, J. C., & Xing, B., 2012, Xylem-and phloem-based transport of CuO nanoparticles in maize (Zea mays L.). Environmental science & technology, 46(8), 4434-4441.
3. 2010MA241B ("Impact of the hemlock woolly adelgid on the water cycle in New England: Differences in hydrologic fluxes between hemlock and deciduous forest stands") - Articles in Refereed Scientific Journals - Guswa, Andrew J. and C. M. Spence, 2012, Effect of throughfall variability on recharge: Application to hemlock and deciduous forests in western Massachusetts, Ecohydrology, 5(5), doi: 10.1002/eco.281.
4. 2010MA237B ("Surface water-groundwater interactions on the Deerfield River") - Other Publications - Yellen, Brian, 2012. How Does Hydropeaking Alter the Hydrology of a River Reach? A Combined Water Budget, Modeling, and Field Observation Study. Deerfield River, Massachusetts, Masters Theses 1896-2013
5. 2008MA125B ("Estimation of Climatic and Anthropogenic Influences on Freshwater Availability") - Dissertations - Tsai, Yushiou, 2012, Statistical Methods for Assessing Climatic and Anthropogenic Impacts on Streamflow, Storage Reservoir Yield, and Effectiveness of Water Conservation Programs. Tufts University
6. 2010MA231B ("Monitoring and Modeling Chromophoric Dissolved Organic Matter in Neponset River and Boston Harbor Using GIS and Hyperspectral Remote Sensing") - Dissertations - Zhu, Weining, 2012, Inversion and analysis of chromophoric dissolved organic matter in estuarine and coastal regions using hyperspectral remote sensing, University of Massachusetts, Amherst.
7. 2011MA286B ("A Remote Sensing Algal Production Model to Monitor Water Quality and Nonpoint Pollution in New England Lakes") - Articles in Refereed Scientific Journals - Adam Trescott and Mi-Hyun Park, 2013, Remote Sensing Models using Landsat Satellite Data to Monitor Algal Blooms in Lake Champlain, Water Science and Technology, 67 (5), 1113-1120
8. 2010MA248B ("An assessment methodology for differential impact on environmental justice populations of releases of industrial toxics to water in Massachusetts") - Articles in Refereed Scientific Journals - Ash, M., Boyce, J. K., Chang, G., & Scharber, H., 2013, Is environmental justice good for white folks? Industrial air toxics exposure in Urban America. Social Science Quarterly, 94(3), 616-636.
9. 2011MA291B ("Elucidation of the Rates and Extents of Pharmaceutical Biotransformation during Nitrification") - Articles in Refereed Scientific Journals - Sathyamoorthy, S. and C.A. Ramsburg, 2013, Assessment of Quantitative Structural Property Relationships for Prediction of Pharmaceutical Sorption during Biological Wastewater Treatment. Chemosphere, in press, DOI: 10.1016/j.chemosphere.2013.01.061
10. 2011MA291B ("Elucidation of the Rates and Extents of Pharmaceutical Biotransformation during Nitrification") - Articles in Refereed Scientific Journals - Sathyamoorthy, S., & Ramsburg, C. A.,2013, Assessment of quantitative structural property relationships for prediction of pharmaceutical sorption during biological wastewater treatment. Chemosphere, 92(6), 639-646.
11. 2003MA19G ("A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management") - Articles in Refereed Scientific Journals - Manda, A. K., Mabee, S. B., Boutt, D. F., & Cooke, M. L.,2013,. A method of estimating bulk potential permeability in fractured-rock aquifers using field-derived fracture data and type curves. Hydrogeology Journal,

21(2), 357-369.

12. 2009MA177B ("Bacterial Toxicity of Oxide Nanoparticles and Their Adhesion") - Articles in Refereed Scientific Journals - Zhao, J., Wang, Z., Dai, Y., & Xing, B. (2013). Mitigation of CuO nanoparticle-induced bacterial membrane damage by dissolved organic matter. Water research, 47(12), 4169-4178.
13. 2010MA231B ("Monitoring and Modeling Chromophoric Dissolved Organic Matter in Neponset River and Boston Harbor Using GIS and Hyperspectral Remote Sensing") - Articles in Refereed Scientific Journals - Zhu, W., Tian, Y. Q., Yu, Q., & Becker, B. L. (2013). Using Hyperion imagery to monitor the spatial and temporal distribution of colored dissolved organic matter in estuarine and coastal regions. Remote Sensing of Environment, 134, 342-354.
14. 2010MA231B ("Monitoring and Modeling Chromophoric Dissolved Organic Matter in Neponset River and Boston Harbor Using GIS and Hyperspectral Remote Sensing") - Articles in Refereed Scientific Journals - Zhu, W., Yu, Q., & Tian, Y. Q., 2013, Uncertainty analysis of remote sensing of colored dissolved organic matter: Evaluations and comparisons for three rivers in North America. ISPRS Journal of Photogrammetry and Remote Sensing, 84, 12-22.
15. 2011MA286B ("A Remote Sensing Algal Production Model to Monitor Water Quality and Nonpoint Pollution in New England Lakes") - Articles in Refereed Scientific Journals - Adam Trescott, Elizabeth Isenstein, and Mi-Hyun Park, 2013,Remote sensing of chlorophyll a and cyanobacteria in Lake Champlain, Vermont, Water Science and Technology, 13(5) 1402-1409 2013
16. 2011MA291B ("Elucidation of the Rates and Extents of Pharmaceutical Biotransformation during Nitrification") - Articles in Refereed Scientific Journals - Sathyamoorthy, S., K. Chandran, and C. A. Ramsburg, 2013, Biodegradation and Cometabolic Modeling of Selected Beta Blockers during Ammonia Oxidation. Environmental Science & Technology, Vol. 47, no. 22, 12835-12843. doi: 10.1021/es402878e
17. 2011MA298B ("Assessing Human Impacts on Sediment and Contaminant Trapping within Oxbow Lake, Northampton, Massachusetts") - Articles in Refereed Scientific Journals - Woodruff, J. D., Martini, A. P., Elzidani, E. Z., Naughton, T. J., Kekacs, D. J., & MacDonald, D. G., 2013, Off-river waterbodies on tidal rivers: Human impact on rates of infilling and the accumulation of pollutants. Geomorphology, 184, 38-50.
18. 2011MA306B ("Authentic Research Projects for Undergraduates based on Groundwater Contamination Issues Related to Arsenic") - Articles in Refereed Scientific Journals - Elci, L., Elci, A., Berg, T. A. and Tyson, J. F., 2013, “Dispersive liquid-liquid microextraction and microsample injection system coupled with inductively coupled plasma-mass spectrometry for inorganic arsenic speciation in natural waters,” International Journal of Environmental Analytical Chemistry 93(10), 1065-1073.
19. 2008MA135B ("Toxicity of carbon nanotubes to the activated sludge process: protective ability of extracellular polymeric substances") - Articles in Refereed Scientific Journals - Parise, A., Thakor, H., & Zhang, X.,2014,. Activity inhibition on municipal activated sludge by single-walled carbon nanotubes. Journal of Nanoparticle Research, 16(1), 1-9.